22d Congress,
1st Session.

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Ho. of Reps.

COMPARISON

OF

WEIGHTS AND MEASURES

OF

LENGTH AND CAPACITY,

REPORTED TO

THE SENATE OF THE UNITED STATES

BY

THE TREASURY DEPARTMENT IN 1832;

AND MADE BY

FERD. ROD. HASSLER,

M. A. P. S., ASS. R. AST. S. L., &c.

WASHINGTON:

PRINTED BY DUFF GREEN.

1832.

National Oceanic and Atmospheric Administration

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WEIGHTS AND MEASURES.

REPORT

FROM

THE SECRETARY OF THE TREASURY,

IN COMPLIANCE

With a resolution of the Senate, showing the result of an examination of the Weights and Measures used in the several Custom-houses in the United States, &c.

July 2, 1832.

Printed by order of the House of Representatives.

Treasury Department,
June 20, 1832.

Sir: I have the honor to transmit Mr. Hassler's report of the examination made by him, under the superintendence of this department, of the weights and measures used at the principal custom-houses, as directed by a resolution of the Senate of the 29th of May, 1830.

This examination has been made with great care and ability; and the report presents fully both the results, and the means employed in obtaining them. It will be seen that great discrepancies exist between the weights and measures used in the different custom-houses—some being too small, and others too large; but, that the mean corresponds nearly with the standards as fixed by the English laws, previously to, and at the epoch of the declaration of American independence.

The existence of these discrepancies is not surprising considering the manner in which the weights and measures have been obtained in the custom houses. It is, nevertheless, a serious evil, inasmuch as it produces inequalities in the duties levied at the different ports; and thus contravenes the spirit of the constitution, which declares that all duties, imposts, and excises, shall be uniform throughout the United States. It is believed, however, that this department has full authority to correct the evil, by causing uniform and accurate weights and measures, and authentic standards, to be supplied to all the custom-houses. With this view, proceedings were instituted by my predecessor, with the President's approbation, and are now in progress, for effecting that object, by fabricating at the United States' Arsenal in this city, under the immediate personal superintendence of Mr. Hassler, the necessary standards, as well as weights and measures, which will be adjusted by him, with all the exactness that the present advanced state of science and the arts will afford.

The report made by this department to the Senate, on the 3d of March, 1831, a copy of which is annexed, described the authentic units which were to be adopted in the preparation of these weights and measures. The avoirdupois pound, which is the pound of commerce, and with which the custom-houses will be supplied, will be derived from the troy pound of the Mint therein referred to, by the legal proportions of 5760 grains, which constitute the troy pound, to 7000 grains troy, which constitute the avoirdupois pound. The liquid measure will be the wine gallon of 231 cubic inches, and the dry measure, the Winchester bushel of 2150.42 cubic inches, according to the standard of 36 inches adopted as the English yard, and referred to in that report.

I am, respectfully,
Your obedient servant,
LOUIS McLANE,
Secretary of the Treasury.

The honorable the President *of the Senate.*

Report from the Secretary of the Treasury, relative to a comparison of weights and measures as used at the several custom-houses of the United States, which was required by a resolution of the Senate of May 29th, 1830.

Treasury Department,
March 3, 1831.

Sir: I have the honor to report to the Senate, that, in obedience to the directions of their resolution of the 29th May, 1830, a comparison of the weights and measures used at the principal custom-houses in the United States, was commenced under the immediate superintendence of Mr. Hassler, whose reputation, as well for his researches in general science, as for his experience in this particular branch, recommended him as peculiarly qualified for this undertaking. I regret, however, that the work could not be completed as early as was desired. It was deemed essential to the accuracy of the operation, to have the advantage of temperatures below as well as above the freezing point; and the undertaking was, therefore, necessarily postponed until the winter season. In the mean time, the apparatus had been provided in New York, and was shipped from thence to this city early in December. The vessel was unfortunately stranded in the Chesapeake, and part of the apparatus lost. The delay occasioned by this accident, has prevented the completion of the comparison in time for a report to the Senate during the present session. The work, however, is far advanced; and it has exhibited such a remarkable disparity in the weights and measures used at different custom-houses, as to demonstrate the urgent necessity of providing standards for their regulation.

Among the instruments which had been procured, some years ago, under the direction of the President, for the survey of the coast, was a standard measure of length, exactly corresponding with the British Parliamentary standard, as established in 1758, with which that of 1760 is identical, as tested by Sir George Shuckburgh in 1798, and by Captain Kater in 1821, on the occasion of the last determination of the weights and measures in England, when it was adopted as the legal unit. This standard measure has, by means which will be explained in a future report, been compared with the pendulum vibrating seconds in London, and also with the French mètre, which is based upon measurements of arcs of a meridian of the earth. With such evidence of its character, and such an opportunity of correcting any alteration by reason of decay, it was, without hesitation, adopted as the unit for the comparison of measures of length.

The troy pound used in the Mint, is known to be identical with the latest established standard troy pound of Great Britain, as regulated by the British laws, and standarded by Captain Kater in 1824, having been constructed by him at the special request of Mr. Gallatin, upon the same principles, and in the same manner, that he had employed in the construction of the British standard. Being found by various tests, which will also be presented hereafter, to be worthy of its character for accuracy, it was adopted as the unit for the comparison of weights.

The examination of measures of capacity has not yet been so far completed as to authorize a satisfactory conclusion as to what units for these measures ought to be adopted. But as soon as this shall have been accomplished, the necessary preparations will be made to secure, as far as the power vested by law in the Treasury Department will permit, an entire uniformity in the weights and measures used at the respective custom-houses.

I have the honor to be,
Very respectfully,
Your obedient servant,
S. D. INGHAM,
Secretary of the Treasury.

The honorable the President
of the Senate of the United States.

Washington City, *27th January*, 1832.

Most honored Sir: With this I have the honor to present to you my report upon the comparisons of weights and measures, of length and capacity, which I am entrusted with by your department, in consequence of a resolution of the Senate of the United States of the 29th May, 1830.

This comparison comprehends all that could be collected of standards preserved in public departments; all such weights and measures as were received upon call from the various custom-houses; and I thought it an advantage that I could join, moreover, various other valuable standards and interesting weights from friendly communications.

I flatter myself that it will be found to present a considerable mass of information upon the subject of my inquiry, adequate to any aim which the Government may form in relation to it.

I considered myself bound to devote to this investigation all my exertions and care, making use of the best methods I could devise in principle, and creating the means for the operations which had necessarily to be adapted to the circumstances under which I worked, and therefore were in many respects novel; their success has therefore been so much more satisfactory to me.

To assist the clear view of the subject, and simplify the perusal of the report, this is made as concise as possible, containing only the principles, general results, and conclusions, having reference to the use of the Government. The detail results in support of them are collected in a series of additional statements, in a tabular form, letter A, to N, that they may be perused with more ease in any detail investigation.

These two papers, therefore, contain all the elements upon which any disposition of the Government may be grounded.

I shall now continue the detailed description of the principles and modes of operating, which I have made use of in this work, as it may be interesting for the general public, and be instructive upon the nature and the mode of proceeding in such operations. The much more numerous details of this part of my account must necessarily also delay it longer. I hope, however, to be able to present it yet, during the present session of Congress.

I have the honor to be, with perfect respect and esteem, most honored sir, your most obedient servant,

F. R. HASSLER.

The Hon. Louis McLane,
Secretary of the Treasury of the U. States,
Washington City.

Report upon the comparison of weights and measures, of length and capacity, made at the City of Washington, in 1831, under the direction of the Treasury Department, in compliance with a resolution of the Senate of the United States of the 29th May, 1830, by Ferdinand Rodolph Hassler.

1. Among the means of distributing justice in a country, which is the aim of the establishment of Governments, rank unavoidably the fixation and distribution of accurate weights and measures for all the daily dealings of active life.

Faint traces of such regulations have been preserved for us by history from early nations, anterior even to those which we are in the habit of calling the ancients. But the researches upon these have interest only for the philosophic inquirer, and are entirely foreign to the practical purposes of an establishment of standards in the present times. To quote here the fact, is only to show that establishments of this kind are, by their nature, subject to lose the sufficient accuracy, regularity, and even the recollection of their principles; that, therefore, they need, at certain epochs, a complete revision, or even new establishment, by the more improved scientific means of the time, to adapt them to the more refined social intercourse.

2. Within the last 40 years, all the nations of Europe have successively revised or established anew their systems of weights and measures. During the same period, the subject has often occupied Congress, and many of the State Legislatures of our country. The difficulties accompanying it increase naturally with the greater complication of the social intercourse.

3. It would, undoubtedly, have been a great advantage to the country, had a regular system, founded upon a scientific base, and single unit, been established, together with the first regulations for the organization of the country, before the great increase of population, and consequent great active intercourse had created and increased the difficulty of attacking old habits, and produced an irregularity, which amounts to an actual distribution of injustice.

This observation was very properly made by the late Mr. Jefferson, in his report upon weights and measures, 1793.

At present, and until the advantages of a scientific system may be more generally felt, the task is reduced to ascertaining the actual state of things, and *fixing the standards* of each kind, to that what their general tenor indicates to be intended by them. The necessity of the realization of at least this, is proved by the present as well as by earlier investigations.

4. It is evident that, in this respect, regularity must be fully established wherever the Government is in dealing with the citizens on a large scale, as is, for instance, principally the case in the custom-houses; the law directing that the duties shall be collected equally in all, renders uniformity in weights and measures indispensable.

The influence of this example, and the means thereby presented to obtain accurate measures and weights, which every citizen, more or less, desires, will gradually introduce uniformity in the country itself, without the need of a special law to that effect.

5. Without a scientific form in these inquiries, by which the results are worked out from their principles, it is impossible to give to that establishment the credit necessary to secure confidence, and make it acceptable.

The accuracy aimed at must be far greater than might at a first glance appear necessary, if that which is indispensable is to be secured with certainty, and proved so fully as to command confidence; thence time, care, and assiduity, cannot be spared in the operation.

6. The last revision of the English standards, ordered by Parliament in 1814, and finally reported upon in 1824, resulted in the acceptation of certain old standards, considered as most trust worthy, and a small change in the units of the dry and liquid measures of capacity, the bushel, and the gallon. The introduction of these has as yet been limited to the custom houses and excise in a similar manner as proposed above, without any change of the units, which are decided by existing laws of Congress. The new standards were executed in England in 1825, and called the imperial standards.

7. Extensive works were undertaken in France in order to establish a complete system, grounded upon one single unit, taken from nature, namely, the length of the ten-millionth part of the quadrant of the earth, called mètre. They produced results of considerable utility in many other respects, improvements in mathematical and natural sciences, and in mechanical arts, besides the establishment of the best, and most consistent, system of weights and measures hitherto devised. Its accurate determinations, the satisfactory and ample scientific account that has been published of all the works, and the accuracy with which copies of the standards are executed, have caused it to be most generally adopted in Europe for scientific determinations; and many Governments there have determined their system by certain ratios to its units.

8. The great irregularity existing in the weights and measures of this country, has been fully proved by the report made in 1821, by the honorable late President, John Q. Adams. The inquiries established for it in the custom-houses showed, that, for the yards, the weights, and the gallons, hardly in any place another authority existed than standards of city sealers, of unknown origin. The wine gallon was generally merely *stated* by its legal capacity of 231 cubic inches. The comparisons of the dry measures, made by admeasurement, and by the weight of the water they contained, show a crossing and gross disparity, certainly due to the accumulation of the errors

of both. The statement lettered A, extracted from Mr. Adams' report, all being reduced to the bushel, exhibits the details. The maximum of the differences is considerable, viz. in the measurement = 433 cubic inches, or about $\frac{1}{5}$ of the whole; in the weight = 13 lb. 6 oz. avoirdupois, or about $\frac{1}{6}$ of the whole. Besides, it is well known that a kind of benefit or loss in the dealings between different States is grounded upon this want of order both in private and custom-house business.

9. This state of things naturally called for the resolution of the Senate of the 29th May, 1831, in obedience of which the investigation was directed by the Treasury Department, of which the account is here rendered.

10. For the present comparison, it was considered more proper to call into the Treasury Department copies of standards of the principal custom-houses, to be able to compare them upon one and the same system, and with the same regular and constant unit. This call showed again that hardly any custom-houses had actual standards; all equally refer, for the weights and measures of any kind, to the city sealers of the place, or those appointed by the respective States. The statement lettered B, shows as well the measures received from the custom-houses, as the accounts rendered by the collectors of the state of things in this respect. Whatever measures or weights were obtained, were, of course, compared, and with rather more care than they generally appeared to call for. The details appear in their proper places.

11. The Department of State has a collection of authentic copies of English standards, copies of the French standards carefully compared, and certified, besides several other standards. The first of these were, in fact, intended to make the connecting link of the weights and measures of this country with the English, and would have been used as the principal means for this comparison, had their arrangement been calculated for that purpose, and their subdivisions more consistent within themselves. A catalogue of the whole, with the quotations of their vouchers, is contained in the statement letter C.

12. To make the comparison of the standards of a country complete, it is necessary to include in it as much of foreign, well authenticated, weights and measures, as can be procured. The nature and extent of the commerce of this country, renders this part, for us, peculiarly useful; and it was so much more interesting as, besides the assistance afforded by the collection of the State Department, I had several other communications, and, most valuable of all, a French *original mètre*, an *original kilogram*, and a well executed *toise*, lent to me for the purpose by the Philosophical Society of Philadelphia. These I had myself brought to this country, on my first arrival in 1805, and the society acquired them from me. The nearer particulars of these means, and their vouchers, appear in the statement letter D.

13. A comparison of standards of different values requires, indispensably, (for each kind) the reference to one, unique, accurate, and within itself consistent, standard; and the verification of this, within itself, is as much an object of investigation as any other part of the comparison. For this, I had provided many means, by the collection of the instruments for the survey of the coast, where accurate lineal standards were, at all events, indispensable. From this collection, all the parts subservient to the present comparison were employed, as their arrangement was expressly adapted to the aim. The particulars are here referred to in proper places.

14. The details of the operation will best form the subject of a separate account to follow the present report hereafter; which will also show more clearly the works required to obtain the data here to be related, and the means and principles made use of for the purpose.

Comparison of the length measures.

15. The standard scale of 82 English inches, arranged for a comparateur, forming part of the collection of instruments for the coast survey, constructed by Troughton, in London, was purposely made of a length sufficient to take in the double mètre length; therefore, also, the double yard and the toise. It is exactly of the same form and arrangement, with microscopes and micrometers, as that of Sir George Shuckburgh Evelin, of 60 inches in length, with which the first accurate comparisons of English length measures were made in 1797, and which was again used by Captain Kater in the last operations for the new establishment of the British imperial standards. Of the comparison of Sir George Shuckburgh, it appeared to me not improper to insert the ultimate results, by the small table letter E.

16. The consistency of Troughton's large scale within itself, was tested by measuring every length, or the nearest decimal subdivision, that was compared to each kind of standard, upon as many parts of the scale as it admitted, by steps of one inch from one another. The account of this, belonging more particularly to the mode of proceeding in my work, is referred to the separate future detailed account of my operations.

This scale having the same origin with that of Sir George Shuckburgh, may be considered as identical with it, within the limits of obtainable accuracy, by the present means of dividing, in which Mr. Troughton is well known to rank first in accuracy.

17. The results of the comparisons of the different English standards of the yard and the ell, are collected in the table letter F. This table furnishes the following remarks and conclusions, viz.

(*a*) The ell is altogether inadmissible as a standard, and has, therefore, also been disregarded in the late English comparisons. Its results deviate for about four-hundredths of an inch from their legal ratio to the yards, which are with them of the same origin. This may be the result of improper use of the standards in the exchequer, even since the time of Sir George Shuckburgh, who obtained yet more coinciding results; it might suggest the idea that the standard of the yard is a piece cut to length that has become shorter by use, and that of the ell, a distance between two butting pieces, or what is called *a bed*, which, by use, has become larger. This difference will be seen by comparative reference to table E and F.

(*b*) The copy of the yard and ell together, in form of a bed, shows itself unworthy to enter into the line of comparison among the other standards, both by its apparent rough workmanship, and its result in the comparison.

(*c*) The measurement of the 51,2 inches, laid off by Troughton upon the scale, now of the Treasury Department, shows a coincidence with the 82 inch scale, within the limits of accuracy admissible in the present state of the arts, and is corroborating the accuracy of the connection of the present comparison with that made in England for the establishment of the new imperial standards.

(*d*) The mean yard of the scale, which I divided from that of 82 inches of Troughton, gives for the yard 36,0002465 inches.

(*e*) The new English standard establishment, adopted the yard of the Parliamentary standard, which will be found in Sir G. Shuckburgh's results = 36,00023 inches. This result differs from the mean of the scale of the Treasury Department only 0,0000165 of an inch, an entirely inappreciable quantity. This striking coincidence brings the scale of the Treasury Department to be entirely equal to the British Parliamentary standard, which was adopted in England. An arrangement has been made for it similar to that of the scale of Troughton, for its use in future comparisions, and the construction of standards for the custom-houses.

(*f*) The extreme difference between all the yards obtained by this comparison amounts yet to 0,035939, which is too great to be admissible in the present state of the arts, and the nicer wants of society in this respect, and shows to what error an indiscriminate adoption of standards may yet lead. But the old standard of the State Department is too rough to be admitted in the rank of standards. The scale of Thomas Jones appears to be made only for very common use; the scale of the Virginia University is evidently too short in its unit. All the results of the ell are altogether inadmissible, and I should allow the full rank of standard, besides, to Troughton's scale of 82 inches only, to the yards marked in front of the statement letter F, by an (*a*,) which gives the extreme difference = 0,0010242. Or, if the scale of the Treasury Department is included on account of its coincidence with the Parliamentary scale, this might be stated at = 0,0012707. With proper care it is possible to reduce all error in the construction of standards within smaller limits.

18. The scant list of length measures received from the custom-houses, contained under letter G, with their results, reduced to the yard, shows no more coincidence than might be expected from mere wooden sticks, adjusted upon standards of uncertain origin, and proves the propriety of furnishing the custom-houses with proper standards, so arranged that they may preserve themselves, and the measures to be compared may be easily applied to them, for which a proper model has been given.

19. The above exhausted the comparison of English length measures. Of the ratios to foreign measures, those of the French mètre and the toise were the most important to be ascertained. A platinum copy of the first was the only foreign measure included in the English comparison. A considerable number of mostly well authenticated copies of the mètre, and a fully original iron mètre of those standarded by the Committee of Weights and Measures in Paris, and distributed indiscriminately among the deputies of foreign nations, being present for that purpose, as stated §12, they were compared with the scale of 82 English inches by a peculiar method, explained already in my papers upon the coast survey.

20 The results of this comparison of the mètres are contained in the statement letter H, which furnishes the following remarks and conclusions:

(*a*) The standard metal of the French mètre is iron, of which metal all the mètres distributed to the deputies of foreign nations, present at the committee which established them, were made; only one of them was made of platinum, which is preserved at the observatory of Paris. The expansion of the iron, though greater than that of platinum, is much better known, and the refining of the platinum is yet made so unequally, that an iron mètre, or standard of any kind, is preferable to one of platinum.

(*b*) The standard temperature of the French iron mètre is that of melting ice, or 32° Fahr. The British standards are of brass, and the standard temperature is 62° Fahr. This requires a reduction, to present the one in the dimension and temperature of the other. The habit prevails in England to give the length of the mètre in iron at 32°, in inches and decimals of the brass English scale, at 62°. This result is evidently too much dependant of the ratio of the reduction adopted for the different expansion of the two metals by the temperature; thence the result is too much affected by accessory calculations, and, besides, impossible to present in nature; which I consider a requisite of a result of a comparison. I have always preferred to present the comparisons at the same temperature, and selected for it the melting ice point, (32° Fahr.) which is in itself a fixed point of the thermometer; thereby the result becomes even more independent of the thermometer itself, and I made the comparisons as near to that temperature as circumstances would admit; thence arises that the numbers of the table H, will not agree with the English results of mètre comparisons, but they can be reduced.

(*c*) It will be observed that the copies of the mètres are shorter than the original mètre of the committee. This I have found to be uniformly the case in copies of standards cut to a length.

(*d*) The extreme difference between the French mètre copies is less than that between the English standards. Their extreme difference between themselves is=0,0009291, and their mean deviates from the original committee mètre=0,00070869. The two last mètre dimensions, upon the scale of the Virginia University, and upon that of the Treasury Department, not being of French origin, cannot come in comparison here, and are merely registered. The latter follows evidently the unit of its own scale, which is too small.

(*e*) The nearest coincidence is that of the iron mètre standard adjusted by myself, which is=0,00013443 of an inch.

21. The old French standard, the toise, having already been determined with great accuracy, and extensively used, its comparison was of importance, and the copies employed are of considerable authority, as appears from the account given of them in statement letter D. The results obtained for them, as also for the double length of the pendulum under the equator, for the Amsterdam foot, and the two Algerine picks, which were the only other foreign length measures on hand, of any authenticity, are presented under letter J, and require no peculiar remarks.

Comparison of the Weights.

22. The scale for the comparison of the weights was furnished by the grain weights of Troughton; and up to the weight of the French kilogram the very excellent and sensible balance belonging to them was used. (See statement letter D.) These weights, being found consistent within themselves, formed the base of all comparisons by weights for the whole operation; the collection of the State Department has no grain weights, and is not consistent enough within itself in its smaller parts to serve as base of a comparison, a circumstance well known in England of the originals themselves, and evident from the second part of statement letter K. This extent of this balance included all the single units of weights, which are usually considered as standards, the kilograms, the single pound, and the two pound weights.

23. The subdivided kilograms would have served equally well, as for their accuracy within themselves, but their unit, the gramme, would have been less familiar in the language of this country in relation to weights; thence they were not adopted as such, though they were compared as a very essential part of this work. I had here again the advantage of having an original kilogram of brass, standarded by the Committee of Weights and Measures in Paris, exactly equal with all those of the deputies from foreign nations present at the committee; where, again, only one was made of platinum, which is preserved in the French archives.

24. The weight of the kilogram is taken in France in vacuum; but none

of the English weights being referred to that state, it was, of course, in this comparison, proper to omit this, except with respect to the platinum kilogram, to render it comparable with that of brass, which is the metal of all the other standard weights, both English and French.

25. The Troy pound of the United States' Mint at Philadelphia having been adopted by law as the standard for the coinage of the country, and being well authenticated, was naturally to become the standard unit, by which the exact coincidence of the weights of this country with the English exchequer weights was secured.

The determination of this in grains of the above collection of Troughton was, therefore, an essential operation. This has been done once at the Mint, in presence of the Director, Dr. Moore, and again in Washington, where he brought it himself, and was again present at the comparison. In both comparisons it was determined to be = 5762,41 grains of Troughton, as used in this comparison. Therefore, all the results of weights in this comparison will be given in both—the grains of Troughton, by which they were measured, and in their proportional value of the Mint weight, as future standard.

26. The higher weights are generally made by the multiples of smaller standard weights; and, as the usual balances diminish in sensibility with the increase of the weight, their accuracy can hardly, by the common ways of adjusting them, be proportionally the same as in the smaller. It will therefore generally be found, in the weights that I have compared, that their results, reduced to the Mint weight, are variable.

27. There are considerable difficulties in obtaining scale beams uniting great accuracy for large weights with the necessary strength to support them. They can hardly be said to be in use, unless especially made for a certain aim, as has been done for the British standard establishment and similars. They, besides, cannot keep their accuracy long, because this depends on the sharpness of the knife edges; and these must soon lose their edge under a heavy pressure; thence, besides their very expensive construction, they require the constant presence of an artist to repair them after a few weighing operations. To attempt to employ these means in this comparison would have made it dependant upon an artist of Europe, which would have delayed it for several years, without levying the difficulties inherent in the instrument itself. (Some sets of small weights, needed for the comparison, and ordered pressingly from London in July, 1830, though promised immediately, have not yet been obtained; and I have been obliged to supply the deficiency by making some myself.)

28. For these reasons, I proposed, and caused to be executed, by artists in this country, at a proportionally small expense, and within a reasonable limit of time, balances never yet applied to any practical use, but described by my friend and teacher, the late Professor Tralles, of the Academy of Berlin, who invented them for other physical experiments, at the time I was with him. They are grounded upon the same hydrostatic principle as the hydrometers, are capable of the greatest accuracy with considerable weights, without needing any very minute, or delicate, and difficult workmanship; they are, also, not subject to any loss of accuracy by the use, being free of friction. A sufficient number of them was constructed to suit the different capacities of weights. The liquid, in which, by their principle, they float, is for a weight up to 16 lb. the *distilled water*, and above that, the *mercury*. Their nearer description will appear in the detailed account

of my operations. Their results have been very satisfactory, and they will serve in future for the construction of the larger standard weights.

29. It would have appeared proper to adopt as guide the collection of the English standard weights of the State Department, had this not been superceded entirely by the much superior authenticity and accuracy of the troy pound of the United States' Mint. The result of the comparison of the English standard weight, of this collection, together with those of the other English standards, quoted in the respective statements, are contained in the tables under letter K, and furnish the following observations.

(*a*) Of the whole of the standards of the State Department, only five individual weights come up to, or exceed, the pound of the Mint in Philadelphia; all the others are rather nearer to their legal nominal, if this is taken in Troughton's grain weights. The averages of the larger weights of the troy nest, and avoirdupois pile, holds about the middle between the two.

(*b*) The single pound, bell-formed, is yet upwards of half a grain below the nominal value of the avoirdupois pound, deduced from the Mint pound by the legal ratio.

(*c*) The results of the tower troy nest generally favor the weights of Troughton's grains; the 16 ounce weight agrees with it to 0,07 of a grain, and this is usually the weight of the nest of troy weights made for the public.

(*d*) The denomination of tower troy, suggests the idea that these standards might be those corresponding to the weights of the English mint, which is well known to be an appendage of the tower. In the English comparison of weights, the mint weights were not included, and Capt. Kater stated, in a letter to a friend, upon my request, that this comparison did not form a part of the subject of his inquiry, but that he was informed, by officers of the mint, that their troy pound was exactly equal to that of 1758. However, the difference between Troughton's weights and the exchequer standard, was already observed by Sir George Shuckburgh, (Philos. Trans. of London, 1798;) he found the troy pound of 1758 by a mean of two, *one pound;* and two *two pound* weights, to be, in Troughton's grains, = 5763,78, which exceeds yet the difference determined here by the Mint weight, by 1,37.

(*e*) The troy pound of the Treasury Department, originating from Troughton, though of a different epoch than the grain weights, agreed exactly with them.

(*f*) The weights of the Virginia University agree, of course, with the Mint pound, because they have been made upon the new British standard establishment, by Gilbert, the same artist who made the imperial standards.

(*g*) It was only late in the progress of this comparison that the old English original standard weights, bearing the stamp of G. I., were obtained from the custom-house of Portsmouth. It will be observed that they agree nearly and most regularly with the new United States Mint standard, of any of the other weights, the new ones of Gilbert excepted: they thus proved a valuable datum for this comparison.

30. The weights received from the custom-houses, though more numerous than the length standards, were, generally speaking, not much more satisfactory in accuracy. The results of their comparison are in the table L, which needs no special remarks.

31. The comparison of foreign weights was the most interesting of the comparisons of foreign standards, both by its number, and by the authenticity, and general good execution of those on hand, as is evident from the account given of them in the respective statements. The results of the

comparison expressed in Troughton's grains, Mint weights, and French grammes, to make them generally comparable, are presented in the table letter M, upon which the following remarks may be made, viz.

(*a*) The kilogram of the late President, Mr. Adams, has the surplus weight, for the wearing in commercial weights, allowed legally in France under the name of "tolerance."

(*b*) The weights of the troy pound of the Mint, in French grammes, resulting from this comparison, is = 373,2223 grammes.

An English standard troy pound was sent to Paris for comparison, on account of the last comparison of standards, which the French Minister of the Interior states to be = 373,233 grammes; therefore differing from my determination only 0,0107 part of a gramme, or 0,16513 of an English grain.

(*c*) For both the preceding remarks, see letter of the French Minister of the Interior to the English Consul General, Paris, 28th February, 1821, in the English Parliamentary papers upon weights and measures.

(*d*) The French kilogram is determined legally as in the vacuum; but this reduction I considered proper to omit, because none of the other weights is thus reduced.

In the comparison of the platinum and brass kilogram, however, this introduces, of course, a difference in their weight in the air, by their different buoyancy, dependant on the specific gravity of the air; and this is somewhat different, according to the ratio adopted; thus, if, like in the English standard determination, the specific gravity of the air is accepted $\frac{1}{830}$ of the water, the platinum kilogram will, in value, present, in that of brass, as coinciding value - - - = 1000,00213 grammes,

If the French determination of $\frac{1}{770}$ is adopted, it will be - - - - = 999,999163

The difference between the two results - - = 0,0029,67

is yet an ascertainable quantity, and shows how far the difference of the data employed in reductions, may yet influence the results; thence proves the propriety of my wish to reduce them every where to the smallest influence possible.

Comparison of Capacity Measures.

32. If the comparison of linear dimensions has already presented discrepancies, the capacity measures, in which these increase according to the cube, must naturally present still greater deviations, when made to depend on their dimensions, as was the case with the legal determinations of the bushel and the gallon, in the old English system of standards. The Winchester bushel being determined to 2150,42 cubic inches, and the wine gallon to 231 cubic inches.

33. To execute, with accuracy, capacity measures, particularly of a large size, is a more difficult task than might be thought at first; thence arose in England, already among the constructors of measurers, the habit of determining them by weight, either of water, or some regular small seed or grain, according to the maker's choice, rather than by their dimensions or contents in cubic inches, as directed by the old laws.

34. The new English standard establishment, substituted for the bushel a measure containing 80 lbs. avoirdupois, of distilled water, at 62° Fahr. temperature, and 30 inches barometer, and gave to the gallon 10 lb. or the one-eighth of it. These standard measures were made of brass, so that,

properly, the state of expansion of the brass, proportionably to the water, is included, though not named by the law. This appears to have nearly agreed with one of the inferior standards, from which, therefore, it was derived by multiplication, as the table of the results of the standards in this comparison will furnish similar instances.

35. The temperature of 62 degrees Fahrenheit, is, however, rather unfavorably chosen, in general principles, because the water at that temperature, which it is always difficult to keep the same, is under considerably variable influence, expanding differently for each degree of temperature above or below it, and varying its density according to the depth of the vessel, and the difference between the temperature of the water and that of the surrounding air.

36. Two sets of metal standards of the English system of capacity measures, before the last alterations, have been compared here, as described in statement letter C; the first belonging to the State Department, of the date of King George IV.; the other belonging to the State of New Hampshire, with the stamp of George I. Unfortunately this latter has, only in late years, suffered some alteration, by being sent to Boston for adjustment, where four of the measures have been diminished, by lead poured in the bottoms, but, however, with the exception of only the smallest one, without obliterating the stamp, or altering the tops; so that they could be restored to their original value, by only melting the lead out of them.

37. Both these sets of standards concur in testifying to a double set of original standards in England itself, most likely of different dates, the memory of which is obliterated. To show the actual relation of the different parts of the standards, the statement letter N has, in its two last columns, the proportional weights, in grains of distilled water, of the gallon and of the bushel, resulting from each measure.

38. In the set of the State Department, it is evident that the so called Winchester pint and quart belong to the same original standard as the coal bushel; while the Winchester gallon and Winchester bushel form another agreement, upon a smaller bushel than the former.

The wine gallon gives of course a much inferior bushel. This has indeed no relation to the bushel; and the inquiries made on the occasion of the last settlement of standards in England, has proved this to be the result of gradual deterioration upon the original gallon, formerly corresponding to the bushel, until it was arrested, at the content of 231 cubic inches, by an act of Parliament.

39. The set of the State of New Hampshire, which is more numerous in its subdivisions, leads to the same conclusions: the one-eighth and one-fourth pint of it show the same origin as the wine gallon. The half-pint and the pint, which have not been altered, evidently have reference to the coal bushel; they even exceed it, as the pint and the quart of the set of the State Department do also.

The quart and the half gallon were probably constructed for reference to the same coal bushel, and have been altered, so as to refer now to the Winchester bushel; by the pouring of lead into them, as stated above.

The gallon, peck, and half bushel, refer directly to the more usual Winchester bushel; while the whole bushel has again been put down, from near the content of the coal bushel, to that of the Winchester bushel, by about 19,14 cubic inches of lead poured into it.

40. All these references agree, of course, only within the limits of accu-

racy that may be expected from the old ways of adjusting standards in England, and are not fully exact, but clearly enough indicated, to warrant the conclusion drawn from them above. All the above quoted standards, from the half pint to the half gallon inclusive, would furnish a bushel of upwards of 80 lb. avoirdupois of distilled water; which is the weight now adopted in England for the bushel and its subdivisions, and which agrees again nearest with the coal bushel, while the gallon, peck, and half bushel, approach again nearest to the Winchester bushel of the State Department. It will, however, be observed, that this latter is too small for its legal capacity, both by measurement and by weight, and that the same is the case with the bushel of New Hampshire in its present reduced state.

A comparison of the numbers of the first and second part of statement N, will show all these relations in a detail, with which it would be improper to fill this report here.

41. In England, the bushel of 80 lb. avoirdupois was formed by the multiple of the quart, for which no special reason is assigned, except that 80 lb. might in round numbers agree nearest with the mean of the standards. No regard was paid to the form of the measure, or to the materials of which it is made; two points which are not without notable influence when it is the question of accurate standards.

The ultimate act of Parliament upon the subject, was worded differently from what the scientific operators in the determinations had proposed. It is evident from the above, that, if an alteration was desirable, the same authorization might be derived from the standards which I have compared. For the varieties of the English standards, and the numerous obsolete laws relating to them, I take the liberty to refer to the appendix of the first report of the Commissioners on Weights and Measures, of July, 1819, in the Parlimentary papers upon that subject.

42. The bushel sent in by the custom-houses were most generally wooden tubs, which admitted determinations only by measurement; these are under art. 5, of the statement let. N. The few metallic measures sent in have been determined both by measurement, and by the weight of distilled water they contain, as seen in art. 3, statement let. N. It appears from these two articles, that the actual custom-house measures agree nearer with the Winchester bushel than with the coal bushel, and generally are even below the former. Still additional statements given by the collectors of Philadelphia and of Richmond, contradict, in part, the very measure which they themselves sent in, namely:

The collector of Philadelphia states, that, by a trial of weighing the half bushel with water, in 1820, it was found to contain 39 lb. 5¼ oz. of water, which would bring it nearly to the new English bushel.

And the collector of Richmond states, that their bushel was considered to be the English Winchester bushel, of 2256 cubic inches; this exceeds even the size of the coal bushel, and the half bushel sent in by him for 91 cubic inches. This statement might therefore be a mere error, and be meant for 2156, which nearer agrees with the measure sent in by the collector.

43. The wine gallons sent in by the custom-houses were but few, and little adapted to the accurate mode of determination, which it was evidently proper to adopt for the present comparison. Their result appear equally in the statement let. N.

44. All the determinations of the weights of the water that the metallic

capacity measure contained, were made with distilled water, the temperature of which was carefully ascertained, and the height of the barometer was observed. By these two data the results were reduced to the maximum density of the water, the state of the expansion of the metal measure at that temperature, and to 30″ height of barometer.

The weighing was made by the same kind of balances as quoted in art. 28°, particularly by those adapted to mercury, which, for the heavy metal bushels, it was necessary to increase to the weight of near 226 lb. The detail of this will appear in the account to be given of my mode of operating.

45. For the aim of the present comparison, and the statement of standards, where no alterations can be in contemplation, it is proper to give to the old bushel, legally determined by its cubic capacity, that determination by weight which will render it the most stable, and the possible alterations by a change of temperature the smallest; thence the easiest determined, and the least dependant upon data, taken by calculation from physical elements. For this, the distilled water furnished the very favorable property of having a point (as it may be called) of maximum density, which is at the temperature of 39°,83 of Fahr. thermometer; from which it diminishes in density for all temperatures, both above and below; therefore at that temperature it changes its volume the least, proportionably to the change of temperature. This temperature, or rather the indication of the maximum density, is therefore very properly chosen to determine the bushel and gallon, by the weight of distilled water which their legal capacity will contain.

46. Considerable calculations were of course required to determine these weights, and to select for them the best data furnished by experimental philosophy. In the operations for the French system of weights and measures, this temperature of the maximum density has been adopted for the standard units of weights, and of capacity measure; by taking the *weight* of the *decimètre cube of distilled water at the maximum density* for the *kilogram*, and its *capacity* for the *litre;* taking this absolutely, and reduced to the vacuum, by which all refer to one single unit: the length of the mètre.

It appeared also preferable to determine a certain stand of the barometer, rather than to reduce to the vacuum, as this is in common practice more independent of physical elements of the calculation; the mean stand of the barometer in this country, of 30 inches, is therefore chosen, by which means also the reductions dependant on this determination, which is rather a delicate one, will always be smaller; and brass being chosen for the metal of the weights, and length measure; though its nature, in respect to other qualities, may present considerable variety, its expansion and its buoyancy in the weighing, in proportion to water, are sufficiently constant and well ascertainable. In respect to the ratio between the dimensions of the dry measures, it is proper that their diameters shall be double their depth. The nearer discussion of this part belongs of course to the detailed account of the work of comparison, and the future construction of the standards.

48. Thus were determined, in weight of the Mint in Philadelphia, to contain distilled water, at the maximum density, and at 30 inches barometer, the bushel = 543391,89 grains = 77,627413 lbs. avoirdupois the gallon = 58372,1754 grains = 8,33888220.

To which, therefore, these measures will be regulated, and thereby present exactly the meaning of the law, and the nearest mean between the measures in use, by means of determinations the most accurate, and the best adapted to the aim, and to the ease of application.

General Conclusions.

49. Having thus stated the ultimate results of the whole of my operations, of which the nearer details, and the scientific means employed in it, must necessarily make the subject of another, and later account, interesting rather the inquirer, than the legislator requesting these results for public use, I take the liberty to add a few accessory remarks, relating to the subject in a general point of view.

(*a*) It is evident that the French standards here compared, have a much greater accuracy than the English. This is due to two causes; namely, *first*, the scientific principles upon which the first are grounded, which furnish means of verification far superior to the mere imitation, which is the only principle upon which the English standards can be executed; and, *second*, that the French standards are the works of actual, and first rate, artists in the mathematical instrument making line, while the English are generally the works of mere sealers of weights and measures. From this remark, are however, duly excepted the works of Mr. Troughton, and the copies of the exchequer length measures by Thomas Jones; their well earned fame for accuracy would even dispense from stating this exception.

(*b*) From the preceding arises the conclusion, that the first standards to be made for distribution in this country must be executed upon scientific principles, and with artists' means, if the ambiguity which the common sealers' habits are evidently capable of introducing, shall be avoided.

Therefore, arrangements have been made to have the future standards for the custom-houses made by the means of the same establishment as the present comparisons have been made in; besides that, this uniformity will secure also uniformity in the ultimate results. It would even be desirable that the State Governments should be furnished by the same means, in order that the sealers might have accurate and uniform points of reference in future.

(*c*) The adoption of brass as the metal for all standards uniformly, is rather a consequence of old habits, which gave it the preference, as the cheapest metal, not subject to prompt very evident oxydation. Its compound nature might introduce differences in the ratio of its expansion by temperature, which, absolutely and scientifically speaking, would be a defect; but this variation is proved by experiments to be too minute to have any effect upon the practical application to standards within the limits of magnitude they generally have.

The introduction of platinum, instead of brass, might be thought of, on account of its less destructible nature; but, the expansion of it is by no means so well known as that of brass; thence the reduction dependant on that element would be even more uncertain, and still increased by the uncertainty of the state of purity of the platinum; it being in nature mixed with various other metals that must be separated from it, the greater or less perfection of the process of working it, must introduce differences in this respect, at least equal to those of the brass, and perhaps greater, as in its alloys it changes its properties at least as much as the brass does.

(*d*) The adoption of the temperature of the maximum density of the water for the determination of the capacity measures, and the same metal as has served for the length measures and the weights, at the same temperature, introduces an uniformity which is very desirable; indeed it is the only point of reference, at which the desirable accuracy can be obtained; as at any other temperature the variation of the expansion of the water, in the neighborhood of the determining point of temperature, are variable within themselves, and thence introduce an increased influence upon the accuracy of the result, that it is absolutely necessary to avoid.

(E.) Besides the additional statements and tables now joined to this report, it is intended to have it followed by a detailed descriptive account of the operations and the means that have been employed in it, to enable to judge of the degree of confidence that may be placed in the results, and to show the principles that must guide an operation of this nature.

F. R. HASSLER.

WASHINGTON CITY, *January 27th*, 1832.

A.

CONTENT of the different dry measures by admeasurement, and by the weight of water they contain, as obtained at the different custom-houses, by the investigation directed by late President, John Q. Adams, reduced to the bushel resulting from each.

NAMES OF THE CUSTOM-HOUSES.	Contents of the bushel,			
	In cub. inch.	Avoirdup's w'ts.		
		lb.	*oz.*	*dwt.*
Bath, in the State of Maine,	1925,00	74	2	
Belfast,	2063,76	76		
Frenchman's Bay,	2216,70	84	7	8
Kennebunk,	2203,32	78		
Machias,	-	75	4	
Lubec,	2158,33	77; 78	14	
Portland,	-	76	6	
Falmouth,	-	76	15	
Saco,	2215,80	80		
Wiscasset,	-	78		
Portsmouth, in New Hampshire,	2153,74	77	12	
Boston, Massachusetts,	2211,6	78	4	
Newburyport,	2150,52			
Gloucester,	2150 40	78	8	
Dighton,	2062,78	75	6	
New Bedford,	2155,12	77	13	8
Barnstable,	2153,83	77		
Edgartown,	2232,73	76	8	
Nantucket,	-	76		
Providence, Rhode Island,	2194,50	78	8	
Bristol,	2155,13	78		
Newport,	2160,18	77	14	
New London, Connecticut,	2232,06	78	10	
Fairfield,	2249,86	79		
New York, (by a mean)	2152,36	78	13	4
Rochester, State of New York,	2202,58			
Philadelphia,	2186,20	78	12	
Wilmington, Delaware,	2192,20	77	4	12
Baltimore, Maryland,	2150,42	77	8	
Oxford,	2060,94	80		
Washington, District of Columbia,	2117,20	76	7	10
Georgetown,	2152,60	77	14	2,62

CONTENT—Continued.

NAMES OF THE CUSTOM-HOUSES.	Contents of the bushel, In cub. inch.	Avoirdup's w'ts. lb.	oz.	dwt.
Alexandria,	2118,80	77	11	
Cherry Stone, Virginia,	2225,48	83	4	
Norfolk,	2127,24	78		
Petersburg,	2147,08	78		
Richmond,	2112,60	77	8	
Camden, North Carolina,	2152,20	79	8	
Edenton,	2160,78	77	6	
Newbern,	2115,60	87	8	
Ocracoke,	2153,10	76		
Plymouth,	2358,58	77		
Washington,	2128,02	72	12	
Charleston, South Carolina,	2172,03	77	12	12
Savannah, Georgia,	2013,32	76		
St. Mary's,	2019,34	78	4	
New Orleans, Louisiana,	2162,02	77	11	7,1
The indiscriminate mean between all the above bushels,	2153,0	77	15	1,04
The old legal determination of the Winchester bushel by measurement, is	2150,42			
Difference from the above mean,	2,18			
The legal bushel will hold of distilled water, at the temperature of maximum density, and at 30 inches barometer, 543392,0 grains,	-	77	10	5,9
Difference from the above indiscriminate mean,	-		4	11,14
Difference from the new English imperial bushel,	-	2	0	14,96

B.

Statement of the Weights and Measures received from the Custom-houses, and the accompanying letters.

Portland sent nothing; says that there are no standards in the custom-house: they use measures of the State, sealed by the sealers of the town of Portland. Dearborn's balance is used for weighing, which is sent to Boston to repair, when needed. The Winchester bushel is said to be used, but no account given of it.

Portsmouth sends weights, a 32 lb., 16 lb., and 8 lb., with large hooks, adapted to Dearborn's balance, said to be duplicates of those in the office, and a wooden half-bushel. States that the standards used are those of the State of New Hampshire, no United States' standards having ever been established: that they have no use for length measures, no importations requiring it.

Boston sent one copper half bushel measure,
one do. gallon,
one 56 lb. brass weight,
one wooden yard stick, divided into hundredth parts, for the ease of reduction to square yards.

PROVIDENCE sent two brass length measures, each ½ of a yard long,
two single pounds brass weights,
one copper wine gallon measure,
one copper quarter of bushel measure.

MIDDLETOWN sent nothing; and said there are not, and never were, any standards in the custom-house. The weights and measures are proved and corrected by standards established by State authorities, and in the possession of officers appointed by the State.

NEW YORK sent two large wooden tubs, used for measuring salt and coal, and a set of common iron weights, from 1 lb. to 56 lb. A letter of the Surveyor of the port, of 21st September, 1831, states that no standards of any kind are in the custom-house; that the weights and measures are twice a year verified by the city sealers.

PHILADELPHIA sent a copper half bushel, and a set of 5 brass weights of 28, 14, 7, 4, and 2 pounds, the best worked that have been received. One common folding yard rule, and one measuring tape. The office has standards of weights and bushels, of which an account is given, namely, English tower standard troy weights. The half bushel is very old, and is said to contain 1093,1024412 cubic inches, and hold water at the temperature of 52° Fahrenheit, 39 lb. 6 oz.

BALTIMORE sent one yard tape, and one yard stick, divided into hundredths; a set of common iron weights, from 1 lb. to 56 lb.; one wooden 6 bushel salt barrel; and one tin wine gallon.

WILMINGTON, in Delaware, sent one set of iron weights, from 1 lb. to 56 lb.; one wooden, iron bound, tub.

RICHMOND sent one measuring stick of 48 inches; one bushel measure of wood, iron bound; one tin gallon, sealed, as used for the custom-house by the city sealer. States that the bushel is considered to be the Winchester bushel of 2,256 cubic inches, which is even larger than the coal bushel was found.

NORFOLK sent two 50 lb. iron weights spoiled by rust, kept since before the introduction of Dearborn's balance, which is now used altogether; one iron bound tub of two bushels, standarded by the standard of the State of Virginia, which is stated to be the Winchester bushel.

CHARLESTON, South Carolina, sent one half bushel, sealed by the sealer of the city, which arrived so worm eaten as to be useless; states that the measures used were those of the State, and there had never been any difficulty with importers. For weighing, Dearborn's balance is used, and for liquid measure, the gauging rod of Kutz, in New York.

SAVANNAH sent nothing; uses Dearborn's balance, brought from New York. The salt measures are stated to be the same as in Philadelphia; the casks are gauged by Gunter's rule.

NEW ORLEANS sent seven brass weights from 56 lb. to ½ lb.; one half bushel bucket: gives no special information.

C.

A list of standards preserved in the Department of State of the United States.

LENGTH MEASURES.

One brass standard of the exchequer *yard* and *ell*, of the form called *a bed.* (1)

One copy of the exchequer *yard*; made by Th. Jones, in London. 2)

One copy of the exchequer *ell*; made by the same. (2) Both these are cut to length.

One brass scale or rule, upon which the *yard* and the *ell* are marked, by lines upon strips of silver; made by the same. (3)

One French mètre of platinum, (à traits;) the mètre marked by crossing lines; made by Fortin, in Paris. (4)

One brass metre (à bout) cut to length of the same maker. (4)

Two brass length measures of Algiers; the larger the Turkish pick, the smaller the Arabic pick. (5)

CAPACITY MEASURES.

One brass coal bushel, One brass Winchester bushel, One do do gallon, One do do quart, One do do pint, One brass wine gallon,	(1)

One brass litre modèle, with ground glass cover; made by Fortin. (4)

WEIGHTS.

One set of seven pieces brass avoirdupois weights, of bell form, being 1 lb., 2 lb., 4 lb., 7 lb., 14 lb., 28 lb., 56 lb. One old brass weight, marked A, C. One pile of 12 pieces brass avoirdupois weights, round flat from 8 pounds down by halves to 1 cwt., One brass nest troy weight of ounces, from 256 oz. down to ¼ oz.	(1)
One French kilogram of platinum, cylinder form; of Fortin, One French kilogram of brass, cylindric, with a nob; of Fortin, One French subdivided kilogram of brass, cubical form; of do.,	(4)

One set of brass Coelnish mark weights from 50 marks down, being 50m., 32m., 16m., 8m., 4m., 2m., 1m., and all the loths by successive halving, with grains.

Two small brass weights from Algiers. (5)

The vouchers for the authenticity of the standards in the State Department, are as follows, viz.

1. The whole old set of English standards of weights and measures noted, (1) is accompanied by a parchment indenture, stating them to be received from the exchequer by Edward Abraham De Grave, No. 59, St. Martin Legrand, sealer, weight and measure maker, dated 8th December, 1820; and a certificate of Thomas Jones, mathematical instrument maker, &c., that they were made under his direction, dated the same day.

2. The rods of the yard and the ell of Thomas Jones (2) have an indenture similar to the foregoing, to certify their authenticity, dated 27th May, 1822. They bear, besides the exchequer stamp, and those of Queen Elizabeth and King George IV., an engraved inscription certifying them as

exact copies of the exchequer standard of 1601, made expressly for the Government of the United States, in May, 1822, at 60° Fahr. temperature.

3. The scale of Thomas Jones, noted (3) being apparently only made for the purpose of common use, has no certificate.

4. The French standards noted (4) were procured by Mr. Gallatin, when at Paris. The platinum mètre is certified by Mr. Arago to be $\frac{11}{1000}$ths of a millimètre longer than the platinum mètre of the board of longitude; the same is also engraved on the inverse side of the mètre itself.

The brass mètre of Fortin is not quoted in the certificate.

The platinum kilogram (4) is also certified by Mr. Arago to have been compared with the platinum kilogramme in the archives of France, and not to differ from it in weight for one milligramme. A silver plate on the box contains an inscription to the same effect.

The brass kilogram of the same form as the original ones distributed by the Committee of Weights and Measures in Paris: the subdivided square kilogram and the litre modèle, have not been mentioned in the certificate of Mr. Arago, dated Paris, 5th September, 1821.

5. The Algerine length measures, (noted 5) and the two different ounce weights, are accompanied by a detailed account upon the coins, weights, and measures, and the special use of each, from the American Consul in Algiers, Mr. Wm. Shaler, dated 26th March, 1821.

6. The collection of Coelnish mark weights, noted (6,) has been procured from the mint of Copenhagen, by Mr. Forbes, United States' Consul there, in 1818. They are well executed, but, being adjusted by lead put in the interior of the brass, they have lost the accuracy of their adjustment by the galvanic oxydation.

D.

A list of standards included in this comparison, and obtained from other sources than the State Department.

1. From the collection of instruments made for the survey of the coast of the United States, deposited in the War Department.

LENGTH MEASURES.

One large brass scale of 82 inches, divided upon silver into tenth of inches, with a parallel scale bearing microscopes, with a micrometer; made by Mr. Edward Troughton, in London, with a tracing apparatus to make other scales from it.

An iron yard, cut to proper length by Troughton, of a bar similar to the French iron mètres "à bout."

One brass mètre of Lenoir, in Paris.

One iron toise of the same.

CAPACITY MEASURES.

Two litres modèles, made by Fortin, in Paris.

WEIGHTS.

One steel balance, with a set of weights, from ten thousand grains to the hundredth part of the grain; of Troughton.

Two subdivided square kilograms, with decimals of grammes to the milligramme; made by Fortin, in Paris.

2. From the Philosophical Society of Philadelphia.

LENGTH MEASURES.

One iron mètre, *original* standard, made by the Committee of Weights and Measures in Paris.

One iron toise, made by Canivet, at Paris, in 1768.

WEIGHTS.

One kilogram, in brass, original standard, made by the Committee of Weights and Measures in Paris.

3. From the Treasury Department.

LENGTH MEASURES.

A brass scale of 52 inches, divided into tenth of inches, by F. R. Hassler, from the 82 inches scale of Troughton; and having upon it also a mètre copy; and the distance of 51.2 inches, from Sir George Shuckburgh's scale, marked upon by Mr. Troughton.

A brass scale made by Troughton, having between points, in platinum dots, the length of the English yard, and that of the Amsterdam foot.

One iron mètre, standarded in the course of this comparison.

A brass mètre "à bout," of Fortin, in Paris.

WEIGHTS.

One troy pound of Troughton, exactly agreeing with the grain weights of his scale above.

4. The United States' Mint at Philadelphia possesses a new troy pound; made by Captain Kater, in London, which being the legal standard of the Mint, was adopted for the unit weight of comparison here, the weight of it being determined in grain weights of Troughton's balance above.

One mark of Castile, of the Madrid mint.

One mark of the Mexican mint.

5. From the Collector's office of Portsmouth.

A series of metal standards of weights and capacity measures, belonging to the State of New Hampshire, viz.

WEIGHTS.

Four bell form brass weights of 4 lb., 14 lb., 28 lb., and 56 lb.

CAPACITY MEASURES.

Ten metal capacity measures, viz.

One bushel.

One half bushel.

One peck.

One gallon, and its subdivisions by halving.

6. In the Engineer Department were also found two brass mètres of Lenoir, that were compared.

7. From the office of the Secretary of State of the State of New York.

One brass yard, cut to length.

8. The honorable late President, John Q. Adams, communicated to me, for the use of this comparison, the following weights:

One brass avoirdupois pound, of Boston.

One brass kilogram nest.

One brass nest of weights of one Russian pound.
One iron standard pound of Russia.
One brass nest Amsterdam pound.
One brass nest Swedish victualling pound.
Seven Chinese brass weights, from 20 tales to 8 mace.

9. From the Virginia University, in Charlottesville.
One brass scale of 40 inches, English, made by Gilbert, in London.
One set of brass troy weights, with decimal subdivision of the pound, from 5 lb. to the minutest parts of decimals of the pound, belonging to a scale in the possession of the University.

10. From Lewis Brantz, esq., of Baltimore.
One ivory beam, regulated upon the Chinese weights for silver.

D.

Vouchers upon the origin and authenticity of the standards included in this comparison, other than those from the State Department.

1. Standards from the collection of instruments for the coast survey.

The accuracy of the unit of length measure to be employed in the coast survey, was such an indispensable requisite, that I took, of course, all necessary measures to obtain it, when I was in Europe, to procure instruments for that work. The French mètre is the absolute unit of length which has been the most accurately determined. It is presented multiplied in the original by 15 bars of iron and one bar of platinum, cut to that length; and the temperature of melting ice, or 32° Fahrenheit, is the standard temperature for the same.

The English standard of length consisted, until the late changes made in England, in a brass scale of undefined length, divided into inches and tenths of inches, the mean of which, for any length, measured upon as many parts of the scale as found proper, was considered a standard of that length, at the standard temperature of 62° Fahrenheit. As it was naturally desirable that the distances of the survey would be given in both lengths, I caused Mr. Troughton, in London, to construct the scale of 82 inches English, quoted in the preceding list, which he made by doubling his own scale, after having made a new table of errors, to correct this transfer by it, from the same he had already divided the scale of Sir Geoge Shuckburg Evelin, which has served for his comparison in 1795, and since for those lately made by Captain Kater. This scale, the accuracy of which within itself is exhibited by the statement to be seen in the detailed account of the operation of the present comparison, forms, therefore, a direct link to unite the present comparison with the late English determinations of the yard and pendulum, as well as the general means of comparison.

Mr. Lenoir, the mechanician, of Paris, who constructed the mètres for the Committee of Weights and Measures, having, at the same time with those above quoted, standarded a brass mètre for himself, at the temperature of 32° Fahrenheit, I procured a copy of the same, which was compared at the Observatory of Paris with the mètre there preserved. The certificate signed by Messrs. Bouvard and Arago states it to be too short for 1-100 part of a millimetre, or 0,000393810 of an English inch, and is dated 16th March, 1813.

The iron toise was also made by Lenoir, and compared at the Observatory at Paris by Messrs. Bouvard and Arago, under the above date.

Having by the above so much of the standards, I found it proper, and hoped in future useful, to make the small additional expense of procuring also accurate weights. The balance of Troughton, with grain weights, which were again exactly verified by him. Of Fortin, the mechanician in Paris who had constructed the weights, and litres modèles for the Committee of Weights and Measures, I procured two subdivided cubical kilograms, with the decimals to the milligramme, and two litres modèles; by procuring two individuals of each kind, I obtained the indication of the degree of accuracy with which they are made, and their coincidence has been very satisfactory.

2. The Philosophical Society in Philadelphia is in possession of several, and, in their kind, the most valuable standards; which I brought with me to this country on my arrival in 1805. I was favored with a loan of them for the present comparison.

The iron mètre is one of the original standards made by the Committee of Weights and Measures, as quoted above.

That part of the work being under the special direction of Professor Tralles, my friend and teacher in mathematics, member of the committee, as deputy from the Helvetic Republic, he made three of the above iron mètres more than what was required for the deputies present; one of these he made a present of to me, which is the one here compared. It is, therefore, fully accurate, and of original authenticity.

The same is the case with the kilogram of the society. Its origin and history is in every thing exactly the same, except that it was Mr. Van Swinden, deputy from the Batavian Republic, who had the special care of their construction. The one present is No. 2, as a label in the box indicates. A private paper of Mr. Tralles, in my possession, not yet printed, detailing the ultimate comparisons of the metres, the kilogram, and also those of the toises, designated this kilogram No. 2 as entirely exact.

The toise of Canivet, of 1768, I purchased in Paris, in 1796, from the heirs of the late Mr. Dionis Dusejour. It is in perfect preservation, being guarded by a matrix, so as never to expose its determining ends; it has marked on the reverse the double length of the pendulum under the equator, which indicates its having been designed for the comparison; when, at the epoch of its construction, this length was proposed as an unit standard from nature.

The society possesses, also, two copies of the well known toises of Lalande, made by myself, on the occasion of my triangulation of Switzerland in 1791. They were included in my comparison for the coast survey, but I did not find proper to make them enter into the present.

3. The Treasury Department acquired of me lately the standards which I had yet in my possession for my private use. The scale of 52 inches has also marked upon it the distance 51,2 from Sir George Shuckburg's scale. On account of that, I immediately purchased it from Mr. Troughton, when I saw it in his workshop, as it furnished a direct comparison with that scale; which has become of great importance by its use in the English comparisons.

Before I delivered the instruments for the coast survey, when that work was interrupted, I laid off upon it, 1st, from the middle of the large scale of Troughton the divisions in tenths of inches; 2d, the mètre from the brass mètre of Lenoir, in the coast survey collection; 3d, the half toise from the half of the toise of Canivet.

The yard between platinum dots, I procured from Mr. Troughton, upon yet imperfect information upon the new yard established by the last English determinations, which proved what since became public; and the result of the present comparison shows: that it is actually only the old exchequer yard that was adopted: it is less than the exchequer copy of the State Department, of Jones, only by 0,00005275 of an inch.

The Amsterdam foot was marked upon it, on account of its frequent occurrence in the measurement of land and lots in New York upon old titles; and for this also its comparison result, given in this report, may be useful.

The brass metre of Fortin I had acquired in this country from an European scientific gentlemen, finding it in full good preservation. Fortin certifies it to be fully correct, under date 24th December, 1824.

Knowing the occasions I would have to compare standards, I had an iron bar constructed for myself, at the same time as those intended for the base measuring apparatus, which are all equal in breadth and thickness to the original iron metres of the committee. This I intended to convert into a mètre for myself; when near, still above the proper length, it was taken up in the comparisons made for the coast survey, where an additional mètre was needed. Only on the occasion of the present comparison, I had the opportunity to adjust it fully, it being besides necessary for the comparison of the iron mètres by combination.

The troy pound I had brought with me to this country in 1805. It was made in Switzerland by a careful artist of Arau, Mr. Esser, after one that I had received from Mr. Troughton. Mr. Patterson, Director of the Mint in Philadelphia, compared it in 1805, with the troy pound of the Mint then in use, and found them exactly equal; but the Mint pound having since been in frequent use, while I preserved mine always carefully, on a comparison made, in the fall of 1830, the former was found considerably lighter.

4. The *troy pound of the United States' Mint at Philadelphia*, was made by Captain Kater, purposely for the Mint, upon the request of Mr. Gallatin, who considered this an authority far superior to the comparison of the Exchequer. The weight is in form similar to those made by Kater for the Exchequer, and enclosed within its box, in a brass form, upon which is engraved, Pound Troy, 1824, Bate, London. A detailed certificate of Captain Kater, dated London, 30th June, 1827, certifies to the comparison, and quotes the ultimate experiments with the same. A certificate of Mr. Gallatin, of the 24th July, 1827, testifies to its origin, and President Adams, under date of 13th October, 1827, to the safe and undisturbed reception thereof, so as to warrant full trust in its accuracy.

The *mark* weights of *Madrid* and of *Mexico* were also received by authority; the former, called marco-castilliano, is one of two made at Madrid upon orders of Mr. Everett, ambassador of the United States, and found exactly equal to that at the Madrid Mint, as certified by him under date of 30th January, 1827. It arrived entirely safe and well preserved at the Mint of Philadelphia, as testified by the officers of the Mint, 9th August, 1828.

The *Mexican mark* was procured from the Mint in Mexico, with the standard of which it was found exactly equal, by Mr. Poinsett, United States' ambassador there, as testified by him under date of 30th February, 1828. It was received in perfect order at the Mint, as testified by the officers thereof, 9th August, 1828.

5. When the present comparison was already in a considerable state of forwardness, information was received, that there was still extant, in the custom-house of New Hampshire, a set of standards of weights and capacity

measures, from the old provincial Government of that State. Upon the request of the Treasury Department, they were forwarded here by the collector, and proved a valuable acquisition to the object of this comparison.

They bear generally the stamp of G. I., besides that of the Exchequer; are, generally speaking, in good preservation; but unfortunately, since the report inserted of them in the Report upon Weights and Measures of the honorable late President, John Q. Adams, they were sent to Boston for verification, where several capacity measures were reduced, by means of lead fixed in their bottoms. This was evidently intended to bring them down to the newer standards, which appear generally to have suffered a reduction by negligence. The weights appeared not to have been altered, except the 14 and 56 lb., which had a little lead added to the bottom.

6. The two brass mètres of the Engineer Department have no special authority or certificate, except the name of the maker, Lenoir, engraved upon them.

7. The city of New York having procured a set of copies of the Exchequer standards, they were lent to the State Government to make standards for the State from them.

The yard of this collection remained in Albany at the office of the Secretary of State of New York. The weights are still in keeping of the street commissioners in New York, and only copies are at the State office in Albany.

Of capacity measures, none exist in either place that bear any Exchequer stamp, or other mark of authenticity; the State Government having yards made for each county, the Secretary of State lent to me one of them, which had been intended for the county of Chatauque, of which it bears the inscription.

8. The interest which the late President John Q. Adams has always taken in the proper regulation of the weights and measures of the country, has prompted him, on my communication of the operation in which I was engaged, to favor me with the loan of the different weights quoted as coming from him.

9. The University of Virginia has a scale of 40 inches, upon which also the French mètre is laid off, and a set of weights, but no certificates are with them, upon their comparison with other standards than the present. Dr. Patterson, professor of natural philosophy of that University, was so good as to communicate them to me for the use in this comparison.

10. Lewis Brantz, esq., in Baltimore, lent to me the ivory beam, which is of the kind used in commerce to weigh the silver in China, from whence he brought it.

11. Extract from a letter of John Upham, collector of Portsmouth, N.H., to the Hon. John Q. Adams, Secretary of State, dated Portsmouth, Dec. 17, 1819.

"A set of avoirdupois weights, a set of measures for dry, and a set for wine measure, belonging to the State of New Hampshire, and which are the legal standard for those measures in this State, are, at my request, deposited and kept in the custom-house, and by which are regulated all the weights and measures used in the collection of duties.

"For dry measure, they consist of a bushel and its parts, down to one-eighth part of a pint. They are made of hardened copper, and were imported from England before the revolution by the then colony of the New Hampshire. They are sealed and stamped with the King's arms."

E.

EXTRACT from the results of Sir G. Shuckburgh's comparison of standards of English Length Measures, reduced to the yard, and measured by his scale with microscopes made by Troughton.

	Inches of Troughton's scale.	Difference.
Mean of 36 inches on the standard of Henry VII., of 1490,	35,924	— 0,076
The same on that of Elizabeth, 1588,	36,015	+ 0,015
The same, from the ell of the same,	36,016	+ 0,016
Mean of the yard bed of Guildhall, 1660,	36 032	+ 0,032
From the ell of the same bed,	36,014	+ 0,014
Yard of the Clockmaker company, 1671,	35,972	— 0,028
Yard of Rowley's tower standard, 1720,	36,004	+ 0,004
Mean of Graham's scale, by Sisson, E. 1742,	36,0013	+ 0,0013
Do. do. do. in the Exchequer,	35,9933	— 0,0067
Mean of General Roy's scale, } all made by Bird, 1745 and 1760,	36,00036	+ 0.00036
Do. Mr. Aubert's do. } all made by Bird, 1745 and 1760,	35,99880	— 0,0012
Do. Royal Society's do. } all made by Bird, 1745 and 1760,	35,99955	— 0,00045
Bird's Parliamentary standard, 1758,	36,00023	+ 0,00023
Mean of Troughton's scale of Sir George Shuckburgh,	36,00000	

F.

RESULTS of comparisons of the English Length Measures in inches of the mean of Troughton's 82" scale.

		Yard in inches and tenths.
First. From the State Department.		
The copy of the Exchequer yard, of Ths. Jones, (a)	- -	35,9990285
The copy of the Exchequer ell, of the same,	45,0389644	
This last, reduced to the yard by its legal ratio, gives	- -	36,031171
The yard between lines traced upon silver, of Th. Jones's scale,	- -	35,9938350
The ell, upon the same	45,03343	
This last, reduced to the yard by the legal ratio, gives	- -	36,26744
The yard, of the bed of the older standards,	- -	35,987497
The ell, of the same,	45,26101	
This latter, reduced to the yard by its legal ratio, gives	- -	36,020881
Second. From the Treasury Department.		
The yard of Troughton's scale, between platinum dots, (a)	-	35,9989758
The yard, mean of the scale divided by myself,	-	36,0002465
The 51,2 inches of the same scale, taken from Sir George Shuckburgh's scale, measured	51.1992977	
The yard resulting from this length, proportionally, is (a)	- -	35,999506
Third. From other sources.		
The scale of the University of Virginia, by Gilbert, in the mean,	- -	35,9952318
The iron yard of the Eng'r Dep't, cut to length by Troughton,	-	35,998776
The brass yard, from the Secretary of State's office in Albany,	- -	36,01545

G.

Results of the comparisons of the Length Measures sent in by the Custom-houses.

	Actual length. Inches.	Resulting yard. Inches.
A folding yard rule, from Philadelphia,	- -	36,0002465
A sixty inch tape, from do.	59,6	35,76
A yard stick, from Boston,	- -	36,02581
A yard stick, from Baltimore,	- -	36,0156
A tape, from do.	- -	36,05
One octagon 48 inch stick, from Richmond,	48,12	36,09
Brass rules of one-third yard, from Providence:		
No. 1,	12,026	36,078
No. 2,	12,055	36,165

I.

***RESULTS** of the comparisons of the Toise and other Foreign Length Measures, reduced to 32° Fahrenheit.*

	Individual result in English inches.	Mean final in Eng. inches.
1st. The iron toise of Canivet, of 1768:		
By the present comparison,	76,74290511	76,74312493
By the comparison for the coast survey,	76,74334472	
The iron toise of Lenoir, of the coast survey collection:		
By the present comparison,	76,74047599	76,74120154
By the comparison for the coast survey,	76,74192710	
Double length of the equatorial pendulum, as marked upon the rear of the toise of Canivet, (compared only this time,)	- -	77,99815740
2d. The foot of Amsterdam, between platinum dots upon the yard scale of Troughton, in the Treasury Department,	- -	11,30346
The two Algerine length measures, called pick, in the State Department collection:		
The long or Turkish pick,	- -	25,075
The short or Arabic do.	- -	9185

H.

Results of the comparisons of the Metre Standards with the 82 inch scale of Troughton, reduced to the temperature of 32° Fahrenheit, for both the scale and the mètre.

	Individual results in English inches.	Definitive mean in Eng. inches.
1st. Original iron mètre "à bout" of the committee of weights and measures, by the combination results of the present comparisons, - - - -	39,3808643	39,38091714
By the comparison for the coast survey, 1817, -	39,381022708	
2d. Iron mètre "à bout" of the Treasury Department, standarded by myself in the present comparison, -	- -	39,3807827
3d. Iron mètre "à bout" of Lenoir, in the coast survey collection, by the present comparisons, - -	39,3799120	39,3799487
By the comparison for the coast survey, - -	39,37972015	
By a comparison made in London, 1814, by Mr. Troughton with his own scale, - - -	39,3802506	
4th. Platinum mètre of the State Department, corrected according to certificate of Mr. Arago:		
By all my comparisons, - - - - -	39,3803278	39,3804194
By comparisons made by Mr. Nicollet, - -	39,380511	
5th. Brass mètre of Lenoir of the coast survey, corrected according to the certificate of Messrs. Bouvard and Arago:		
By the present comparisons, - - - -	39,3804470	39,3803688
By the comparison for the coast survey, 1817, -	39,380247972	
By comparison of Mr. Troughton, London, 1814, -	39,3803333	
6th. Brass mètre of Lenoir, found in the Engineer Department, and marked Mr:		
By the present comparison, - - - - -	39,3801714	39,3804404
By a comparison made in 1829, - - -	39,3807095	
7th. Brass mètre of Lenoir, of the Engineer Department, marked Md, only compared in this comparison, -	- -	39,38052739
8th. Brass mètre, of Fortin, of the State Department:		
By the present comparisons, and by comparisons made in 1829, - - - - - -	- -	39,3796084
9th. Brass mètre, of Fortin, of the Treasury Department:		
By the present comparison, - - - - -	- -	39,3795983
10th. The mètre laid off upon the scale of the Treasury Department, by myself, from the Brass mètre of Lenoir of the coast survey collect'n, corrected f. C.	- -	39,3802718
11th. The mètre upon the scale of Gilbert of the Virginia University, - - - - - -	- -	39,365408
REMARK.—The means of the last column are not the means of the preceding numbers, but the means all individual comparisons.		

K.

RESULTS of the comparison of the English Brass Standard Weights of the State Department, and from other sources.

DENOMINATION AND ORIGIN.	Weight in grains of		Pounds resulting from other wei'ts, in grs. of	
	Troughton.	Mint pound	Troughton.	Mint pd.
1 lb. troy, of the Mint of Philadelphia, -	5762,41	5760,0		
1 lb. do. Treasury Department, -	5760,00	5757,52		
1 lb. do. average of the tower troy nest of the State Department:				
from 1 oz. and upwards,	-	-	5760,286	5757,93
from 4 oz. and upwards,	-	-	5761,611	5759,2
1 lb. do. of Virginia University, -	5762,526	5760,116		
1 lb. do. average of the four Virginia University weights, -	-	-	5762,504	5760,093
16 oz. Tower troy nest of State Department,	7680,07	7676,86	5760,052	5757,643
16 oz. Average mean of combination of same,	7680,217	7677,004	5760,160	5757,753
1 lb. Avoirdupois in Troughton grains, taking the Mint pound for unity, at the legal ratio of 5760 to 7000, -	-	-	7002,9288	7000,00
1 lb. Avoirdupois of the pile of State Dept.	7001,277	6998,347		
1 lb. do. average of the pile:				
of 1 lb. and upwards, -	-	-	7001,813	6998,899
of 4 oz. and upwards, -	-	-	7001,088	6998,17
1 lb. do. bell-form of State Dep't,	7002,376	6999,447		
1 lb. do. from late Pres't Adams, marked Boston, -	7002,45	6999,52		
Old weight in the State Departm't collection, marked A. C. - - - - -	6952,535	6949,63		
2 lb. Avoirdupois of the pile in the State Department, - -	14001,77	13995,91	7000,885	6997,955
2 lb. do. bell-form of the same, -	14002,43	13996,57	7001,215	6998,285
4 lb. do. pile of the same, -	28012,74	28001,00	7003,185	7000,25
4 lb. do. bell-form of the same, -	28016,12	28004,4	7004,03	7001,1
7 lb. do. do. do. -	49014,38	48993,88	7002,05	6999,126
8 lb. do. pile do. -	56015,23	55992,36	7001,904	6999,045
14 lb. do. bell-form - -	98015,8	97974,8	7001,13	6998,20
28 lb. do. do. - -	196024,578	195942,58	7000,877	6997,95
56 lb. do. do. - -	392093,0	391929,0	7001,66	6998,73
1 lb. do. average of all bell-form weights, - -	-	-	7001,905	6997,584
4 lb. New Hampshire stand. from G. I. -	28015,83	28004,11	7003,96	7001,03
14 lb. do. do. -	98050,555	98009,655	7003,61	7000,69
28 lb. do. do. -	196098,193	196013,148	7003,505	7000,469
56 lb. do. do. -	392205,75	392041,7	7003,673	7000,741
1 lb. average of the N. Hampshire stand's,	-	-	7003,687	7000,732

Details of the Weights of the Tower Troy nest of State Department.

DENOMINATION OF WEIGHTS.	In Troughton's grains.	In U. S. Mint weight.	Resulting pound in,	
			Trought. grains.	Mint weight.
¼ oz. smallest piece, - - - -	118,800			
¼ oz. next smallest piece, - -	121,000			
½ oz. following piece, - - -	239,490			
1 oz. - - - - - -	479,480	479,2795	5753,76	5751,35
2 oz. - - - - - -	959,590	859,189	5757,54	5755,13
4 oz. - - - - - -	1920,617	1919,813	5761,88	5759,47
8 oz. - - - - - -	3840,72	3839,114	5761,08	5758,67
16 oz. - - - - - -	7680,07	7676,86	5760,146	5757,736
32 oz. - - - - - -	15364,020	15357,59	5761,01	5758,60
64 oz. - - - - - -	30735,620	30722,77	5762,98	5760,51
128 oz. - - - - - -	61469,125	61443,42	5762,73	5760,32
256 oz. - - - - , -	122912,87	122861,48	5761,51	5759,1
The whole nest, - - - - -	245841,407	245738,636	5761,907	5759,499
Average troy pound from all above ½ oz. -	-	-	5760,286	5757,93
Do. do- do. 2 oz. -	-	-	5761,611	5759,20
Average troy ounce, from the weight of the whole nest, - - - -	-	-	480,1592	479,959

Details of the Weights of the Avoirdupois pile of the State Department.

	In Troughton's grains.	In mint weight.	Resulting pound.	
			Trought. grains.	Mint weight.
1 dwt. smallest piece of pile, - -	28,650			
2 dwt. - - - - - -	54,80			
4 dwt. - - - - - -	109,50			
8 dwt. - - - - - -	218,42			
1 oz. - - - - - -	437,02			
2 oz. - - - - - -	875,43			
4 oz. - - - - - -	1749,90	1749,161	6999,60	6996,67
8 oz. - - - - - -	3499,84	3498,376	6999,68	6996,75
1 lb. - - - - - -	7001,277	6998,347	7001,277	6998,347
2 lb. - - - - - -	14001,77	13995,91	7000,885	6997,955
4 lb. - - - - - -	28012,74	28001,00	7003,185	7000,250
8 lb. - - - - - -	56015,23	55992,36	7001,904	6999,045
The whole pile, - - - - -	112004,597	111957,753	7001,9935	6999,065
Av. Avoirdupois pound from all above 2 oz.	-	-	7001,088	6998,17
The same, from 1 lb. and upwards, -	-	-	7001,813	6998,899

L.

***RESULTS** of the comparison of Weights sent in by various Custom-houses, which are all Avoirdupois Weights.*

NAMES OF PLACES.	Trought. grains.	Value referred to the Mint pound.
Brass weights.		
2 lb. Philadelphia,	14011,27	14005,41
4 lb. do.	28023,14	28011,4
7 lb. do.	49023,93	48980,86
14 lb. do.	98077,81	98036,9
28 lb. do.	196150,816	196068,57
½ lb. New Orleans,	3491,5	3490,04
1 lb. do.	7013,47	7010,534
2 lb. do.	13997,55	13991,7
4 lb. do.	28028,74	28017,0
7 lb. do.	49069,8	49049,3
14 lb. do.	98089,4	98048,4
56 lb. do.	391895,3	391731,5
1 lb. Providence—No. 1,	6998,53	6995,603
No. 2,	7004,1	7001,17
56 lb. Boston,	392317,0	392153,0
8 lb. Portsmouth, for Dearborn's balance,	56034,807	56011,37
16 do. do.	112070,63	112023,74
32 do. do.	224102,481	224008,84
Mean pound from Portsmouth weights,	-	7001,060
1 lb. New York, iron weight,	7016,22	7013,285
2 lb. do. do.	13996,76	13990,9
4 lb. do. do.	28017,14	28005,4
7 lb. do. do.	49025,48	49004,9
14 lb. do. do.	97984,47	97943,5
28 lb. do. do.	196161,227	196079,227
56 lb. do. do.	392354,8	392191,0
1 lb. Baltimore, do.	6973,07	6970,15
2 lb. do. do.	13664,55	13661,9
4 lb. do. do.	28000,14	27988,4
7 lb. do. do.	49031,5	49011,0
14 lb. do. do.	98120,41	98079,5
28 lb. do. do.	196378,627	196296,445
56 lb. do. do.	391855,4	391691,5
1 lb. Wilmington, Delaware, iron weight,	7078,47	7075,52
2 lb. do. do.	13969,27	13963,4
4 lb. do. do.	27902,24	27890,51
7 lb. do. do.	48894,1	48872,5
14 lb. do. do.	97768,6	97727,6
28 lb. do. do.	196169,727	196987,681
56 lb. do. do.	392780,8	392616,6
50 lb. weights, received from Norfolk, were in so bad a state as not to be worth comparing.		

M.

RESULTS of the comparison of Foreign Weights.

DENOMINATION OF THE WEIGHTS.	In Trought. grains.	In Mint pd. grains.	In French grammes.
Original French brass kilogram, of the Committee of Weights and Measures, - - -	15439,619	15433,15902	1000,000
French brass kilogram copy, of the State Depart.	15439,619	15433,15902	1000,000
Do. platinum kilogram, of the same, -	15441,02342	15434,56344	1000,0910
Do. brass cubic subdivided kilogram of the State Department, - - -	15439,642	15433,18202	1000,0015
Do. of the coast survey collection—No. 1, -	15439,7039	15433,24392	1000,0055
No. 2, -	15439,673	15433,21302	1000,0035
Brass kilogram nest of late President Adams, -	15442,6755	15436,21424	1000,198
English troy pound, according to Trought. gr. -	5760,00	5757,52	373,0661
Do. do. by the Philadelphia Mint wt.	5762,41	5760,0	373,2223
English avoirdupois pound, in Troughton grains,	7000,00	6997,07	453,379
Do. do. by the Mint wt. of Philad'a,	7002,9288	7000,00	453,5685
One grain of Troughton, - - - - -	1,0	0,9995816	0,06477
One do. of Mint weight, - - -	1,000411	1,00	0,647955
One brass mark of Madrid Mint, - - -	3555,86	3554,3723	230,3068
The same, determined by Dr. Moore at the Mint,	-	3554,4	
One brass mark of the Mexican Mint, - -	3551,83	3550,4439	230,0466
The same, determined by Dr. Moore at the Mint,	-	3550,4	
One brass nest, Russian Mint pound, } Of late	6309,97	6307,316	408,687
One iron pound, Russian standard, } President	6314,05	6311,41	408,9512
One brass nest, Amsterdam pound, } John Q.	7633,95	7630,76	494,439
One brass nest, Swedish victual'g lb. } Adams.	6542,07	6539,33	423,7195
The set of brass Coelnish weights of the State Department, gave the Coelnish mark in a mean,	3610,88	3609,27	233,865
The Algerine weight in the State Department, brass angular ounce weight—the lighter, -	479,82	479,619	31,0067
the heavier, -	529,13	528,9086	34,2709
Brass weights of late Pres't Adams, give by a mean the Chinese tale, - - - -	579,8766	579,634	37,5567
The ivory beam of Lewis Brantz, esq. gave, by a mean, for the Chinese tale, - - -	586,4766	586,2313	37,882
Russian coins, entirely new—silver rouble piece,	320,964	320,830	20,7884
platinum, 3 roubles,	159,884	159,817	10,35545
gold, 5 roubles,	121,384	121,335	7,86186

NOTE.—The Holland's troy pound which Mr. Van Swinden brought to Paris when Member of the Committee of Weights and Measures, was found to weigh, in French grains, 9266,1168

This gives in French grammes - - - - - - 492,16802

The Amsterdam pound of late President Adams weighed, grammes - 494,439

Thence it is heavier than the Van Swinden troy pound in grammes - - 2,277

Which denotes a different weight.

N.

RESULT of the determinations of the Capacity Measures.

DENOMINATION OF MEASURES AND ORIGIN.	Legal dimension.	Dimension in cubic inches by measurement.	Weight of distilled water at maximum density, and 30 inches barometer, of the measures themselves.		Reduced to the		Remarks.
			Troughton grains.	U. S. Mint weight.	Gallon, U. S. Mint weight.	Bushel, U. S. Mint weight.	
1. *Metal standards of State Department, with the stamp of* G. IV.							
The wine gallon,	231,0	235,04	58484,63	58460,2	58460,2	467681,6	
The pint, Winchester,	33,6	35,063	8814,89	8811,21	70489,68	563917,44	
The quart, do.	67,2	71,654	17691,61	17684,21	70736,84	565894,72	
The gallon, do.	268,8	274,325	68599,7	68571,0	68571,0	548568,0	The stamps upon the edges are dis-
The bushel, do.	2150,4	2124,1	540208,45	539981,3	67497,66	539981,3	advantageous to the greatest accuracy
The coal bushel,	-	2211,26	560249,3	560050,0	70007,1	360050,0	in the filling.
2. *Metal standards of the State of New Hampshire, bearing the stamp of* G. I.							
The 1/8th pint,	-	3,56	957,55	957,15	61257,60	490060,8	The top ground off; stamps disappear'd
1/4 do.	-	7,125	1914,75	1913,95	61246,4	489971,2	
1/2 do.	-	16,90	4441,04	4439,2	71026,9	568215,0	In good order.
Pint,	-	33,86	8855,27	8851,57	70812,56	566500,5	
Quart,	-	66,87	17089,95	17082,7	68330,8	546646,4	Considerably diminished, by lead
Half gallon,	-	134,97	34229,22	34214,9	68429,8	547438,4	poured in the bottom.
Gallon,	-	269,59	68777,97	68749,2	68749,2	549993,6	
Peck,	-	537,35	136756,03	136698,76	68349,4	546795,0	In good order, and unaltered.
Half bushel,	-	1074,2	271648,0	271534,4	67883,6	543068,8	
Bushel,	-	2099,2	543994,0	543766,2	67970,8	543766,2	About 19 cubic inches of lead cast in the bottom.
3. *Metal Capacity Measures from the Custom-houses.*							
Copper half bushel, from Boston,	-	1076,3	271496,15	271382,6	67845,4	542765,2	
Do. do. Philadelphia,	-	1076,55	275398,15	275284,2	68821,05	550568,4	
Do. quarter bushel, from Providence,	-	539,7	136591,6	136537,6	68268,8	546150,4	
Do. gallon, do.	-	219,5	57809,4	57785,2			
Do. do. Boston,	not measu	rable form.	58568,5	58544,0			
Sheet tin gallon, from Baltimore,	-	224,1	58690,9	58666,5			
Do. do. Richmond,	-	226,5	59392,604	59367,73			
4. *French Metal Litres—Modèles.*							
Of the State Department,	-	61,075	15407,84	15401,33	-	-	The tops being well ground, they ad-
Of the coast survey collection—No. 1,	-	-	15411,21	15405,08			mit very nice weighing with water.
No. 2,	-	-	15411,85				
5. *Wooden Capacity Measures from the Custom-houses, which do not admit determinations by weight of water.*							
			Res'g bush.				
Half bushel, from Portsmouth,	-	1078,35	2156,7				
Two bushel tub, of New York,	-	4115,56	2057,78				This proves that even for coal and salt
Three do. do.	-	6168,78	2056,29	-	-	-	a diminished Winchester bushel is
Half bushel, from Wilmington, Dela.	-	1074,16	2148,32				used instead of the coal bushel.
Six bushel tub, from Baltimore,	-	13040,38	2100,94				
Half bushel, from Charleston, S. C.	-	1047,05	2094,1				
Bushel tub, from Richmond,	-	2165,2	2165,2				
Half bushel, from New Orleans,	-	1076,97	2153,94				

WASHINGTON CITY, January, 1832.

F. R. HASSLER.

REPORT

FROM

THE SECRETARY OF THE TREASURY,

On the subject of Weights and Measures, in further compliance with a resolution of the Senate.

July 3, 1832. Read.—July 7, 1832.—Ordered to be printed, and that 3,000 additional copies be furnished for the use of the Senate.

Treasury Department, *June 30th*, 1832.

Sir: Referring to a report from this department, under date of the 20th instant, relative to the examination made in pursuance of a resolution of the Senate of the 29th of May, 1830, of the weights and measures used at the principal custom-houses, I have now the honor to transmit the second part of Mr. Hassler's report, showing the means which were employed in making the comparison.

I have the honor to be,
Very respectfully,
Your obedient servant,
LOUIS McLANE,
Sec'ry of the Treas.

The Hon. the President of the Senate.

Washington City, *29th June*, 1832.

Most honored Sir: Herewith I have the honor to present to you my account of the means and methods employed in the comparisons of the weights and measures entrusted to me, forming the second part of my report upon that subject, presented the 27th January last, which had been devoted, principally, to the statement of the results of the operations of which the nearer account is herewith rendered.

This part, forming the voucher of the results, will, I hope, satisfy upon the propriety and fitness of the means employed, and give the necessary insight into the principles that must guide in such an investigation, and in the establishment and construction of standards to secure confidence and the necessary uniformity and accuracy.

Of the very numerous experiments which I have made upon the expansion of water by temperature, which is the necessary element of the determination of capacity measures, I cannot add more than the immediate observations of one series, as the time will not allow more, and it would be improper to separate the account of my operations, by too long a time, from my report upon their results.

I have the honor to be,
With perfect respect and esteem,
Most honored sir,
Your most obedient servant,
F. R. HASSLER.

Honorable Louis McLane,
Secretary of the Treasury U. S.
Washington City.

An account of the means and methods employed in the comparison of weights and measures, ordered by the Senate of the United States, under direction of the Treasury Department, in 1831, *by Ferdinand Rod. Hassler.*

1. That an establishment of standards of weights and measures may obtain the confidence which is necessary for its credit and proper reception by the public, it is necessary that it be grounded upon scientific operations, and that a public account be rendered of these, and of the means employed in them, by which every man possessed of the proper knowledge may satisfy himself upon the degree of accuracy obtained by the operations. Such an account forms a part of the work, distinct from the report to the Government, and the statement of the ultimate results, which form the part upon which the Government acts; it may also lead to establish uniformity in future operations for the comparison of individual standards, and the construction and verification of new ones, in the country.

2. The report to the Government can only present the ultimate results of the operations, the principles and determining reasons for the steps taken to activate and execute the work, and what relates generally to the practical use and application of the same—the detailed account of the scientific part, would encumber it improperly. The two first parts are contained in my report and the additional statements accompanying it; for the third, the present paper is intended.

3. The units required to regulate all dealings, being—length measures, weights, and capacity—measures, the work divides naturally in three distinct branches; each of which needs the application of different means of applied mathematics and natural philosophy. The unit of length measures ought, indeed, in a well regulated system, to be the base of the whole, by as simple ratios as possible. The exertions made with this view, and the success and advantages obtained by it, in the French system of weights and measures, are well known, but cannot enter here in the discussion. In the present operation, the aim could only be to determine a certain fundamental unit in each kind, the type of which is in general given by the habits of the country, and to determine the differences, or ratio, of all weights and measures, that came under consideration, with these, or their multiples or subdivisions.

Upon the length measures.

4. In my papers upon the coast survey, I have detailed my method, there pursued, for the comparison of the French metres with the English scale of 82 inches, made by Troughton, in London, for the use in that work. The approbation with which that was received by the men of science, besides my own satisfaction with the results, have decided me not to deviate essentially from it, in the present operation; it being, nevertheless, proper that in this place an account be given of them, I hope to be excused if I am obliged to repeat myself in some parts. Besides that, I shall give a description of the arrangements of the comparateur and scale that has been used both times, notwithstanding that a similar one has been described by Sir George Shuckburgh, in giving an account of his operations in 1797.

5. In England, until the late establishment of the yard as the standard unit of length measure, any desired length was determined by the means of any selected number of distances representing that length, upon a brass scale, from which the measure was laid off; thence arose a variation between the *ratios* of the length of different measures or scales, rather too great, and, principally, between the scales of different artists. Among these, however, Bird obtained the ascendancy about the middle of the last century; since when, gradually, more perfection was introduced in the methods. Bird was principally occasioned to make more accurate scales, by the use which he made of them for dividing his mural quadrants.

6. Of Bird's scales several exist in London; one in the Philosophical Society, one in the keeping of the Parliamentary archives, &c. From one of them originated that scale of Mr. Troughton, from which he made that of 60 inches, which Sir George Shuckburgh used in his comparisons in 1797, and which has been used also by Captain Kater, in the last establishment of British standards, made between 1814 and 1824. The present scale of 82 inches, as already stated, originates from the same, with all corrections indicated by a new trial of it.

7. Since this new British establishment, *the yard* is more decidedly adopted as the *single legal unit* of length measure, at the temperature of 62° Fahrenheit, and in *brass;* in the same manner as in France the metre, in *iron,* at the temperature of 32° Fahrenheit; and, previous to this, the toise. It is therefore to this unit, or yard, that all the comparisons of English length measures will be referred in future. For the ease of expressing smaller parts, the inch, and its decimal subdivisions, are, and remain, habitual. These were therefore used in the present comparison, uniformly, as unit of comparison.

8. The temperature of 32° Fahrenheit, or the melting ice, is a fixed point of the thermometric scale, generally ascertained by actual experiment; thence more to be relied upon than others, which are determined by different proportions. It is adopted for the French length measures. The necessity to account for the expansion of the metal of the scale, and to reduce the results to certain temperature, makes it desirable to select for this a point as well fixed as possible, and which in practice may be easily maintained, particularly when the standards to be compared are of different metals. This last consideration, I suppose, has, in England, occasioned the adoption of 62° Fahrenheit as standard temperature; but I found it in this country very unsteady, and not maintainable, while the temperature of 32° Fahrenheit can be much better maintained, and even the influence of the proximity of the observer is less. Therefore, in the most important comparisons, I select-

ed the temperature the nearest possible to that point, and, if possible, on both sides of it, reducing all results equally to that temperature; as they must present a fact that can be presented in nature, and not a result of calculations, as is the case when the *metre in iron* at 32° is given in inches of the English *brass scale* at 62° Fahrenheit. When the scales compared are of the same metal, and about the same thickness, the reduction becomes insensible; but when the scales are of different thickness, the lighter taking the changes of temperature quicker, it becomes necessary to keep account of their difference, when the temperature is not constant; and when the scales are of different metals, a reduction for the difference of their expansion is in all cases necessary. Therefore, in all comparisons, several thermometers are always laid upon each scale.

Description of Troughton's standard scale, and comparing arrangement.

9. The scale forms a large brass rule, of about 84 inches in length, 2½ inches broad, and ½ inch thick; (*a*, *a*, Fig. 1.) A silver strip is laid in through the middle of its whole length, in the same manner as is done in the circular instruments. A division into tenths of an inch is traced through the whole length, which therefore forms the proper standard scale.

10. Another brass rule of the same breadth and thickness (*b*, *b*,) but about six inches longer than the former, is laid parallel to the same; this has also a division in tenths of inches through its whole length, but traced only upon the brass, its destination being only to lead in placing approximately the supports of the microscopes (*cc*, *cc*,) that slide upon this rule, by the indication of their verniers. The lower part of this rule is about ½ inch narrower than the upper, in order to afford, by the projection of the upper of about ¼th inch on each side, a hold to the microscope supports, against their rising, as seen by the section of it in figure 2.

11. The two supports and microscopes differ somewhat in their arrangement, appropriately to their different functions. The one at the left side consists in a sliding case (*c*, *c*,) of about six inches long, embracing the rule as just stated, and shown in fig. 2; the lower parts have springing strips of brass, to hold the slide gently down to the rule, and the inner side the same, so as to maintain constantly the contact at the side that turns towards the standard scale. This support can be fastened in any position, by means of two screws (*d*, *d*,) at the side towards the observer. Upon this sliding case are three perpendicular brass columns, of 2½ inches high, and ½ inch diameter; these support a horizontal brass plate, of such a form as to reach about 1⅔ inch over the slides, towards the standard scale, and bring the microscope over the middle of the division of the standard scale.

The microscope is about five inches long, moving by friction, in a vertical tube that is screwed into the above plate. In the inner focus of it is a set of wires, as seen in fig. 3, furnishing one wire straight across, and two others crossing one another at an angle of about 20°: for a division of a scale by points, the single wire is used; and for one by lines, the crossing wires; with their intersection, the image of the division is brought in contact, so that it divides this angle equally, at their crossing point, in the centre of the microscope. This microscope, once placed, furnishes the fixed point in any comparison, from which the distances are measured in their minute parts by the micrometer of the other microscope.

12. The other microscope support, which is placed to the right hand side, is, in its main parts, similar to the one described, as evident by the figure, but it has, in addition to it, on the right side, a detached part of about two inches broad, of the same section as the slides, which has a strong perpendicular clamping screw, (*k*,) to fix it at any place of the rule; its use is evidently to form a support for the longitudinal fine and strong screw, (*h*,) which is running in a nut upon the top of it, and working in another one rising up from the microscope bearer, by means of which this is carried along the scale, in the minuter movements, for the adjustment of the micrometer microscope to the division, and determining the end point of the measure to be taken between the two microscopes. The two side screws, (*d*, *d*,) serve also here to fix the microscope support in its place, and when this is done the clamp screw, (*k*,) is released, in order to make the support independent of the longitudinal screw (*h*.)

This microscope has in its focus a system of wires exactly equal to that in the left hand one, but it is fixed in a frame moving by a micrometer screw. The micrometer head of this screw is divided into 100 parts, which denote each the 0,0001 of the inch, and are read off by the coincidence with a line presented to the edge of the division by an upright piece fixed to the frame of the micrometer. In the focus of the eye piece is fixed a rake made by the thread of the micrometer screw, upon the sharp edge of a thin piece of brass, by which the revolutions of the screw are indicated and read off, each division of which, therefore, represents 0,01 of the inch.

The system of wire slides along this rake, and the coincidence of the middle of the crossing wire with the corresponding part of the rake, is indicated by a very minute wire fixed to the micrometer frame, which presents itself sliding along this rake; each fifth tooth of the rake is indicated by a deeper cut, and, at one of them, a small hole is bored behind, to indicate the (*o*) point of the micrometer by the transparency; this is adjusted to coincidence with the (*o*) point of the micrometer head, by turning this latter around its axis, to which it holds only by hard friction. The paths of the micrometer screws are held to contact by the force of a watch spring, to the box of which a piece of watch chain is fastened, and to one side of the wire frame, which is counteracted by the screw from the opposite side. By this, all empty motion is avoided; these particulars are easily seen in figure 4, shewing a horizontal section of the micrometer part of the microscope. The object glass of the microscope is double, or achromatic, and the two-eye glasses act together, to form a very near focus, in which the wires are placed. The magnifying power is about 14 times.

13. The microscopes must, of course, be so adjusted that the scale, being exactly in the focus of the objective, proper for the distance of the wires, it measures exactly the tenth of the inch, by the nominal subdivision of its micrometer rake and screw head, when distinct vision is obtained. This requires the corresponding motion of the whole microscope, and the tube holding this object glass; therefore, the tube that holds it has a screw by which it may be brought nearer or farther to, or from, the wires. It is somewhat a chance to make this exactly, at the same time that the screws hold all their adjustments fast; the only approximate coincidence of this equal measure is, however, sufficient, provided the exact proportion of it is known. I preferred, therefore, always to bring the adjusting screws to a good rest, at an approximate adjustment, and determined the value of the micrometer corresponding to the tenth of an inch, by measuring every deci-

mal that falls under the microscope, at the same time when the scrutiny of the whole length to be measured upon the different parts of the scale, was made, as will be seen in the results of those made for the present comparison. In the use, it is, of course, necessary that the system of wires be exactly perpendicular to the longitudinal direction of the scale: this can be effected by placing them so as to make the single wire coincide with a division line of the scale, when also the angle of the wires will stand so as to be exactly bisected by the division.

Method of using this apparatus for comparisons.

14. The use of this whole apparatus for comparison, is as follows:

The standard scale is laid upon a solid stand, made of two 3 inch planks, edge barred upon one another, of double the length of the scale, and supported by six stout legs, the surface of which is exactly adjusted, so that no twisted, uneven position can take place; it must be as smooth as possible, that the scales may slide well in their necessary movements in a comparison, for it is not allowed to ease this motion by the interposition of any thing, because it would take away the steadiness of the lying of the scales, which is an indispensable requisite of the comparison. Along side of this, the parallel rule bearing the microscopes upon slides, is laid so as to bring the middle of the microscopes exactly over the middle of the divisions of the scale.

15. The choice of the points of the standard for comparison, must always be made so as to get it about equidistant from both ends, which will furnish for the distance the most accurate part of the scale; if the scale has been previously compared with itself upon that distance, a selection will offer itself in this, by chosing that distance which, in the scrutiny, has proved itself to correspond to the mean of the distances compared, as will be seen by the account of the scrutiny established in this comparison.

The microscope to the left, having the fixed system of wires, is now placed over the point to the left, selected for the beginning of the distance, and when in perfect coincidence, the sliding support is fastened by the two screws, (*d*, *d*,) then the microscope to the right is slided over the end point at the right of the intended distance, by the micrometer screw, the moveable wire system of it is placed in coincidence with the dotted (*o*,) of the rake, and the (*o*,) point of the micrometer head is made to coincide with its reading index, (*g*;) then the microscope is brought to exact coincidence, by means of the longitudinal screw, (*h*,) for which the detached part of the support is clamped to the scale by the screw, (*k*;) when exactly coinciding with the proper division of the scale, the support is fastened by the two screws (*d*, *d*,) and the clamping screw (*k*,) is relieved, so as to free the support from all influence of the additional piece and the long screw, (*h*.)

In the clamping by the screws (*d*, *d*,) it must be observed that, notwithstanding the very small play of the slide of the supports of the microscope, they must necessarily affect the coincidence of the microscope with the scale, by their different pressure, as they work, as to say, upon the two angular points of the base of a triangle, of which the microscope forms the vortex; therefore this coincidence is to be maintained by their more or less proportional pressure.

16. The division lines of a scale, or the line of contact of measures cut to length, with the butting pieces used in their comparison, present, of course, a small furrow in which any side light will produce a lightened and a shaded part, that it is essential to avoid; the apparatus must, therefore, be placed so as to receive the light as much as possible direct in the length of the divi-

sion lines, that is, perpendicular to the scale. This light, if taken direct, would still be glaring, and therefore very unfavorable to reading; the light reflected from an octavo sheet of white paper placed in a slant position behind the microscope, leaning between the two foremost columns and the microscope, will be found the most advantageous for reading, as it presents a full illumination of the scale, without any glare, which is the greatest impediment to exact vision.

17. Another necessary precaution is, against local influences of temperature. Not only the sun must not be admitted to shine upon the scales, or any part of the stand or other arrangement appertaining to the apparatus, and no fire is admissible in the room, which is always subjecting to a variable temperature, and that all during the whole time of the preparation and execution of a comparison. I took, besides, the precaution to nail to the side of the bench directed towards the windows, papers that reached several inches above it, to prevent any draft over the scale, and other large whole sheets on the side towards the observer, near the microscopes, so as to intersect the communication of the heat of the body of the observer to the microscopes and scale, or the effect of his breathing, in the places where the observer has to make the longest stay. A number of thermometers are then distributed over the whole scale and the parallel rule, and if any other scales or measures are to be compared, these scales or measures are laid to the side of the standard in full contact, with thermometers upon them.

18. Thus prepared, it is proper to let all rest until the next day, that the different parts may, what is called, come to rest together, and the temperature distribute itself among them as uniformly as possible. In the actual operation afterwards, it is proper to work with gloves on, to prevent the rapid communication of the heat of the hands to the parts of the apparatus, which, besides, is to be touched as little as possible.

By no arrangement whatsoever is it possible to take a distance between microscopes, and transfer it so to another place with the necessary accuracy.

19. When now the actual comparison is to be made, the standing of the microscopes is to be verified, and, if any deviation has taken place, this must be corrected; the most common variation is a change of place of the scale, by which both points are removed from the coincidence, which appears to be occasioned by the changes of temperature that have taken place since its placing. The left hand division of the scale is, therefore, to be brought again to exact coincidence with the left side, or fixed microscope, and if the micrometer microscope coincides again with the right hand side division, when the micrometer is upon (*o*,) the distance between the microscopes is proved correct; if there is any variation, two means present themselves: either to measure this difference, and to keep account of it in the comparison, that is, taking the distance between the microscopes for that which is indicated by the micrometer; which is the best method when the microscopes are found to be well fixed in their place, or to readjust the microscopes: this can most generally be done by the different moderation of the screws, (*d*, *d*,) as the variation will hardly exceed the limits which they admit.

20. Whenever the scale is to be moved longitudinally, this cannot be done by hand after the preliminary great movement, and would even not be properly effected by any screw motion, or similar arrangement; it is best done by striking the scale on the end from which it is to recede, with the head end of a light piece of wood; the lightest stroke will make effect, though the scale be very heavy; when heavier strokes have been necessary for the adjustment, the scale undergoes a kind of temporary compression of its parts,

in the direction of the length, from which it must be relieved to make it lie free; this will be effected by giving some light strokes to the scale vertically about its middle parts. It is, of course, also necessary to attend that the scale lie actually in a straight line, which may not always be the case, when it has been repeatedly pressed in a lateral direction, to adjust its division exactly under the middle of the microscope; this is relieved, and the scale laid straight by a light lateral touch with the end of the fingers, or the piece of wood. By these means combined, the scale is laid in its proper position to ascertain or present its actual length.

21. The first operation necessary, for the use of any comparison, is the comparison of the scale within itself, upon any distance that is to be compared, for, as already stated, the mean of all such distances, measured upon this scale, is the proper measure to be taken, according to the principle of all English divided scales. Thus, for my purpose, I compared the length of the yard, the division nearest to the metre, and the double metre, and others, all over the scale from every inch division, placed under the left hand microscope, and the divisions corresponding to the right hand microscope, as many times as the length of the scale admitted them, and, at the same time, always measured the decimal falling under the microscope, with the micrometer, to determine the value of its revolutions, which will serve for that individual comparison. The details of these comparisions will be presented in the corresponding tables of results; it will be observed by them that the comparing distance was always selected in the middle of the scale. It required all the work of that part of the day during which the illumination was propitious, to make the comparison from this part to one of the ends of the scale; both sides are then presented united in the regular order of the division of the scale, and I added to the results a column of differences between antecedents and consequents resulting from them. The nearer details of each will be explained by the heading of the columns, and the remarks added to each table.

22. The process of the comparison itself is the following: The scale being laid under the microscopes in the manner above stated, and thermometers distributed upon the scale, and the comparing parallel rule, the coincidence of the left hand miscroscope is made by the method just detailed; the division corresponding to the coincidence of the micrometer microscope is read off by the micrometer, and the indication of the screw head written down, and also the standing of the thermometers, taking a mean of those upon the standard, and a mean of those upon the parallel rule; then I moved the micrometer screw to make the coincidence with the next lower division of the scale, reading again the head of the micrometer; this reading compared with that upon the division near the (*o*) point, will give the value of the decimal thus measured in parts of the micrometer; by the mean of such measures, the micrometer parts that have been in use in any comparison, are then reduced from their nominal value to the real one; then I moved the scale in the longitudinal direction by hand to the next inch, as near as could be done conveniently, adjusted it fully, by striking the one or the other end as before, and the operation was performed upon this division as had been done upon the former. Thus the operation is continued through the whole length of the scale, as much as desired, by the successive repetition of the same operations.

23. The mean of all these measurements gives the value of the distance between the microscopes in the mean value of the standard; and the mean value of the decimal resulting from the micrometric measurement, is to be used for the reduction of the nominal indications of the micrometer to their real

value, in the use that is made of it in the comparisons of other standards; as long, namely, as no alteration is made in the distance, position, or adjustment of the microscopes towards the scale; for, it is evident that this is an individuality of these positions, and that it is an absolute requisite that the scale or standard, that it is intended to compare, be brought exactly to the same focus, as used in this comparison and determination, because, at a greater or less distance from the focus, the division would measure differently in the micrometer.

To compare any scale or standard of another thickness than the scale, it is therefore necessary to have a wooden rule guaged to the thickness necessary, that, when the scale is laid under, its points, that are to be observed, be brought exactly in the focus of the microscope. This rule must be about one inch broader, and six inches longer than the scale, that this may lie easy in the middle.

24. *The operation for a comparison of any other scale or standard* with this, is the following:

The distance of the division of the standard, nearest to the length to be compared, is taken between the microscopes, as stated above, and the micros meter values are determined; when the scale has thus rested a while, with the scale or measure to be compared laid under the microscopes, and thermometers distributed upon them, that all may be considered as having taken the same temperature, the distance being well verified by the standing of the microscopes, the standard is removed, and the other scale or measure, with the rule guaged so as to bring it exactly to the focus of the microscope, is brought under the microscopes, which must of course not be moved, nor even touched, otherwise than the turning of the micrometer head of the screw.

The microscope to the left is now brought to coincidence with the left end of the scale or measure, paying well attention to take the middle of the division, or the breadth of the scale or measure.

The indication of the micrometer head is now read off, and written down, as well as the standing of the thermometers. The first evidently indicates, by its differences from the stand upon the nearest division of the standard scale, the relative length of the measure compared; and the operation may be repeated as often as desirable for the aim in view, and varied in the different ways the scale or measure compared will admit. I must here state, with some detail, the ways I employed in my case, which will serve as explanation to the details of the operations, that it is proper to present united, in a tabular form, to which reference may be had for any case.

25. The simple scales with lines or points, were compared single, and admitted no variation, except the turning of them end for end, which varied the effect of the light in opposite directions upon each of the ends; unless the scale was a divided scale similar to the standard scale itself, in which case the distance was taken upon it repeatedly, in a regular order, as often as admissible or desirable. Of the former kind were the scales of yard and ell of Thomas Jones, and the yard, with platinum dots, of Troughton, the distance of 51,2 inches taken from Sir George Shuckburgh's scale, and the platinum metre. Of the latter kind, were the scale of the University of Virginia, and that of the Treasury Department.

26. Standards of measures cut to length require a different operation; the division line must be produced by making butting pieces of the same metal as the measure, and of the same thickness, well ground together, so as to present a perfect junction in all positions in which they may be presented to one another upon a plane surface. These are placed upon the same wooden rule with the measure compared, and butted against the ends, where they

will present a line, like a division line of a scale, as neat as the workmanship of the measure, and its state of preservation, will admit; and more could in no case be obtained by any other method. In this manner were compared all the metres the yard and ell cut to a length.

27. As I had a number of metres cut to length, (metres à bout) of which therefore the sum of two will always come together under the microscope, as this distance (of about 78,8) was within the limits of the standard scale, I made use again of the method which I employed when comparing them for the survey of the coast.

Two metres were always placed together under experiment, butting ends together in the middle, a third was laid at the side in the middle, reaching therefore half the length of each from the middle, by which their straight direction in one line was secured; to the two ends of their sum were then applied the butting pieces just described.

28. This double metre length admitted, of course, several variations in its combination, of which I employed always four, which I distinguished by the manner of writing the marks by which I designated each of the metres. By this method, the errors that are possible in every observation, applying to the double lengths, will only have half the influence upon each. Three metres thus compared, by the alternation of the sum of each two, will give a result for each by a simple formula, namely, the sum of every two combined distances, diminished by the third, will give the double of the one or the other metre, alternately, according to the combination employed. This method is in fact applicable wherever a number of things are to be compared to diminish the effect of the errors of observation. It admits to multiply the results so much more as the number of things combined are greater. In the present comparison, I had five metres of brass, and three of iron. I could therefore obtain full results, without using, in the same comparisons, metres of different metal. The five brass metres furnished thirty combined lengths, from which six results are deduced for each metre. The three iron metres gave three combinations, and one result for each metre.

29. It is necessary after every comparison, or series of comparisons, when a number of them are made consecutively upon the same distance, that the standard scale be again laid under the microscopes to verify their standing; if too great a difference should be found from the previous reading of the micrometer, it proves some accidental derangement which would make the comparison void, and it would be proper to reject it in the result. For this verification, it is, of course, necessary to let again the two scales some time together, to take the same temperature.

If only such a difference should appear between this reading and the first, as may be considered within the limits of accuracy of the reading, it will be allowed to take a mean between the two, and it is even proper to do so.

30. From these observations, the results of the comparisons are now deduced, with the application of those reductions, which the preceding account of the operations indicate. First, the constant distance of the microscope, that has been used in the comparison, must be determined in the value of its mean distance upon the scale, arising both from the ascertained distance between the microscope in reference to the distance used, and the value of this distance in mean value of the scale. Then, the micrometer readings that were made at any comparison, must be reduced from their nominal to their real value, in the decimal of the inch, by applying the correction of reduction resulting from the scrutiny upon the scale which has been described before. As every measurement of a scale, meter or yard, &c., has

been made several times in varied positions, it is sufficient to apply this reduction to the mean of the results obtained for each measurement.

Each reading having its own temperature, as well of the scale as of the comparing rule, these must be reduced to the same temperature, which may again be done by the means of the several readings of each measurement: as they have been made near to one another in regular succession, they will not differ so much as to need separate reduction. When the measure compared is of the same metal as the comparing rule, (which is brass,) it is sufficient, to render them comparable, to reduce the one upon the other, by the well ascertained expansion of this metal, (brass.) But when the measure compared is of a different metal, as I had the case with the iron or platinum metres compared with the standard scale, it is best to reduce each separately, by its own well ascertained expansion, to the standard temperature adopted, which is best chosen at the melting point of ice, or 32° Fahr.; thus they will become comparable in this respect.

31. The results reduced to that state are those which it is proper to record. They present an actual fact, or phenomenon, which it is possible to produce, as it is an *absolute requisite* that a *comparison* shall be; to present, or rather state, the length of one measure at a certain temperature, in length of another measure of another metal at a different temperature, is not presentable in nature, therefore *cannot be a comparison.*

It is very desirable that the various reductions shall be made as small as possible, by adjusting all as near as possible, and principally that for the temperature; besides, therefore, the precautions above stated to keep the whole apparatus in the same temperature, it is also proper to make the comparison the nearest possible to the standard temperature adopted. I have constantly used my own determination of the expansion of iron and brass, made for the use in the coast survey, and it will not be improper for any one able observer to determine all his own elements as much as possible himself, because there are yet some individual varieties possible, which often render the use of datas taken from others less advantageous.

32. With these explanations upon the methods and principles, made use of in my work, it will be easy to understand the details of the operation, and the results which I present hereafter, in a kind of tabular form, of all the principal measures that I have compared.

33. The results recorded in the statements additional to the report shew the deviation of the English ell from its legal value, in the original standards themselves, which has very properly occasioned its neglect in England itself. I think it, therefore, also not worth giving the details of it here, where my aim is rather to instruct upon the mode of proceeding, appropriate to works of this nature, than to multiply statements that have lost all interest. Still less would it be profitable to say any thing upon the old brass bed of the yard and the ell, formerly sent as standard to the Department of State, notwithstanding its accompanying parchment indenture, or upon the wooden yard sticks sent in by the custom-houses.

Dividing apparatus.

34. What may be more interesting here to describe, is the method of transferring measures from the standard scale upon any other scale, for which the microscope with the micrometer is used, by screwing it in an arrangement called Hindley's tracing tool, that is fastened upon a heavy piece of brass, about 18 inches long, (*g*, *g*,) fig. 5, having the sides made perfectly strait, so as to slide exactly in the same line along side of the scale, (*a*,)

with constantly equal and full bearing through its whole length. In the middle of the length this piece has three setts of two screw holes each, parallel to the sides; the one in the middle of the breadth, fitting exactly to bring the microscope to stand over the division of the scale, (*a*.) By means of the two screws (*p*, *p*,) the support of the tracing arrangement, in form of a knee in its uprights, (*m*,) is fastened in either of the sets of holes, as may be required, to bring the microscope over the division of the above or of another scale: to the upper part of this support, the microscope is screwed upon a horizontal plate, (*n*.)

35. Below the microscope moves an arrangement forming two moveable knees, that present great stability against lateral motion, while they move directly forward and backward, with the greatest ease, upon two pair of pointed steel axis, that are always screwed in the outer piece, and present to the inner piece the points upon which this has its motion; these axes have screws that press upon them from the side, to secure their steadiness when they are placed so as to leave just free motion, without hard pressure or shaking. These two pieces form a kind of broken triangle, the base of which is towards the microscope, and the vertex opposite holds between the two side arms a square piece of brass, through which passes the tracer, (*r*;) this piece has an axis upon which it revolves by hard friction in the outer parts of the triangle; by this the proper inclination is given to the tracer, which must lean somewhat backwards at the upper part, in order that, when the stroke is made, by drawing this point towards the microscope, the point makes a *cut* by dragging; in another direction it would cause it to make a *scratch* with an uneven burr at the sides, and to take a wavering motion by different resistance of the metal.

36. The tracer is fixed in the brass square by a sliding piece behind it, which is screwed fast when properly placed. The section of the cutting part presents not a circular point, but the edge of two sections of elipsoids, intersecting one another at the point; this form and position, when properly executed, is so greedy in cutting, that, instead of pressing to make the mark, it is necessary to prevent its lying up with the full weight. This section being, of course, placed so as to present the sharp part in the direction of the cut.

37. To make the movement of the tracer perpendicular to the scale, the whole arrangement is moved, and by means of the two screws, (*p*, *p*,) it is fixed in the proper position; for this purpose, the holes in the flat piece of the frame are somewhat larger than the screws, to allow a little play to this position. This position may be tried by making a line upon a small plate, having two sides well parallel, which applied in two opposite positions to the other side of the scale, (*a*,) when the apparatus is placed alongside, the traces made in the two positions must coincide, or be parallel, when the support is properly adjusted.

38. The use of this apparatus, in tracing scales from the standard scale, is evident from the above description; the new intended scale, (S,) is fastened in a position parallel to the standard, (*a*,) on the side opposite from the observer; the short solid rule that bears the whole arrangement, is slided along the side of the scale to the coincidence of the microscope's cross wires, with the division intended to be transferred, by the same methods as have been explained for the comparisons; in this position the trace is made upon the new scale, lying fastened on the outside; the apparatus is thus moved from division to division, and if any subdivision is desired, that is not upon the standard, the micrometer is moved so as to give to the cross wires the position corres-

ponding to the measure intended to lay off, in which state it is then brought to coincidence with the corresponding division of the scale, and the tracer will mark the line in the proper place. Thus, therefore, any scale, the corresponding divisions of which are determined in parts of the standard, can be laid off from it, by successively bringing the apparatus in the proper position of the standard, designating its parts, and the errors of a standard, that may have been determined by proper methods of comparison, can be corrected, and an accurate scale can be laid off from one less accurate, as Mr. Troughton did in making the scale of 82 inches, used in the present comparison, from his own, by doubling the middle part of forty and odd inches of his own.

Upon the tableaux of the comparison.

39. It would lead into much length to go into detailed explanation of the particulars of the comparisons, and the deducing of the results from them; the general description of the operations, which has been given above, will suffice for the understanding of the details, for any man who may wish to take the trouble of a nearer investigation, as the main results of the tables that will follow will present them in their regular succession, and the data of any reduction will be always quoted; such remarks as will be dictated by circumstances will appear in their proper place. These tableaux will, therefore, exhibit a fully detailed account of the numerical part of the comparisons, and the detailed individual observations will be stated wherever they may be of interest, that is, in the comparisons of the standards of most importance.

40. When my report, and the statements accompanying the same, were already delivered, and this account almost completed, I had the satisfaction of the visit of Mr. J. N. Nicollet, astronomer of the Royal Observatory of Paris, member of the Board of Longitude of France, &c., acquainted with these subjects in detail, from the circumstance that the Observatory of Paris is the place of deposite of the original French standards, to which the copies, intended for authentic, are compared. He took so much interest in my work, and the methods which I employed in it, that he repeated the comparisons of the principal metres and yards with the large standard scale of Troughton, in the same manner as I had done. These results I considered proper, with his leave to that effect, to introduce, in their respective places, together with mine. The coincidence between the results of two observers, which is thus presented, is evidently within the limits of the unaccountable incidental influences of the variations of temperature, and therefore fully satisfactory.

41. The ratios of expansion which I used in the reductions were, for brass and for iron, those resulting from my own experiments made in Newark, N. J., in April, 1817, in which the iron bars were of the same iron as those of the two iron metre copies present; for the platinum I adopted a mean between the determination of Borda and that of Troughton.

These ratios, and their amount for the yard and the metre, are for one degree Fahrenheit, as follows:

	Proportional.	In 1 yard or 36″.	In 1 metre or 39″,4.	Differences.
Platinum	=0,0000051344	0″,0001848384	0″,00020219327	0″,0002116523
Brass	=0,00001050903	0 ,0003732508	0 ,0004138456	
Iron	=0,000006963535	0 ,00025068726	0 ,0002737190	0 ,0001396216

42. ***RESULTS** of the comparisons of Troughton's scale of the Comparateur within itself; and determination of the value of the micrometer screw on each place, taking the length of the yard or 36" for the fixed distance of comparison.*

Temperat. Fahrenh.	Points of the scale.	Micrometer readings.	Differ. c—A.	Places of the decimals.	Micromet. readings.	Micromet. value of decimals.	Differen. c—A.	
55°,0	60"—24	0,0		60",0—59,9	+11,5	+11,5		
	35 + 1	—0,7	—0,7	35 ,0—34,9	16,3	15,6	+4,1	First series.
	36 — 0	0,0	+0,7	36 ,0—35,9	16,0	16,0	+0,4	
	37 — 1	+1,1	+1,1	37 ,0—36,9	15,3	16,4	+0,4	
	38 — 2	+2,8	+1,7	38 ,0—37,9	14,0	16,8	+0,4	
53°,8	39 — 3	+1,1	—1,7	39 ,0—38,9	15,4	16,5	—0,3	
	40 — 4	+0,6	—0,5	40 ,0—39,9	16,2	16,8	+0,3	
	41 — 5	0,0	—0,6	41 ,0—40,9	14,0	14,0	—2,8	
	42 — 6	—2,0	—2,0	42 ,0—41,9	17,7	15,7	+1,7	
	43 — 7	—1,1	+0,9	43 ,0—42,9	16,6	15,5	—0,2	
	44 — 8	—1,2	—0,1	44 ,0—43,9	15,6	14,4	—1,1	
	45 — 9	+0,8	+2,0	45 ,0—44,9	15,0	15,8	+1,4	
	46 —10	+1,0	+0,2	46 ,0—45,9	12,8	13,8	—2,0	
52°,7	47 —11	—1,3	—2,3	47 ,0—46,9	14,0	12,7	—1,1	
	48 —12	0,0	+1,3	48 ,0—47,9	14,1	14,1	+1,4	
	49 —13	+0,3	+0,3	49 ,0—48,9	13,0	13,3	—0,8	
	50 —14	0,0	—0,3	50 ,0—49,9	14,2	14,2	+0,9	
	51 —15	+0,2	+0,2	51 ,0—50,9	12,2	12,4	—1,8	
	52 —16	+0,8	+0,6	52 ,0—51,9	11,7	12,5	+0,1	
	53 —17	+0,7	—0,1	53 ,0—52,9	11,1	11,8	—0,7	
51°,3	54 —18	+1,2	+0,5	54 ,0—53,9	11,7	12,9	+1,1	
	55 —19	+1,0	—0,2	55 ,0—54,9	10,2	11,2	—1,7	
	56 —20	+0,5	—0,5	56 ,0—55,9	12,0	12,5	+1,3	
	57 —21	+1,2	+0,7	57 ,0—56,9	9,4	10,6	—1,9	
	58 —22	+0,3	—0,9	58 ,0—57,9	9,4	9,7	—0.9	
50°,6	59 —23	—0,6	—0,9	59 ,0—58,9	11,3	10,7	+1,0	
38°—38,7	60 —24	+0,1	-	60 ,0—59,9	13,4	13,5	+2,8	Second series.
	61 —25	—2,7	—2,8	61 ,0—60,9	13,6	10,9	—2,6	
	62 —26	—0,6	+2,1	62 ,0—61,9	11,6	11,0	+0,1	
	63 —27	—1,3	—0,7	63 ,0—62,9	13,3	12,0	+1,0	
39°,2	64 —28	—1,7	—0,4	64 ,0—63,9	13,4	11,7	—0,3	
	65 —29	—1,3	+0,4	65 ,0—64,9	13,9	12,6	+0,9	
	66 —30	—2,0	—0,7	66 ,0—65,9	13,1	11,1	—1,5	
	67 —31	—2,7	—0,7	67 ,0—66,9	13,4	10,7	—0,4	
	68 —32	—2,6	+0,1	68 ,0—67,9	13,2	10,6	—0,1	
	69 —33	—0,8	+1,8	69 ,0—68,9	12,3	11,5	+0,9	
	70 —34	—0,2	+0,6	70 ,0—69,9	11,4	11,2	—0,3	
	71 —35	—1,2	—1,0	71 ,0—70,9	12,0	10,8	—0,4	
	72 —36	—3,9	—2,7	72 ,0—71,9	13,9	10,0	—0,8	
40°—41°,5	73 —37	—5,8	—1,9	73 ,0—72,9	16,0	10,2	+0,2	
	74 —38	—2,9	+2,9	74 ,0—73,9	16,7	13,8	+3,6	
	75 —39	—5,3	—2,4	75 ,0—74,9	16,7	11,4	—2,4	
40°—41°,5	76 —40	—5,9	—0,6	76 ,0—75,9	18,0	12,1	+0,7	
	77 —41	—7,0	—1,1	77 ,0—76,9	19,1	12,1	0,0	
	78 —42	—5,7	+1,3	78 ,0—77,9	19,0	13,3	+1,2	
	79 —43	—6,1	—0,4	79 ,0—78,9	18,0	11,9	—1,4	
	80 —44	—3,7	+2,4	80 ,0—79,9	18,0	14,3	+2,4	
	81 —45	—4,3	—0,6	81 ,0—80,9	18,0	13,7	—0,6	
	Means	—1,268	—0,0869			+12,662	+0,0423	

The distance upon the scale 60″—24″ is therefore larger than the mean of all the 36″ inches that can be measured upon the scale of Troughton, between full inches, by 1,268 of the micrometer, or 0″,0001268; and the following distances may be considered as agreeing with that mean, viz.

44—8	giving	—1,2
47—11	. .	—1,3
63—27	. .	—1,3
65—29	. .	—1,3
71—35	. .	—1,2

Therefore, 60—24=36″,0001268 of mean 36″ of the scale; and by the above, also, 79″—43″=60″—24″—6^m,1=36,0001268—0,00061=35,9995168 of mean, and 37″—1″=60—24+1^m,1=36,0001268+0,00011=36,0002368.

The mean micrometer values give for 0,1 of the scale = 0,101266 of micrometer; all values read by it must therefore be reduced by $1+c:1$ = reading : result, or multiplied by =0,98749.

Remark.—The C—A indicates the subtraction of any antecedent number of the preceding column from the immediate consequent, with attention to the sign of the result.

43. ***RESULTS** of the comparison of Troughton's large scale of the comparateur within itself, upon the distance of 39″,4 used for the comparisons of the metres; and measurements of the micrometer values by the last decimals.*

Temperature.		Points of the scale.	Microm. reading.	Diff. c—A.	Place of the decimals.	Microm. readings.	Microm. diff.	
Scale.	Com-para-teur.						Value of decimals.	c—A.
37°,0	36°,5	63″,4—24	0,0	0,0	63″,4—63″,3	+10,8	+10,8	+7,0
36 ,6	36 ,4	38 ,4+ 1	0,0	+0,4	38 ,4—38 ,3	+17,8	17,8	—2,1
		39 ,4— 0	+0,4	—0,9	39 ,4—39 ,3	15,3	15,7	+0,6
		40 ,4— 1	—0,5	+1,1	40 ,4—40 ,3	16,8	16,3	—1,7
36 ,6	36 ,4	41 ,4— 2	+0,6	—1,1	41 ,4—41 ,3	14,0	14,6	+0,6
		42 ,4— 3	—0,5	—0,3	42 ,4—42 ,3	15,7	15,2	—1,0
		43 ,4— 4	—0,8	—1,2	43 ,4—43 ,3	15,0	14,2	+1,2
		44 ,4— 5	—2,0	—1,2	44 ,4—44 ,3	17,4	15,4	—0,3
36 ,1	36 ,0	45 ,4— 6	—3,2	—0,1	45 ,4—45 ,3	18,3	15,1	—1,1
		46 ,4— 7	—3,3	+1,4	46 ,4—46 ,3	17,3	14,0	+1,1
		47 ,4— 8	—1,9	+3,6	47 ,4—47 ,3	17,0	15,1	+0,4
		48 ,4— 9	+1,7	—1,5	48 ,4—48 ,3	13,8	15,5	—2,1
		49 ,4—10	+0,2	—1,3	49 ,4—49 ,3	13,2	13,4	—0,1
35 ,5	35 ,7	50 ,4—11	—1,1	+0,1	50 ,4—50 ,3	14,1	13,3	+0,2
		51 ,4—12	—1,0	+1,5	51 ,4—51 ,3	14,5	13,5	+0,4
		52 ,4—13	+0,5	—1,8	52 ,4—52 ,3	13,4	13,9	—2,0
		53 ,4—14	—1,3	+1,9	53 ,4—53 ,3	13,2	11,9	+0,7
35 ,4	35 ,5	54 ,4—15	+0,6	—0,6	54 ,4—54 ,3	12,0	12,6	—1,8
		55 ,4—16	0,0	+1,2	55 ,4—55 ,3	10,8	10,8	+0,4
		56 ,4—17	+1,2	—0,4	56 ,4—56 ,3	10,0	11,2	+0,9
		57 ,4—18	+0,8	+1,1	57 ,4—57 ,3	11,3	12,1	—1,4
35 ,2	35 ,2	58 ,4—19	+1,9	—0,9	58 ,4—58 ,3	8,8	10,7	—0,9
		59 ,4—20	+1,0	0,0	59 ,4—59 ,3	9,6	10,6	+0,4
		60 ,4—21	+1,0	—0,6	60 ,4—60 ,3	10,0	11,0	—0,9
35 ,1	35 ,2	61 ,4—22	+0,4	—0,1	61 ,4—61 ,3	9,7	10,1	+0,1
34 ,5	34 ,5	62 ,4—23	+0,3	—0,3	62 ,4—62 ,3	9,9	10,2	+0,6
34 ,8	34 ,3	63 ,4—24	0,0	+0,25	63 ,4—63 ,3	9,45	10,8	—0,6
36 ,3	36 ,2	64 ,4—25	+0,25	—2,1	64 ,4—64 ,3	10,95	10,2	+0,4
		65 ,4—26	—1,95	+0,3	65 ,4—65 ,3	8,65	10,6	+0,9
36 ,7	36 ,4	66 ,4—27	—1,65	+1,1	66 ,4—66 ,3	12,45	11,5	—0,3
		67 ,4—28	—0,55	—1,9	67 ,4—67 ,3	10,65	11,2	—1,6
		68 ,4—29	—2,45	+0,9	68 ,4—68 ,3	12,25	9,6	+1,2
		69 ,4—30	—1,55	—2,2	69 ,4—69 ,3	12,35	10,8	—1,5
		70 ,4—31	—3,75	+1,4	70 ,4—70 ,3	13,05	9,3	+0,7
		71 ,4—32	—2,35	+0,8	71 ,4—71 ,3	12,35	10,0	+0,8
37 ,0	37 ,0	72 ,4—33	—1,55	—2,4	72 ,4—72 ,3	12,35	10,8	—0,5
		73 ,4—34	—3,95	+1,7	73 ,4—73 ,3	14,25	10,3	—0,9
37 ,2	37 ,0	74 ,4—35	—2,25	—0,6	74 ,4—74 ,3	11,65	9,4	0,0
		75 ,4—36	—2,85	—2,8	75 ,4—75 ,3	12,25	9,4	+1,5
		76 ,4—37	—5,65	+1,0	76 ,4—76 ,3	16,55	10,9	+2,1
37 ,6	37 ,4	77 ,4—38	—4,65	+1,4	77 ,4—77 ,3	17,65	13,0	+0,3
		78 ,4—39	—3,25	—2,4	78 ,4—78 ,3	17,55	13,3	—1,3
		79 ,4—40	—5,65	+0,4	79 ,4—79 ,3	17,65	12,0	—1,9
		80 ,4—41	—5,15	—1,5	80 ,4—80 ,3	15,25	10,1	+3,1
37 ,9	37 ,5	81 ,4—42	—3,65		81 ,4—81 ,3	16,85	13,2	
		Means	—1,280	—0,151			12,253	+0,0204

The distance 53",4—14" may be considered as representing this mean exactly, being —1,3, the units being micrometer values, or ten-thousandth of inches.

The comparison of this scrutiny of the scale with that upon the yard, gives the following means and differences—

		c—a			c—a
By the yard	-	—1,268—0,0869	-	Micr. 12,662	+0,0423
By the metre	-	—1,280—0,151	-	12,253	+0,0204
Means	-	=—1,274—0,1189	-	12,4575	+0,03135
Difference	c—a	=—0,012—0,0641—	-	— 0,409	—0,0219

44. *COMPARISON of the distance used for the metres in the preceding comparisons, with the distance used in the comparison of the double metre, namely, from* 1",0 *to* 79",8, *dividing it into two parts,* 1",0 *to* 40",4, *and* 40",4 *to* 79",8; *the microscopes were again fully adjusted to the distance used heretofore, viz.* 63",4—24", *upon which they had been left since the last comparisons.*

The resulting comparisons were as follows:

Thermom. on		Stand of micrometer.	Microm. reading.
Compar.	Scale.		
62,3	62,1	63,"4—24	0,0
62,4	62,4	40 ,4— 1	+0,6
62,7	62,5	79 ,8—40,4	—2,5
62,5	62,6	63 ,4—24	0,0

Hence results the distance of 79",8—1", in parts of 63",4—24", as used this time = 78",8+0m,6—2m,5=78",8—1m,9=78",79981; 63",4—24", exceeding the mean by =0,000128, gives, by reference to the general mean, =78",800066 (by subtracting twice this excess) for the mean value between the microscopes when they are placed to 79",8—1" on the scale.

45. The standard *scale of Gilbert*, sent by Dr. Patterson, of Virginia University, was compared with this same distance, that is, 63",4—24",0 of Troughton's scale.

				C—A.		Microm.	Value M.	C—A.
62,8	62,9	39",4—0,0	—40m,25	+1,25	39",4—39",3	—52,1	11,9	—2,4
		39 ,5—0,1	41 ,5	—0,8	39 ,5—39 ,4	51,0	9,5	+2,5
		39 ,6—0,2	40 ,7	+1,8	39 ,6—39 ,5	52,7	12,0	—2,6
		39 ,7—0,3	42 ,5	—2,55	39 ,7—39 ,6	51,9	9,4	+2,55
		39 ,8—0,4	39 ,95	+4,75	39 ,8—39 ,7	51,9	11,95	—2,15
		39 ,9—0,5	44 ,7	+0,4	39 ,9—39 ,8	54,5	9,8	+0,1
		40 ,0—0,6	45 ,1	+2,1	40 ,0—39 ,9	55,0	9,9	+0,2
		40 ,1—0,7	47 ,2		40 ,1—40 ,0	57,3	10,1	
				+1,007				—0,26
Means - - -			—42 ,74				10,56	
Micrometer correction -			+ 0 ,53					
			—42 ,21					

The scale being turned over to measure the metre, the distance of it gave reading by the micrometer = — $\left\{\begin{array}{l}348,4\\ +3,68 \text{ corr.}\\ \overline{344,72}\end{array}\right\}$ or the 39″,4, being by Troughton's scale = 39″,4—42^{m},21 of Troughton, this difference subtracted from the reading for the metre, that is, 344,72—42,21=302,51 of micrometer, is to be subtracted from 39″,4 to give the metre of the scale in parts of this scale, viz. 39″,4—0,030251=39,369749=metre on the scale itself.

Compared to Troughton's scale, it would therefore be, according to the above placement and comparison, upon 63″,4—24″=39″,4—348^{m},4 or 39″,4—0″,03484=39″,36516; and correcting this distance for the value of it in the mean distance of the metre upon the whole scale, viz. —0″,000128, the result is =39″,365032, which being still corrected for the reduction of the nominal micrometer values, (that is, 348,4 × 0,98956,) is 39″,4—0″,0344763 - - =39,3655237

Reduction to mean distance — 0,000128

39,3653957 = value of its metre in mean distance of Troughton's scale.

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45. *COMPARISON of the yard upon the scale of Dr. Patterson, from Virginia University, made by Gilbert.*

Taking, upon Troughton's scale, the distance of 36″, by 60″—24″, between the microscopes, and comparing it upon the scale, the following results were obtained:

Temperat. of Compa.	Temperat. of Scale.	Distance used.	Microm. reading.	c—A.	Place of decimals.	Microm. decimal.	Value of decimal.
57,9	57,8	60—24 Fr. sec.	0,0		60″—59,9	10,0	10
Virginia	scale.	36″—0″	—40,7		36″—35,9	48,9	8,2
58,0	58,1	37 —1	—49,5	+8,8	37 —36,9	55,3	5,8
		38 —2	—51,0	+1,5	38 —37,9	55,3	4,3
		39 —3	—51,8	+0,8	39 —38,9	59,3	7,5
58,1	58,2	40 —4	—53,4	+1,6	40 —39,9	59,5	6,1
Returned	to -	36 —0	—40,8				
Returned	the large	Troughton's scale.					
58,2	58,7	60 —24	+ 0,2				
Means resulting of Virginia scale =			—49,26				+ 6,4
Correction for micrometer value -			+ 0,31				
Real mean - -			—48,95				

Thence the yard of the Virginia scale by the mean is in Troughton's large scale = 36″—48^{m},95=36″—0″,004895=35″,995105, keeping account of the excess of the distance 60″—24″ on Troughton's scale over the mean obtained from the whole scale of 0,0001268, and adding this to the above result, the ultimate corrected result = 35″,9952318.

46. *COMPARISON of Troughton's scale within itself, upon the approximate distance of the French toise, taking the middle part of the scale from 1" to 77",8 for constant reference.*

Temperature. Compar.	Temperature. Scale.	Distance on the scale.	Microm. reading.	C—A.	Place of decim. measured.	Microm. reading.	Value of microm.	C—A.
58,5	58,2	77,8—1	0,0		77,8—77,7	+11,4	11,4	
58,9	58,5	76,8—0	—1,1	—1,1	76,8—76,7	+11,0	9,9	—1,5
59,1	59,0	75,8+1	+1,3	+2,4	75,8—75,7	9,7	11,0	+1,1
59,1	59,0	74,8+2	—1,8	—3,1	74,8—74,7	11,8	10,0	—1,0
59,0	59,1	77,8—1	+0,4	—1,4	77,8—77,7	10,7	11,1	+1,1
59,3	59,1	78,8—2	—1,9	—2,3	78,8—78,7	12,9	11,0	—0,1
59,4	59,1	79,8—3	+2,5	+4,4	79,8—79,7	12,3	14,8	+3,8
59,4	59,3	80,8—4	0,0	—2,5	80,8—80,7	12,9	12,9	—1,9
59,3	59,2	81,0—4,2	+0,1	+0,1	81,0—80,9	12,0	12,1	—0,8
59,5	59,3	79,0—2,2	+0,4	—0,3	79,0—78,9	10,9	11,3	—0,8
59,5	59,3	80,0—3,2	+0,9	—0,5	80,0—79,9	12,8	13,7	+2,4
59,6	59,5	78,0—1,2	+0,4	—0,5	78,0—77,9	12,4	12,8	—0,9
59,7	59,6	77,0—0,2	0,0	—0,4	77,0—76,9	10,8	10,8	—2,0
59,8	59,7	76,0+0,8	—0,4	—0,4	76,0—75,9	10,0	9,6	—1,2
60,0	59,9	75,0+1,8	+1,4	+0,8	75,0—74,9	8,0	9,4	—0,2
60,1	60,0	77,8—1	+1,8	+0,4	77,8—77,7	9,6	11,4	+2,0
		Means -	+0,31	+0,126			11,45	+0,06

The toise of Canivet was now put under comparison, in the two admissible positions, and observed as follows:

Comparateur. Toise.

60,3 60,2 Tc — 657,0 }
60,5 60,8 Tc — 656,7 } = 656,85 = 76,7343 15

Reduction { + 8,184 for micrometer.
{ + 0,31 — place of scale.

76,7351 644

Reduction to 30° Fahr. - - + 0,0077 4071

Value of toise at 32° - - 76,7429 0511

The iron toise of Lenoir of the coast survey laid under gave:

60,6 60,7 T' — 682,0 }
60,6 60,7 T, — 686.3 } —681,57 } 76,80 } = 76,7326234
60,8 60,7 'T — 680,0 } + 7,804 } — 0,0673766 }
60,7 61,0 ,T — 678,0 } For var. of temp. = 28°,75 } = 0,007821586

76,740444986

Microscope stand correction - - - - = + 31

Value of toise at 32° - - - - - - 76,740475986

The scale again laid under for verification:

Thermometers.			
60",7	60",5	77,8—1	—0,7

47. *COMPARISON of the large scale of Troughton within itself, upon the distance of* 51",2 *used with the distance from the point on the scale made by myself, now belonging to the Treasury Department, to the line at the other end of the scale, as explained.*

Thermometer. Compar.	Thermometer. Scale.	Point of scale.	Microm. reading.	C—A.	Place of decimals.	Micrometer Reading.	Micrometer Value.	C—A.
66,9	66,9	50,2+ 1	+2,1	—1,3	50,2—50,1	+6,7	—4,6	+2,0
		51,2— 0	+0,8	+1,2	51,2—51,1	+7,4	—6,6	—2,5
		52,2— 1	+2,0	—0,2	52,2—52,1	+6,	—4,1	+0,9
		53,2— 2	+1,8	+0,9	53,2—53,1	+6,8	—5,0	—0,5
		54,2— 3	+2,7	—2,7	54,2—54,1	+7,2	—4,5	+2,2
		55,2— 4	0,0	0,0	55,2—55,1	+6,7	—6,7	+0,4
		56,2— 5	0,0	—2,6	56,2—56,1	+7,1	—7,1	—0,5
		57,2— 6	—2,6	+2,2	57,2—57,1	+5,0	—7,6	+0,8
		58,2— 7	—0,4	+1,0	58,2—58,1	+7,0	—8,4	—3,0
65,9	65,9	59,2— 8	+0,6	+1,6	59,2—59,1	+6,0	—5,4	+1,5
		60,2— 9	+2,2	—1,9	60,2—60,1	+9,1	—6,9	+0,1
		61,2—10	+0,3	+1,6	61,2—61,1	+7,3	—7,0	—1,0
		62,2—11	+1,9	—1,1	62,2—62,1	+7,9	—6,0	+2,3
		63,2—12	+0,8	0,0	63,2—63,1	+9,1	—8,3	—0,7
		64,2—13	+0,8	—0,3	64,2—64,1	+8,4	—7,6	—0,8
		65,2—14	+0,5	—0,3	65,2—65,1	+7,3	—6,8	+1,6
64,2 66,9 68,5	65,0 66,9 68,5	66,2—15	0,0 +0,2 +0,4		66,2—66,1	+8,3 +8,7	—8,3 —8,5	
		67,2—16	+0,8	+0,5	67,2—67,1	+9,0	—8,2	—0,2
		68,2—17	+1,0	+0,2	68,2—68,1	+8,8	—7,8	—0,4
		69,2—18	+2,0	+1,0	69,2—69,1	+9,7	—7,1	—0,7
		70,2—19	+0,3	—1,7	70,2—70,1	+9,7	—9,4	+2,3
		71,2—20	+0,3	0,0	71,2—71,1	+9,5	—9,2	—0,2
		72,2—21	+0,3	0,0	72,2—72,1	+7,0	—6,7	—2,5
		73,2—22	0,0	—0,3	73,2—73,1	+7,8	—7,8	+1,1
		74,2—23	—0,3	—0,3	74,2—74,1	+7,9	—8,2	+0,4
		75,2—24	—0,8	—0,5	75,2—75,1	+6,8	—7,6	—0,6
		76,2—25	—1,7	—0,9	76,2—76,1	+4,8	—6,5	—1,1
		77,2—26	—1,7	0,0	77,2—77,1	+5,7	—7,4	+0,9
		78,2—27	—1,8	—0,1	78,2—78,1	+6,6	—8,4	+1,0
		79,2—28	—0,9	+0,9	79,2—79,1	+6,2	—7,1	—1,3
68,4	68,3	80,2—29	—1,9	—1,0	80,2—80,1	+4,9	—6,8	—0,3
		Means -	+0,30	—0,139			—7,07	
Referred or	to the	middle 66",2—15"=	+0,10				0",1=	Micr. 992,92

48. ***DIFFERENCES** resulting from the comparison of* 39",4 *upon the large scale, with* 36" *upon the same.*

From 38",4+1" onwards.					From 81",4—42", backwards.				
Places of the scale.	Microm. diff.		39",4—36"=3"±.	Differ. c—A.	Places of the scale.	Micrometric differences		39",4—36"=3,4±.	Differ. c—A.
	of 39",4.	of 36".				of 39",4.	of 36".		
38,4 } + 1 / 35,0 }	0,0	—0,7	+0,7	—0,3	38,4 { +1 / 38,0 { —2	0,0	+2,8	—2,8	+2,1
0	+0,4	0,0	+0,4	—2,0	39,4	+0,4	+1,1	—0,7	—0,4
1	—0,5	+1,1	—1,6	—0,6	40,4	—0,5	+0,6	—1,1	+1,7
2	+0,6	+2,8	—2,2	+0,6	41,4	+0,6	0,0	+0,6	+0,9
3	—0,5	+1,1	—1,6	+0,2	42,4	—0,5	—2,0	+1,5	—1,2
4	—0,8	+0,6	—1,4	—0,6	43,4	—0,8	—1,1	+0,3	—1,1
5	—2,0	0,0	—2,0	+0,8	44,4	—2,0	—1,2	—0,8	—3,2
6	—3,2	—2,0	—1,2	—1,0	45,4	—3,2	+0,8	—4,0	—0,3
7	—3,3	—1,1	—2,2	+1,5	46,4	—3,3	+1,0	—4,3	+3,7
8	—1,9	—1,2	—0,7	+1,6	47,4	—1,9	—1,3	—0,6	+2,3
9	+1,7	+0,8	+0,9	—1,7	48,4	+1,7	0,0	+1,7	—1,8
10	+0,2	+1,0	—0,8	+1,0	49,4	+0,2	+0,3	—0,1	—1,0
11	—1,1	—1,3	+0,2	—1,2	50,4	—1,1	0,0	—1,1	—0,1
12	—1,0	0,0	—1,0	+1,2	51,4	—1,0	+0,2	—1,2	+0,9
13	+0,5	+0,3	+0,2	—1,5	52,4	+0,5	+0,8	—0,3	—1,7
14	—1,3	0,0	—1,3	+1,7	53,4	—1,3	+0,7	—2,0	+1,4
15	+0,6	+0,2	+0,4	—1,2	54,4	+0,6	+1,2	—0,6	—0,4
16	0,0	+0,8	—0,8	+1,3	55,4	0,0	+1,0	—1,0	+1,7
17	+1,2	+0,7	+0,5	—0,9	56,4	+1,2	+0,5	+0,7	—1,1
18	+0,8	+1,2	—0,4	—0,5	57,4	+0,8	+1,2	—0,4	+2,0
19	+1,9	+1,0	—0,9	+1,4	58,4	+1,9	+0,3	+1,6	0,0
20	+1,0	+0,5	+0,5	—0,7	59,4	+1,0	—0,6	+1,6	—0,7
21	+1,0	+1,2	—0,2	+0,3	60,4	+1,0	+0,1	+0,9	+2,2
22	+0,4	+0,3	+0,1	+0,8	61,4	+0,4	—2,7	+3,1	—2,2
23	+0,3	—0,6	+0,9	—1,0	62,4	+0,3	—0,6	+0,9	+0,4
24	0,0	+0,1	—0,1	+3,05	63,4	0,0	—1,3	+1,3	+0,65
25	+0,25	—2,7	+2,95	—4,3	64,4	+0,25	—1,7	+1,95	—2,6
26	—1,95	—0,6	—1,35	+1,0	65,4	—1,95	—1,3	—0,65	+1,0
27	—1,65	—1,3	—0,35	+1,5	66,4	—1,65	—2,0	+0,35	+1,8
28	—0,55	—1,7	+1,15	—2,3	67,4	—0,55	—2,7	+2,15	—2,0
29	—2,45	—1,3	—1,15	+1,6	68,4	—2,45	—2,6	+0,15	—0,9
30	—1,55	—2,0	+0,45	—1,5	69,4	—1,55	—0,8	—0,75	—2,8
31	—3,75	—2,7	—1,05	+1,4	70,4	—3,75	—0,2	—3,55	+2,4
32	—2,35	—2,6	+0,35	—1,1	71,4	—2,35	—1,2	—1,15	+3,5
33	—1,55	—0,8	—0,75	—3,0	72,4	—1,55	—3,9	+2,35	—0,5
34	—3,95	—0,2	—3,75	+2,7	73,4	—3,95	—5,8	+1,85	—1,2
35	—2,25	—1,2	—1,05	+2,1	74,4	—2,25	—2,9	+0,65	+1,8
36	—2,85	—3,9	+1,05	—0,9	75,4	—2,85	—5,3	+2,45	—2,2
37	—5,65	—5,8	+0,15	—1,9	76,4	—5,65	—5,9	+0,25	+2,1
38	—4,65	—2,9	—1,75	+3,8	77,4	—4,65	—7,0	+2,35	+0,1
39	—3,25	—5,3	+2,05	—1,8	78,4	—3,25	—5,7	+2,45	—2,0
40	—5,65	—5,9	+0,25	+1,6	79,4	—5,65	—6,1	+0,45	—1,9
41	—5,15	—7,0	+1,85	+0,2	80,4	—5,15	—3,7	—1,45	+2,1
42	—3,65	—5,7	+2,05		81,4	—3,65	—4,3	+0,65	
			—0,284					+0,084	

49. ***DIFFERENCES** resulting from the comparisons of* 51″,2 *upon the large scale, with those of* 39″,4 *upon the same.*

From 50″,2+1, onwards.					From 80″,2—29″, backwards.				
Places of the scale.	Diff. of microm. of 51″,2.	Diff. of microm. of 39″,4.	51″,2—39″,4=11,18±.	Differ. C—A.	Places of the scale.	Microm. diff. of 51″,2.	Microm. diff. of 39″,4.	51″,2—39,4=11,8±.	Diff. C—A.
50,2 } 38,4 } + 1	+2,1	0,0	+2,1	—1,7	50,2 { 1 50,4 { 11	+2,1	—1,1	+3,2	—1,4
0	+0,8	+0,4	+0,4	+2,1	51,2	+0,8	—1,0	+1,8	—0,3
1	+2,0	—0,5	+2,5	—1,3	52,2	+2,0	+0,5	+1,5	+1,8
2	+1,8	+0,6	+1,2	+2,0	53,2	+1,8	—1,3	+3,1	—1,0
3	+2,7	—0,5	+3,2	—2,4	54,2	+2,7	+0,6	+2,1	—2,1
4	0,0	—0,8	+0,8	+1,2	55,2	0,0	0,0	0,0	—1,2
5	0,0	—2,0	+2,0	—1,4	56,2	0,0	+1,2	—1,2	—2,2
6	—2,6	—3,2	+0,6	+2,3	57,2	—2,6	+0,8	—3,4	+1,1
7	—0,4	—3,3	+2,9	—0,4	58,2	—0,4	+1,9	—2,3	+1,9
8	+0,6	—1,9	+2,5	—2,0	59,2	+0,6	+1,0	—0,4	+1,6
9	+2,2	+1,7	+0,5	—0,4	60,2	+2,2	+1,0	+1,2	—1,3
10	+0,3	+0,2	+0,1	+2,9	61,2	+0,3	+0,4	—0,1	+1,7
11	+1,9	—1,1	+3,0	—1,2	62,2	+1,9	+0,3	+1,6	—0,8
12	+0,8	—1,0	+1,8	—1,5	63,2	+0,8	0,0	+0,8	0,25
13	+0,8	+0,5	+0,3	+1,5	64,2	+0,8	+0,25	+0,55	+0,9
14	+0,5	—1,3	+1,8	—2,2	65,2	+0,6	—0,95	+1,45	+0,4
15	+0,2	+0,6	0,4	+1,2	66,2	+0,2	—1,65	+1,85	0,5
16	+0,8	0,0	+0,8	—1,4	67,2	+0,8	—0,55	+1,35	+2,1
17	+1,0	+1,2	+2,2	1,0	68,2	+1,0	—2,45	+3,45	+0,1
18	+2,0	+0,8	+1,2	+0,4	69,2	+2,0	—1,55	+3,55	+0,5
19	+0,3	+1,9	+1,6	—2,3	70,2	+0,3	—3,75	+4,05	—1,4
20	+0,3	+1,0	—0,7	0,0	71,2	+0,3	—2,35	+2,65	4,6
21	+0,3	+1,0	—0,7	+0,3	72,2	+0,4	—1,55	—1,95	+5,9
22	0,0	+0,4	—0,4	—0,2	73,2	0,0	—3,95	+3,95	—2,0
23	—0,3	+0,3	—0,6	—0,2	74,2	—0,3	—2,25	+1,95	+0,1
24	—0,8	0,0	—0,8	—1,15	75,2	—0,8	—2,85	+2,05	+1,9
25	—1,7	+0,25	—1,95	+2,2	76,2	—1,7	—5,65	+3,95	—1,0
26	—1,7	—1,95	+0,25	—0,1	77,2	—1,7	—4,65	+2,95	—1,5
27	—1,8	—1,65	+0,15	+0,2	78,2	—1,8	—3,25	+1,45	+3,3
28	—0,9	—0,55	+0,35	+0,2	79,2	—0,9	—5,65	+4,75	—1,5
29	—1,9	—2,45	+0,55		80,2	—1,9	—5,15	+3,25	
			+0,88					+1,585	

50. ***DIFFERENCES** resulting from the comparisons of* 51",2 *upon the large scale, with those of* 36", *upon the same.*

Places of the scale.	Reading of micr. 51",2.	Reading of micr. Yard 36",0.	51",2—36"= 15",2±.	Diff. c—A.	Places of the scale.	Microm. differ. 51",2.	Microm. differ. 36",0.	51",2—36"= 15",2±.	Diff. c—A.
35 / 50,2 } + 1	+2,1	—0,7	+2,8	—2,0	50,2 { +1 / —14	+2,1	0,0	+2.1	+1,5
0	+0,8	0,0	+0,8	+0,1	51,2	+0,8	+0,2	+0,6	+0,6
1	+2,0	+1,1	+0,9	—1,9	52,2	+2,0	+0,8	+1,2	—0,1
2	+1,8	+2,8	1,0	+2,6	53,2	+1,	+0,7	+1,1	—0,6
3	+2,7	+1,1	+1,6	—2,2	54,2	+2,7	+1,2	+0,5	—1,5
4	0,0	+0,6	—0,6	+0,6	55,2	0,0	+1,0	—1,0	+0,5
5	0,0	0,0	0,0	—0,6	56,2	0.0	+0,5	—0,5	—2,7
6	—2,6	—2,0	—0,6	+1,3	57,2	—2,0	+1,2	—3,2	+2,5
7	—0,4	—1,1	+0,7	+1,1	58,2	—0,4	+0,3	—0,7	+1,9
8	+0,6	—1,2	+1,8	—0,4	59,2	+0,6	—0,6	+1,2	+0,9
9	+2,2	+0,8	+1,4	—2.1	60,2	+2,2	+0,1	+2,1	+0,9
10	+0,3	+1,0	—0,7	+3.9	61,2	+0,3	—2,7	+3,0	—0,5
11	+1,9	—1,3	+3,2	—2,4	62,2	+1,9	—0,6	+2,5	—0,4
12	+0,8	0,0	+0,8	—0,3	63,2	+0,8	—1,3	+2.1	+0,4
13	+0,8	+0,3	+0,5	0,0	64,2	+0,8	—1,7	+2,5	—0,7
14	+0,5	0,0	+0,5	—0,5	65,2	+0,5	—1,3	+1,8	+0,4
66,2—15 taken as constant	0,0 / +0,2 / +0,4 } +0,2	+0,2	0,0	0,0	66,2	+0,2	—2,0	+2,2	+1,3
					67,2	+0,8	—2,7	+3,5	+0,1
					68,2	+1,0	—2,6	+3,6	—0,8
16	+0,8	+0,8	0,0	+0,3	69,2	+2,0	—0,8	+2,8	—2,3
17	+1,0	+0,7	+0,3	+0,5	70,2	+0,3	—0,2	+0.5	+1,0
18	+2,0	+1,2	+0,8	—1,5	71,2	+0,3	—1,2	+1,5	+2,7
19	+0,3	+1,0	—0,7	+0,5	72,2	+0,3	—3,9	+4,2	+1,6
20	+0,3	+0,5	—0,2	—0,7	73,2	0,0	—5,8	+5,8	—3,2
21	+0,3	+1,2	—0.9	+0.6	74,2	—0,3	—2,9	+2,6	+1,7
22	0,0	+0,3	—0,3	+0,6	75,2	—0,8	—5,3	+4,5	—0,3
23	—0,3	—0,6	+0,3	—1,2	76,2	—1,7	—5,9	+4,2	+1,1
24	—0,8	+0,1	—0,9	+1,9	77,2	—1,7	—7,0	+5,3	—1,4
25	—1,7	—2,7	+1,0	—2,1	78,2	—1,8	—5,7	+3,9	+1,3
26	—1,7	—0,6	—1,1	+0.6	79,2	—0,9	—6,1	+5,2	—3,4
27	—0,8	—1,3	0,5	+1,3	80,2	—1,9	—3,7	+1,8	
28	—0,9	—1,7	+0,8	—1,4					
29	—1,9	—1,3	—0,6						
	+0,3		+0,296					+2,16	
Means referred to 66",2—15"	+0.10								

From 50",2+1", onwards (left half); From 80",2—29", backwards (right half).

51. *DIFFERENCES resulting from the comparisons of 77",8 upon the large scale, with 39",4, the first being the distance compared to the toise, the second that compared with the metre, taking 77",8—1 as standing comparison.*

From 1″ in the excess, onwards.

Places of scale constant.	Microm. differ. of 76″,8.	Microm. differ. of 39″,4.	76″,8—39 ,4=37″,4±.	C—A.
75,8 / 38,4 } 1	+1,3	0,0	+1,3	—2,8
0	—1,1	+0,4	—1,5	+2,75
—1	{ 0,0 / 0,4 / +1,8 } + 0,73	—0,5	+1,25	
—2	—1,9	+0,6	—2,5	—3,75
—3	+2,5	—0,5	+3,0	+5,5
—4	0,0	—0,8	+0,8	—2,2
—4,2	+0,1	—0,8	+0,9	+0,1
—3,2	+0,9	—0,5	+1,4	+0,5
—2,2	+0,4	+0,6	—0,2	—1,6
—1,2	+0,4	—0,5	+0,9	+1,1
—0,2	0,0	—0,4	+0,4	—0,5
+0,8	—0,4	0,0	—0,4	—0,8
			+0,44	

From 81″,4, backwards.

Constant place of the scale.	Micr. diff. of 76″,8.	Micr. diff. of 39″,4.	76″,8—39,4=37,4.	C—A.
75,8+1 / 75,4—36 }	+1,3	—2,85	+4,15	+0,4
76,8—0	—1,1	—5,65	+4,55	+0,83
77,8—	+0,73	—4,65	+5,38	—4,03
78,8—	—1,9	—3,25	+1,35	+6,8
79,8	+2,5	—5,65	+8,15	—3,0
80,8	0,0	—5,15	+5,15	—1,4
81,0	+0,1	—3,65	+3,75	—8,0
80,0	+0,9	—5,15	—4,25	+10,3
79,0	+0,4	—5,65	+6,05	—2,4
78,0	+0,4	—3,25	+3,65	+1,0
77,0	0,0	—4,65	+4,65	+0,6
76,0	—0,4	—5,65	+5,25	
			+3,986	

52. *The same as above, comparing the length of the toise with the yard by their nearest decimals of the large scale.*

	76″,8.	36″,0.	40″,8±.	C—A.
75,8 / 35,0 } +1	+1,3	—0,7	+2,0	—3,1
0	—1,1	0,0	—1,1	+0,73
—1	+0,73	+1,1	—0,37	4,33
—2	—1,9	+2,8	—4,7	+6,1
—3	+2,5	+1,1	+1,4	2,0
—4	0,0	+0,6	—0,6	+0,1
—4,2	+0,1	+0,6	—0,5	+0,3
—3,2	+0,9	+1,1	—0,2	2,2
—2,2	+0,4	+2,8	—2,4	+1,3
—1,2	0,0	+1,1	—1,1	+1,4
+0,8	—0,4	—0,7	+0,3	
			+0,66	

	76″,8.	36″,0.	40″,8±.	C—A.
75,8+1 / 76,0—40 }	+1,3	—5,9	+7,2	—1,3
76,8	—1,1	—7,0	+5,9	+0,53
77,8	+0,73	—5,7	+6,43	—2,23
78,8	—1,9	—6,1	+4,2	+2,0
79,8	+2,5	—3,7	+6,2	—1,9
80,8	0,0	—4,3	+4,3	+0,1
81,0	+0,1	—4,3	+4,4	+0,2
80,0	+0,9	—3,7	+4,6	—1,9
79,0	+0,4	—6,1	+6,5	—1,4
78,0	+0,4	—5,7	+5,1	+1,9
77,0	0,0	—7,0	+7,0	—1,5
76,0	—0,4	—5,9	+5,5	
			+5,641	

53. The following are the results of different comparisons of the principal yards, made at different times, and reduced for the stand of the microscopes; for the ratio of the individual distances taken upon Troughton's standard scale to the mean yard upon the same scale, resulting from the comparison within itself upon the distance of 36 inches, as resulting from § 42, and where needed, also for the difference of temperature between the two scales, which were always only very small.

1. The brass copy of the Exchequer yard, cut to length.

Date of observation.	Individual results of observ.	Means of each set of measures.	General means.	Remarks.
28th Dec'r, 1830	35'',9995168	35'',9991443	35'',99897072	My measurements were made at temp. 41° to 45° Fahr.
29th " "	— ,—93168			
3d Jan'y, 1831	— ,—89968			
12th " "	— ,—87468			
18th April, 1832 by Mr. Nicollet	— ,—88380	35 ,99879715		
	— ,—87561			
Indiscriminate mean of all			35 ,99902835	Mr. Nicollet's, at temp. about 60°.

2. The brass yard between points in platinum, upon the rule of Troughton belonging to the Treasury Department.

28th Dec'r, 1830	35'',9995068	35'',9990034		My measurement at 41° —45° Fahr.
29th " "	— ,—90568			
3d Jan'y, 1831	— ,—87318			
12th " "	— ,—86987			
18th April, 1832 by Mr. Nicollet	35 ,9988850			
Indiscriminate mean of all measurements			35'',9989758	Mr. Nicollet's measurement at about 60° Fahr.

3. The scale which I divided from the large scale of Troughton, and which is now furnished with a parallel rule and microscopes, to form a comparateur for the Treasury Department, was compared upon three distances, viz. from 0'' to 36'', from 8'' to 44'', from 16'' to 52''.
The means of which gave by different comparisons

28th Dec'r, 1830	35'',9999435	36'',0002465		
29th " "	36 ,0007918			
3d Jan'y, 1831	36 ,0000755			
12th " "	36 ,0001751			

If the measurement of the 29th December were omitted, as they deviate rather too much from the others, and therefore might be considered under the influence of accidental variations of temperature, which it is so very difficult to avoid entirely, this mean would become = 36,0000647, deviating from the large scale only for a quantity that may be considered as below what can be warranted in any transfer, or comparison, of a distance upon a scale. See also the report.

The nearer details of the above are omitted as void of interest: their nature will become evident from the detailed discussions that will appear in the comparisons of the metre.

The other yard measures not being intended as standards, their nearer discussion would have no interest here.

54. The 51'',2 upon the scale of the Treasury Department were laid upon by Troughton, from Sir George Shuckburgh's scale, and stated to agree with it within $\frac{1}{1000}$ of an inch. This number admitting bisection till to the single decimal, appears to have been taken by Troughton for the standard large unit of his scales, the subdivisions of which were made by bisection. The comparison of this distance within itself, upon Troughton's large scale, shows also the smallest deviation of all such comparisons. The details of its measurement by the large scale may therefore be related here.

There are two lines all across the scale, near to that distance, which I first mistook for it, until I found, on the one side, a point, very distinct, though a little large, which showed itself to be the proper distance from the line on the other side. In the first operation, the distance between the lines was accurately ascertained; and, in the second, which was made upon the point, also the distance between this and the line before used was accurately ascertained for the reduction.

15th January, 1831. The distance from 63'',2 to 12'' = 51'',2, which is = 51,20007 of the mean value of 51'',2 upon Troughton's scale, at the temperature 28°,6, being taken between the microscopes, the micrometer reading gave - - - - - - { +113m,4 / +111 ,0 } +112m,2

Reduction for the micrometer values - - - -	— 1 ,426
Value in decimals of the scale - - - -	+110 ,774
Added to 51'',2000, gives distance between the lines =	51,21114 74
17th April, measured distance between point and line, near one another { 118m,7 / 118 ,9 } 118m,8; Reduction for micrometer - - — 1 ,02	= 117,78
Distance between the point and the distant line -	=52,19936 94

The same distance was measured directly, by taking it between the microscopes, and comparing it with distances upon the scale, viz.

The distance between the microscopes was exceeding it by = 4,1 of micrometer,

		Micrometer Reading.	Micrometer Value.
Comparing to the large scale	65'',2—14''=51,20007	+12,8	+12,789
	66 ,2—15 =51,20000	+11,7	+11,689

Which gives the reduced distance between the point and line - - - - - - - } =	51,1988011
	—,1988311
Mean	51,1988161
Correction for microscope stand - - -	+ 0,00041
Value in mean of scale - - - -	=51,1992261
Value found by reduction - - -	=—,1993694
Ultimate mean adopted - - - -	=51,1992977
Which is shorter than the nominal value stated - -	= 0,0007023
From this results proportionably the yard - -	=35,9995062

55. *COMPARISON of brass metres by combination; the distance between the microscopes being adjusted between the divisions* 79",8—1",0.

Temperature.		Denomin.	Micrometer readings.	Mean.	Reduced length to mean of the scale from which the micrometer values are to be subtracted =78,8[illegible]0281.
Comp.	Scale.				
51,8	52 0	M^{t+b}	—401,8		
52,0	53,2	$M_{t}+b$	—404,6	—405,15	
52 1	52,6	${}^{t+b}M$	—409,0	+ 5,04	78 7602700
52,4	53,3	${}_{t+b}M$	—405 2	—400,11	— 0,00057938 corr. f. 0°,7
52 1	52 8				78,75969062
52,4	53,4	$M_{t}+d$	—401,2		
52,3	53,5	M^{t+d}	402,7	—403,85	
52,4	53,1	${}_{t+d}M$	404 4	+ 5,02	78,760398
52.6	53,3	${}^{t+d}M$	407,1	—398,83	— 0,00074492 corr. f. 0°,9
52,42	53,32				78,75965308
53,0	53 5	M^{t+r}	—412 8		
53,0	54,5	$M_{t}+r$	—403,8	—408,0	
53,1	54,0	${}^{t+r}M$	—407,6	+ 5,08	78,759989
53,3	54 2	${}_{t+r}M$	—407,8	—402,92	— 0 00053800 corr. f. 0°,65
53,4	54,05				78,75945100
53,2	53,0	Scale	+4,9—1,65	corr. temp.	=+3,35
A.M.next	day		+3,0		

Comparison of the brass metres of Lenoir, by combination.

Temperature.		Denom.	Micrometer readings.	Mean.	Mean length to subtract the micrometer values from =78,800016.
Comp.	Scale.				
46,0	46,0	M^{b+r}	—401,4		
46,0	46,1	$M_{b}+r$	—398,0	—402,85	
46,1	46,2	${}^{b+r}M$	—407,5	+ 5,02	78,760233
46,1	46,5	${}_{b+r}M$	—404,5	—397,83	— 0,00012415 corr. f. 0°,15
46,05	46,2				78,76010885
46,2	46,4	$M_{b}+d$	—397,7		
46,2	46,4	M^{b+d}	—398,2	—398 52	
46,2	46,4	${}_{b+d}M$	—392,4	+ 4,97	78,760661
46,3	46,7	${}^{b+d}M$	—405,8	—393,55	— 0,00020692 corr. f. 0°,25
46,22	46,47				78,76045408
46,4	46,6	M^{r+d}	—396,6		
46,5	46,6	$M_{r}+d$	—390,5	—394,1	
46,6	46,6	${}^{r+d}M$	—394,2	+ 4,9	78.761096
46,6	46,8	${}_{r+d}M$	—395,0	—389,20	— 0.00010760 corr. f. 0°,13
46,52	46,65				78,76098840
46,6	46,5	Scale	—1,0		

Second comparison, by combination, of brass metres, as follows; the scale being re-adjusted to 79'',8—1''=0m,0.

Temperature. Comp.	Temperature. Scale.	Denom.	Micrometer readings.	Mean.	Mean length to subtract the micrometer measure from =78,800226.
48,6	49,5	M^{s+t}	—410,2		
48,9	50,0	M_{s+t}	—410,2	—408,075	
49,1	49,9	${}_{s+t}M$	—406,0	+ 5,08	78,759926
49,5	50,0	${}^{s+t}M$	—405,9	—403,0	— 0,00068698 corr. f. 0'',88
49,02	49,85				78,75923902
50,0	50,5	M_{s+d}	—394,6		
51,7	52,3	M^{s}_{d}	—400,6	—400,5	
52,4	53,0	M^{s+d}	—404,8	+ 4,98	78,760674
52,8	53,1	${}^{s+d}M$	—402,0	—395,52	— 0,00038914 corr. f. 0°,47
51,75	52,22				78,76028486
53,0	53,5	M^{s+b}	—408,4		
53,1	53,9	M^{s}_{b}	—406,6	—405,25	
53,1	53,6	${}^{s+b}M$	—408,3	+ 5,04	73,760205
53,1	53,7	${}^{s}_{b}M$	—397,7	—400,21	— 0,00049661 corr. f. 0,6
53,07	53,67				78,75970839
53,2	53,8	M^{s+r}	—402,3		
53,3	53,9	M^{s}_{r}	—407,8	—404,75	
53,6	53,9	${}^{s+r}M$	—407,5	+ 5,03	78,760256
53,4	54,0	${}^{s}_{r}M$	—401,3	399,70	— 0,00043868 corr. f. 0°,53
53,37	53,9				78,75981732
53,7	54,0	M^{t+b}	—401,6		
53,8	54,2	M_{t+b}	—404,0	—404,2	
		${}^{t+b}M$	—405,7	+ 5,03	78,760309
53,4	54,5	${}_{t+b}M$	—405,5	—399,17	— 0,00057938 corr. f. 0°,7
53,47	54,17				78,75972961
54,0	54,3	Scale	+3,2		

The notations used above to designate the different metres are as follows:

M^t = brass metre, of the Treasury Department of Fortin.
M^s = brass metre, of the State Department of Fortin.
M^b = brass metre, of Lenoir, of the coast survey collection.
M^r = brass metre, of the Engineer Department.
M^d = brass metre, of the same, another one.

Their combination is abridged by adding only the distinguishing letter above: thus, M^{t+b} designates the sum of M^t and M^b, and so on all other, varying the place with the position.

The brass metre of Lenoir, of the coast survey collection, designated M^b, has a certificate of its comparison at the Observatory of Paris, stating it too short for $\frac{1}{100}$ of a millimeter, = 0,00039381 of an English inch, which is therefore proper to apply ultimately to deduce from it the actual length of the French metre in English inches.

Comparison of the iron metres, by combination.

Temperature. Comp.	Temperature. Scale.	Denomination.	Micrometer reading.	Mean.	M^l = iron metre of Lenoir, C. S. M^J = iron metre standarded by myself. M^c = iron metre of the committee.
44,0	44,9	Scale	0,0		
45,4	46,1	$M^l + ^c$	—431,7		
45,4	46,2	$M_l + c$	—436,5		
45,6	46,2	$^l + ^cM$	—427,4	—431,15	Distance to subtract fm. =78,800066
45,6	46,4	$_l + _cM$	—429,0	+ 5,36	78,757487
				—425,79	+ 0,0033892 red. to 32°.
					78,7608762
45,5	46,22				
45,8	46,1	$M^J + ^c$	—425,5		
46,0	46,4	$M_J + c$	—426,0		
46,0	46,4	$^J + ^cM$	—427,8	—425,87	78,757909
46,0	46,4	$_J + _cM$	—424,2	+ 4,3	+ 0,003707 red. to 32°.
				—421,57	78,761616
45,95	46,32				
46,1	46,4	$M^J + ^l$	—430,8		
46,0	46,5	$M_J + l$	—429,7		
46,0	46,4	$^J + ^lM$	—439,3	—433,85	78,757220
46,0	46,3	$_J + _lM$	—435,6	+ 5,39	+ 0,0037211 red. to 32°.
				—428,46	78,760941
46,02	46,4				
46,0	46,4	Scale	0,0		

To deduce the value of the metres from these comparisons, the first discussion is, that of the value of the individual distance upon the scale, to be deduced from the comparison of the scale within itself, upon the distance of 39",4 nearest approaching the metre. By this comparison, the distance of 63",4—24",0, which was the constant distance of comparison, was found in excess over the mean by 1,28 of the micrometer values, or in $\frac{1}{10000}$ of an inch; thence follows 63",4—24,0=39,400128 in mean value. The distance 79",8—1,0 was measured, in applying this distance from 1" to 40",4, and from 40",4 to 79",8 in succession. By this, the 79",8—1",0 were found defective for 1,9 of the micrometer values.

This gave the 78",8 made use of in the comparison - =78,79981.
The excess of the 63",4—24",0, being doubled, gives - 0,000256

Which are to be added to reduce to the mean of the scale,
whereby the distance employed becomes in mean value =78,800066

To this distance must, then, be applied the corrections due to the momentaneous standing of the microscopes, as given by comparisons of the scale at each beginning and end of the operations. Thus were determined the distances written above, from which the micrometer values were subtracted after the reduction to their real value.

58. Having five brass and three iron metres, the combination of all the eight, two by two, would have given twenty-eight single results, but the necessary mixture of brass and iron in the same comparison complicated the reduction for temperature; I preferred to omit it, and to make two separate series, the one of the brass, the other of the iron metres. The formula answering the denominations adopted upon the principles stated in § 28, will stand thus in form:

$$M^t = \frac{M^{t+b} + M^{t+d} - M^{b+d}}{2}$$

with all the mutations of letters adapted to each individual case. The whole of the results will therefore present a scheme of thirty combinations, giving six results for each individual metre. Using only the upper letters, these combinations are

For T.		For S.		For B.		For R.		For D.	
Add	Subtract	Add	Subtract	Add	Subtract	Add	Subtract	Add	Subtract
t+b t+d	b+d	s+t s+d	t+d	b+t b+s	t+s	r+t r+b	t+b	d+t d+s	s+t
t+b t+r	b+r	s+t s+b	t+b	b+t b+d	t+d	r+s r+t	s+t	d+t d+b	b+t
t+b t+s	b+s	s+t s+r	t+r	b+t b+r	t+r	r+b r+s	b+s	d+t d+r	t+r
t+d t+r	d+r	s+d s+b	d+b	b+s b+d	s+d	r+t r+d	t+d	d+s d+b	s+b
t+d t+s	d+s	s+d s+r	d+r	b+s b+r	s+r	r+b r+d	b+d	d+b d+r	b+r
t+r t+s	r+s	s+b s+r	b+r	b+d b+r	d+r	r+s r+d	s+d	d+r d+s	r+s

The following are the numerical results for the brass metres, to be used in the calculation, (taking for t+b a mean between the two observations,) when reduced to the temperature of the comparateur in each comparison, as seen by the calculations at the side, which is all that is needed to render the circumstances equal for those comparisons.

t+s = 78,75923902
t+b = —,75971011
t+r = —,75945100
t+d = —,75965308
s+b = —,75970839
s+r = —,75981732
s+d = —,76028486
b+r = —,76010885
b+d = —,76045408
r+d = —,76098840

The form of the calculation, resulting from any three combined distances, giving three results of the above scheme, but of course in a different order, is the following:

t+s=	78,75923902	t+s=	78,75923902	t+b=	78,75971011
t+b=	—,75971011	s+b=	—,75970839	s+b=	—,75970839
Sum	157,51894913	Sum	,51894741		,51941850
s+b=	78,75970839	t+b=	,75971011	t+s=	,75923902
Difference,	78,75924074	Diff.	78,75923730		78,76017948
Half diff. = M^t=	39,37962037	M^s=	39,37961865	M^b=	39,38008974

The calculation of the full scheme gives the following results:

	M^t	M^s	M^b	M^r	M^d
	39,37962037	39,37961865	39,38008974	39,38001465	39,38034946
	—,37943635	—,—80267	—,—18248	—,37992487	—,—19858
	—,—30362	—,—95540	—,—25550	—,38039316	—,—59524
	—,—52613	—,—70843	—,—00046	—,38010889	—,—51527
	—,—45455	—,—55689	—,37993880	—,38032658	—,—72797
	—,—05784	—,—76953	—,—78726	—,38026043	—,—77781
Means =	39,37939981	39,37973193	39,38004237	39,38017143	39,38052739
	Corrected for certificate +		0,00039381		
	Corrected M^b - =		39,38043618		

59. The iron metres being only three, their comparison furnishes but one result for each, by their mutation, and the scheme is only one single one.

The reduction for the temperature requires, that as well the iron metres as the comparateur be reduced, each by its individual temperature and expansion, to its length at the temperature of 32°, their difference is applied, with its proper algebraic sign, to the distance observed; only thus reduced they become comparable, as under equal circumstances.

The results thus presented, by the comparison of 12th April, at 32° F.

$$I + c = 78'',760876$$
$$J + c = — ,761616$$
$$J + I = — ,760941$$

And their calculation gives the following results for each metre, at 32° F.

$$M^c = 39'',3807755$$
$$M^J = — ,3808405$$
$$M^I = — ,3801005$$

60. The greater the number of equal measures are, thus included in one system of combined comparisons, the more the advantage of the method increases. For any number of such equal measures = n will furnish, $\frac{n(n-1)}{2}$ binary combinations: in these each measure will appear, $n-1$ times; and in the calculation of the results, these will again be combined in a binary form, therefore give $\frac{(n-1)(n-2)}{2}$ results. By the four positions in which the observations are made, and the three alternating sets of observations used in the calculation of the results, each result is properly depending of twelve observations. By the method of calculation employed, each observation obtains equal weight in the result; and it is proper not to vary them unequally. Thus, therefore, in the present case, for five metres were obtained $\frac{5.4}{2}$ = ten combinations, and these gave for each metre $\frac{4.3}{2}$ = six results, each combined from three sets and twelve observations. If I had combined

the iron metres in the same series, I would have obtained $\frac{8.7}{2}$ = twenty-eight combinations; each metre would have been compared seven times, therefore the number of results would have been $\frac{7.6}{2}$ = twenty-one for each metre, each dependant again, alternately, on three sets, of four observations each.

Another advantage of this method of comparison is yet: the unprejudiced manner in which the observations are made, because, from the variety in the combination of their differences, it is impossible to form an idea of what would be a proper reading in any individual observation.

Though I observed, also, the metres, "à bout," singly, I consider the value of results obtained by that method not comparable in accuracy with those obtained by combination. As it is not proper, therefore, to take them up in the ultimate results with equal weight, and their observations present nothing of peculiar interest, different from the observation of a combined length, I think proper to pass them over with silence.

61. The metre, "à traits," of platinum admits no variations in the comparisons, except the inversion end for end. The reductions are as already shown; and, in case of a difference of temperature between the metre and the comparateur, each is reduced to the length it would present at 32°.

The comparisons gave the following results, each by two positions:

One made in the course of the present comparison	=39,38042036
Comparisons of 1829, re-calculated now, and reduced to the medium of the standard scale, give the following results, each the mean of two readings: - - -	—,—082057
	—,—10851
	—,—06247
	—,—100073
	—,—06144
The mean of all is - - - - -	39,38076096
The certificate of comparison, engraved upon the metre, stating it for $\frac{11}{1000}$ millimetre too large, which gives to deduct - - - - - - -	0,00043319
This, deduced, gives the value of the metre, at 32° F. for both English and French standards - - -	39,38032777

The metre being polished, the glare of light resulting is very unfavorable to the reading: the strokes are very fine, therefore, also, do not fill up black, which occasions again a reflection from the sides of the lines.

62. When I had just finished my comparisons, and while engaged in the reduction of this account of them, I had the pleasure of the company of Mr. Nicollet, astronomer of the Royal Observatory of Paris, &c. &c. His acquaintance with these subjects from the Observatory of Paris, where the original standards of France are deposited, invited him to take interest in my work; and he staid a number of weeks with me, during which time he made, by means of my apparatus, and by my methods, by himself alone, a number of comparisons of the principal metres, and the two principal yards. With his leave, I introduce them here with mine.

The comparisons of the platinum metre gave the following results, each being a mean of twelve readings:	=	39,38105884
		—,—088598
		—,—096723
		—,—129403
		—,—075894
		—,—071984
Mean		39,38094414
Correction for certificate		0,00043319
Value of the metre at 32° temperature		39,38051095
The above result		—,—32777
Mean between the result of Mr. Nicollet and mine		39,38041936
Difference		0,00018318

63. Though this coincidence of the results may be considered satisfactory, it appears to me most proper to unite all the individual comparisons, above related, into one mass; and the mean of them I consider the best.

Thus, our results united will present the following:

Platinum metre of the State Department, at 32° temperature, mine of present comparison	=	39,38042036
— of 1829	=	—,—082057
		—,—10851
		—,—06247
		—,—100073
		—,—06144
Mr. Nicollet, by six, according to his way of correcting for micrometer		—,—105884
		—,—088598
		—,—096723
		—,—129403
		—,—075894
		—,—071984
		1025072
Mean		39,38085422
Correction for certificate	=	0,00043319
Ultimate value of this metre	=	39,38042103

The first of the above results, deviating rather more than the others generally do, might be omitted, but the *ultimate result would be affected only* by 0,00003945 of an inch, which is an inappreciable quantity; the mean would be = 39,38046048.

64. Mr. Nicollet also compared, three times, the three principal brass metres by combination, namely, M^t, M^a, M^b, and the three iron metres. His observations furnish the following results: their details of calculation, presenting the repetition of what has been seen, § 58, are not introduced in detail; they are each means of twelve comparisons, each pair of metres being measured in four positions.

	M^s	M^t	M_b
The 11th April - -	39,3803447	39,3797678	39,3807024
18th " - -	—,3797811	—,3797807	—,3802958
19th " - -	—,3795671	—,3798420	—,3803746
Means - -	39,3798976	39,3797968	39,3804576

	M^c	M^J	M^l
The 12th April - -	39,3808935	39,3809699	39,3804519
16th " - -	—,3810781	—,3806473	—,3793431
19th " - -	—,3808879	—,3805584	—,3793758
Means - -	39,3809532	39,3807252	39,3797236

65. It will be proper to take up these results in comparison with mine, and in general to present the comparative view of all the different comparisons that have been made of several of the principal metres, as well in this as in preceding comparisons. They will present differences which are chiefly due to the incidental influence of temperature, which affect either the thermometers, or the measures compared, during the operations, and thereby the reductions to one and the same temperature; they will prove, however, to fall within the limits of what is obtainable in the construction of any length measure. The differences between the means, taken in different ways, as the following tables will present, are so small, that the one or the other may be taken as the ultimate result, according to the views and judgment of any person wishing to make use of them.

1. *Comparison of Mr. Nicollet's and my results in the present comparison.*

OF THE IRON METRES.

	M^c	M^J	M^l
Mr. Nicollet - -	39,3809532	39,3807252	39,3797236
My present comparison -	—,—7755	—,—8405	—,3801005
Means -	39,3808643	39,3807828	39,3799120
Differences - -	+ 0,0001777	— 0,0001153	— 0,0003769

OF THE BRASS METRES.

	M^s	M^t	M^b corrected.
Mr. Nicollet - -	39,3798976	39,3797968	39,3804576
My present comparison -	—,—73193	—,—3998	—,—4362
Means -	39,37981476	39,3795982	39,3804469
Differences - -	+ 0,00016567	+ 0,0003970	+ 0,0000216

66. The collection of all the results obtained at different times, and by different observers, of such of the metres of the present collection, as have been observed repeatedly, presents the following table:

Collection of all the repeated comparisons.

OBSERVER AND TIME.	M^c	M^i	M^J	M^b corrected.	M^s	$\dot{M}^t$	M^p corrected.
Mine in the present comparison	39",3807755	39,3801005	39,3808405	39,3804362	39,3793193	39,3793998	39,3803278
Mr. Nicollet, in do.	— ,—09532	—,3797236	—,3807252	—,—4576	—,—8976	—,—7968	—,—5110
Mine for the coast survey -	— ,—10227	—,3797201	———	—,—2480	———		
Mr. Troughton, in 1813 -	———	—,3802506	- -	—,—3333			
General mean of all -	39 ,3809171	39,3799487	39,3807827	39,3803688	39,3796084	39,3795983	39,3804194

67. The Almanac du Bureau des Longitudes being the authority commonly resorted to for this proportion, I will place here its indication, for the sake of comparison: it gives the metre = 39,37079, that is, less than M^c by 0,0101271, and even yet considerably less than the smallest of Fortin's metres. I cannot help considering this indication as wrong stated in this naked form, where it must naturally be supposed to apply to equal temperature for both measures. The great coincidence of *my* metres, compared repeatedly at different times, and by different observers, I allow myself the liberty to consider as decisive; and these being all reduced to the same temperature, I must consider the indication of the almanac as affected by an unnamed difference of temperature between the two standard units they compare. If the expansion of brass for 30° Fahr. be added, according to my determination, we obtain 39",37960157, which differs from the means of Fortin's two brass metres above, only 0,00000213; but these have no certificate of comparison, and evidently deviate from all others that have authenticity, while his own platinum metre, *uncorrected*, is well agreeing with the fully authentic committee metre. Nor does the difference between the Exchequer yard of the State Department and the eighty-two inch scale of Troughton account for it, as the metre would measure more in a smaller unit of the yard.

68. Among all these, the M^c, or metre of the committee, being an authentic original, I take it of course as the one that must be taken to state the real value of the French metre in English inches, at the temperature of 32° Fahr., and the metre in iron the English scale in brass. It proves itself to be somewhat the largest, and such it is proper that it should be, by all the principles and manners of working in making copies of length measures in general.

The platinum metre of the State Department, and the brass metre of the coast survey collection, having authentic certificates of their comparison at the Observatory of Paris, give a specimen of the accuracy to which these comparisons come with the original. If these metres, thus corrected, were taken up in the determination of the value of the metre in English inches, absolutely speaking, we would obtain $M^c = 39,3809171$

Corrected $\left\{ \begin{array}{l} M^p = —,—4194 \\ M^b = —,—3688 \end{array} \right\}$ 39,3803941

Mean - - - -	=	39,3805684
Greatest difference - - -	=	0,0005483
Difference between the mean of compared copies, corrected, and the original -	=	0,0005230

69. If the results of all these inquiries are turned upon the question of the accuracy with which metre copies are obtained, it will be observed, that the metre copies, "à traits," are likely to become too large: for thus the individual of platinum of the present investigation is, though it is made by Fortin, whose metres, "à bout," in brass are evidently too small, and the two here present, made at different times, are very well coinciding; but they have no detailed certificates of their comparison, and are only stated to be exact; this difference is thus:

By the committee metre, $M^c = 39,3809171$

$$\frac{M^s + M^t}{2} = —,3796033$$

Difference - - $= 0,0013138$

By the mean of committee metre, and the metres verified at the Observatory of Paris, with their corrections.

The brass metres of Fortin, without certificate, give:

$$\frac{M^c + M^p + M^b}{3} = 39,3805684$$

$$\frac{M^s + M^t}{2} = —,3796033$$

Difference $= 0,0009651$

They may, therefore, by a mean, be considered as about $\frac{1}{1000}$ of an English inch too short, while his platinum metre, uncorrected, is only 0,00006288 shorter than the committee metre, that is, may be considered as coinciding with it.

The metres of Lenoir present the following results, when the correction of the brass coast survey metre is omitted, to reduce it to its actual state, as coming from the artist:

$$M^l = 39,3799487$$
$$M^b = —,——750$$
$$M^r = —,3801714$$
$$M^d = —,——5274$$

$$\frac{M_l + M_b + M^r + M_d}{4} \quad - \quad - \quad = 39,3801556$$

$$M^c — \frac{M^l + M^b + M^r + M^d}{4} \quad - \quad = 0,0007615$$

$$\frac{M^c + M^p + M^b}{3} — \frac{M^l + M^b + M^r + M^d}{4} = 0,0004128$$

Thence, therefore, also, these metres are in a mean too small, but only for about $\frac{5}{10000}$ in a mean, and M^d is even to be considered as identical with the mean of the original, and the verifications at the Paris Observatory.

70. This investigation strongly supports the assertion which I have made, that all metre copies, "*à bout*," are apt to be rather too short, it follows exactly the necessary historical origin of the metres in brass, as I have it from the statement of Mr. Lenoir himself, namely: Mr. Lenoir was the artist employed by the Committee of Weights and Measures in Paris, under the direction of my late friend Mr. Tralles, for all the mechanical part of the construction and comparison of the metres.

There were no brass metres intended to be made by the committee, as original standards, iron having always been the standard metal in France for the toise. But Mr. Lenoir, in foresight of the case, that brass metres would also be desired, *made one for himself, which passed through* all the operations of the originals, in iron and platinum, that were made by the committee. Upon this, therefore, also authentic original, Mr. Lenoir constructed his brass metres; and its being the only one, it follows necessarily that all others must be copies of this, if not made by reduction from the iron or platinum ones; therefore, also, Mr. Fortin's brass metre, upon which he makes his copies, must be a copy from this individual, if not otherwise deduced. And thus, if the reasoning were allowed to be followed up, we would find the brass copies from the original one 0,0005 too small, and the copies from these copies = 0,0010 too small, in a mean, giving a pretty regular gradation; which, however, must not be asserted as exactly to be relied upon, but highly probable.

My experience in the construction of such measures is fully in support of that, and shows itself by the M^J which I standarded in this comparison, and brought the nearest of any to the original M^c, holding about a mean between this and the mean of this and the verification results, viz.

$$M^c = 39,3809171$$

$$\frac{M^c + M^p + M^b}{3} \text{ Mean with verifications } —,——5684$$

Mean	- -	39,3807427
M^J	- - =	—,——827
Difference	- =	0,0000400

71. The results of the metres by combination might also be obtained by taking the means of all the results obtained individually, without distinction of the observer and time, as has been done in the platinum metre and the principal yards, which would thereby give equal weight to each individual result; but as my present result was obtained by the combination of five metres, giving six results for each metre, obtained by the concurrence of eleven measurements, in four positions or forty-four measurings, they are about equal in weight to the three of Mr. Nicollet, each upon three metres, giving, therefore, three results each, grounded upon three measurements in four positions.

Another manner of taking the mean would be by throwing all the measurements of each pair of metres in one, taking the means, and from these means calculate one single unique result; but then the results, all influencing each other, would be different in respect to the number of comparisons of each, as Mr. Nicollet did not observe the M^r and M^d. These considerations decided me to the manner of establishing the means, which I have followed in the above exposition, and consider as the best, unless it should be desired to apply to this mean the method of the least squares, used in many cases, which I, however, thought superfluous.

72. I might here now enter into a discussion of considerable length upon the consequences of these results of the comparisons of French and English standards, that would be of interest in a scientific point of view, as upon their ratio s many important geodetic results must be compared; and there is yet some difference in different English statements.

The standards of both kinds that I have compared are, in point of authenticity in their origin, and perfection in their construction, certainly the best that ever were compared. I believe the results will also show that no care, or attention and precaution, so necessary to accuracy, has been neglected. I may, therefore, safely affirm that the ratio given is the most accurate; how it was or *could be* possible to state or get such other ones as I have seen quoted, I cannot account for, and must only regret, as they may mislead.

But the discussions, which this would lead me in, lie rather too far off from the immediate aim of this paper, which is rather an account of my means and methods employed, for the instruction of such persons as may have works of a similar nature. I must, therefore, leave all comparisons of my work with others, and the various consequences and discussions that may follow, to those gentlemen who may have any particular view or interest in this discussion.

73. When Mr. Tralles returned to Switzerland, from his mission to the Committee of Weights and Measures in Paris, he gave me, besides the original metre and killogram, some details relating to the comparisons of the toises and the platinum rules used in the measurements of the bases, for the survey of the twelve degrees of the meridian, upon which the French metric system is grounded, and upon the construction and last comparison of the metres, with which he had been especially charged. These have never been printed, and have some interest. It may be a valuable document for the men of science to whom original metres may come under hands. I, therefore, insert it here, after this special account of my length measure comparisons, (translated from the French.)

It will be observed that the necessity to distinguish the metres in the construction by secret special marks, gives at the same time a criterion of the authenticity of any metre that might, by some means, have obtained the stamp of the committee, without having been in the comparison of the committee itself: when the metre is held before one, with the stamp above, and to the right hand, the marks will be found about three inches from the same end at the off side of the metre.

The individual metre given to me by Mr. Tralles has the mark (:·), the last comparison shows the relation that it ultimately had to any of the others.

The kilograms bear no special marks; they had numbers upon paper, in the chagring boxes to which each belonged. The original kilogram here compared has the number 2 upon the paper still preserved. The short notice at the end of these papers indicates it as entirely exact, as no ascertainable difference was found in the last comparison. They are now with other standards in the possession of the Philosophical Society of Philadelphia, and were lent to me only for this comparison, as stated in its proper place.

TRANSLATION OF THE PAPER OF MR. TRALLES.

1. *Comparison of the Toises made by the Committee of Weights and Measures.*

The toise (called) of Perou placed edgeways, so that the inferior part of the notch is brought in contact with the cylinder of the comparateur. The contact was complete for the whole height of the cylinder, which is about four lines (French). Thence,

Toise of Perou, placed edgeways - -	= 1,004125	Of the comparateur.
Toise of the north, placed the same - -	= 1,0041275	
—— - Lenoir, placed flat - - -	= 1,004125	
—— - Mairan, the same - - -	= 1,004090	
Toise of Perou and that of Lenoir together -	= 2,004070	
Base measuring rod No. 1 - - -	= 2,0040665	

During these experiments, the centrigade mercurial thermometer, placed upon the toises, and the rod No. 1 has been at 12°,0 to 12°,8.

Second Experiment.—*Repetition of the preceding; thermometer at* 10°,2 *at the beginning, and* 11° *at the end.*

Toise of Perou, placed edgeways - - -	= 1,004143
—— - the north, the same - - - -	= 1,004144
—— - Lenoir, in the middle of its breadth - -	= 1,004143
Base rod No. 1, (metallic therm. = 100,5 or 11°,0 centigr.)	= 2,004093
Toise of Perou and of Lenoir, end to end - -	= 2,004080
Toise of Mairan, in the middle of its length, and also at three lines from each side - - - -	= 1,004099

Third Experiment.—With another butting piece (on the comparateur).

Toise of Perou.

At one line from the angles *a* & *b* -	= 1,049062	Of the comparateur.
At two lines from the same -	= 1,049063	
At four lines from the same -	= 1,049069	
At six lines from the same -	= 1,049069	
At $\frac{2}{3}$ from *a*, *c*, and *b*, *d*, or at three lines from the exterior angle - -	= 1,049058	

Toise of the North.

At one line from the interior angle	= 1,049047	Of the comparateur.
At three lines from the exterior angle	= 1,049065	
At two lines from the exterior angle	= 1,049062	
Base measuring rods; No. 1 (metallic therm. = 401,2) (= 8°,6) = 11°,8 - - - - -	= 2,0040833	
—— No. 2 (metall. therm. = 402) (= 8,0) -	= 2,0040825	
—— No. 3 (metall. therm. = 399,0) (=10,1)	= 2,004079	
—— No. 4 (metall. therm. = 400,8) (= 8°,9)	= 2,004088	
—— No. 1 (metall. therm. = 402,0) (= 9,0) = 11°,15	= 2,004077	
Toise of Mairan = toise of Perou - -	— 0,03413 lines	

at 12° centigr. thermometer 4 rods = 8 toises.

Upon the expansion of Iron.

The committee has adopted for the expansion of the iron, for one degree centigrade, - - - 0,00001156 of its length.
According to Smeaton, it is = 0,00001249 (or 0,00001258);
Berthoud, = 0,00001395;
Roy, the expansion of steel is already = 0,00001143:
And all observers state the expansion of steel less than that of iron.

Construction of the Metres.

The metre is = 443,296 lines (French) of the toise of Perou, at the temperature of 16°,25, or = 0,5130740740 of the toise, as resulting from the calculations of the arc (of the meridian) between Dunkerke and Mont Joui, and the comparison between the toise of Perou and the platinum rods used for measuring the base lines.

Metres in iron and in platinum were to be constructed of this length, not at this same temperature, but at the temperature of melting ice.

By the best observations upon the expansion of hammered iron, as well as by those that we undertook ourselves, this expansion is = 0,0000115 of the total length for one degree centigrade mercurial thermometer. From this results, that the metre in iron having at 0° (centigr.) temperat. the length = 0,5130740740 of the toise, must be greater by 0,0000958657 of the toise, or = 0,51316994 of the toise.

But as the toise to which the metre bears this ratio, both being at 16°,25 temp., is in iron, it suffices to give to the metre in iron these 0,5131740740 of the iron toise, at whatever a temperature it may be; this length will always have the determined length at the temperature of the melting ice.

The length of four metres must, therefore, be = 2,05267976 toises.

Mr. Lenoir constructed nineteen pieces of iron, each very nearly equal to the excess of four metres over two toises, that is to say, = 0,05267976 of the toise. These pieces, all joined end to end upon the comparateur, were found to be together greater than the toise of Perou by = 0,000851 of the toise; or, calling these pieces, successively, p^{i}, p^{ii}, p^{iii}, &c., the length of all the pieces gave: $p^{i}+p^{ii}+p^{iii}+$, &c., ... p^{xix} = 1,000851 of the toise; supposing them all equal, the mean length of one would be the nineteenth part of this sum, which, being called Π, gives Π = 0,0526764, the true excess being - - - - P = 0,0526796.

To find the difference of length of these nineteen pieces, Mr. Lenoir constructed an apparatus similar to that made for measuring the dimensions of the cylinder and the rules for the determination of the weights. By this apparatus, the small distances were augmented more than twenty-five times. The following are the results obtained by this means, the numbers being ten-millionth parts of the toise:

$p^{i} = p^{vii} - 5$	$p^{vii} = p^{vii} + 0$	$p^{xiii} = p^{vii} + 0$
$p^{ii} = p^{vii} + 10$	$p^{viii} = p^{vii} - 50$	$p^{xiv} = p^{vii} - 50$
$p^{iii} = p^{vii} + 0$	$p^{ix} = p^{vii} - 40$	$p^{xv} = p^{vii} - 70$
$p^{iv} = p^{vii} - 20$	$p^{x} = p^{vii} - 20$	$p^{xvi} = p^{vii} - 60$
$p^{v} = p^{vii} - 70$	$p^{xi} = p^{vii} + 5$	$p^{xvii} = p^{vii} - 20$
$p^{vi} = p^{vii} - 50$	$p^{xii} = p^{vii} - 70$	$p^{xviii} = p^{vii} - 20$
		$p^{xix} = p^{vii} - 10$

From which is obtained $p^{i} + p^{ii} \ldots\ldots + p^{xix} = 19\,p^{vii} - 0{,}000054$ of the toise; thence, $19\,p^{vii} - 0{,}000054 = 1{,}000851$ toise, or $19\,p^{vii} = 1{,}000905$ toise, and $p^{vii} = 0{,}0526792$; thence, the piece p^{xi} has the required length to one ten-millionth of the toise. However, the piece p^{vii} has been used.

Then the two toises and the piece p^{vii} together were compared with four metres together; and the difference between any two such lengths from the true distance was ascertained by the difference in these measurements, and the length obtained by the above apparatus.

These operations were frequently repeated, Mr. Lenoir always reducing the metres according to the results obtained by the commissioners.

At last was obtained:

· + : + ⁝ + ⁝ = 2 toises + p^{vii} — 0,000004 = 2,0526752

·˙· + ·: + ⁚· + ·⁝ = + 0,000001 = 2,0526802

⁚˙ + ⁝· + ˙.˙ + .⁚ = — 0,000002 = 2,0526772

˙.˙ + ˙.˙˙ + ˙⁚ + ⁚. = — 0,000000 = 2,0526792

This shows the sum of four metres to differ no more from the true value than four-millionth part of the toise at the most: thence, supposing them equal, there is no more than one-millionth part of the toise error upon the metre.

But the comparison of these metres between themselves gave yet the following, in ten-millionth parts of the toise:

· · — ⁝ · = 3	· · — ⁚˙ = 7	· · — · ⁚ = 3
· · — ˙⁚ = 8	· · — · · · = 11	· · — ⁚ · = 2
· · — · ˙. = 6	· · — · ⁚ = —1	· · — · · · · = 6
· · — ˙.˙ = 2	· · — · = +4	· · — ˙.˙ = 0
· · — ⁝ · = 2	· · — .∴ = —3	

This proves again the differences less than one-millionth part of the toise.

· + : + ⁝ + ⁞	=	2,0526752
: — ·	=	4
: — ⁝	=	11
: — ⁞	=	6
4 × :	=	2,0526775
:	=	0,5131693
Metre - -	=	0,5131704

Upon the Weights.

The construction of the weights presented no difficulty. A mass of brass was made, weighing, in weights of the experiments, as much as the result of the determination of the unit of weight had given.

The kilogram weighing 0,9992072 units, a mass was made, which, together with the weight 0,0007928, was equal to the weight No. 1.

The four weights of Mr. Tralles had ultimately given

Kilogram No. 2 =	kilogram + ½	milligramme at farthest.
1 =	+ 0,5	
3 =	+ 1,0	
4 =	+ 1,5	

Remarks.—The comparateur spoken of in the preceding paper: is a strong brass rule, more than four metres in length: at one end a perpendicular steel roller is fastened, or a narrow perpendicular piece, with a cylindrical edge, against which the one end of the measure to be compared is butted. A moveable piece, having at one side a similar roller, or butting piece, slides in a straight direction upon the rule, bearing, at one end, a roller, or butting piece, like the above, when this is placed in contact with the other end of the measure to be compared, and so as to bring it to a certain division of a scale, that is marked at the side of the rule, the butting piece, acting upon the shorter arm of an angular lever, the longer arm moves along an index upon a divided sector at the other end of the sliding piece, upon which it indicates the smaller subdivisions, and thereby their difference indicates the difference between two nearly equal measures thus compared.

The nearer description will be found in the Base du Systeme Metrique, vol. 3.

The rules used for the base measuring apparatus, quoted in this paper, were of platinum resting upon brass. Their nearer description is in Base Metrique, vol. 2.

The toise "du Perou" is that which the French academicians had with them in the measurement of the three degrees of the meridian in that country. That called "du Nord," is that which Maupertuis had with him in the measurement of the degree at the polar circle. The other two explain themselves.

The toise "du Perou" is that which is always taken in France as the original and proper standard, to which all others are compared or referred in their ratio.

Upon the form of standards for practical use.

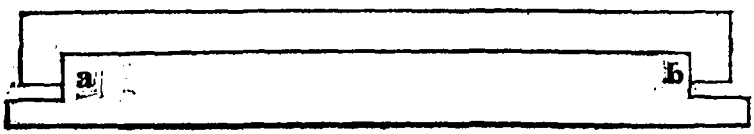
74. It may not be improper here to discuss the most convenient form for standard measures intended for public use, as the construction of such shall be the result of the present investigation.

Divided scales, as more generally in use in England, are very convenient for scientific purposes, but require more artistical skill in their construction; and the work of comparison, or adjustment, of any measure upon them, is of a more scientific character, than may usually be claimed from many persons, whose duty such adjustments may be, in common public use.

It is, therefore, proper to make choice for the practical use of such an arrangement as will give the required accuracy, equally as well as the scale, by more mechanical means, and which at the same time will shelter itself from deterioration, or detect it if occurred.

To this purpose, the French manner, in which the standards of toises were frequently made, is, in all respects, best adapted.

The standard consists in a measure cut to length, and its matrix, with sufficient strength of back to each of them, thus:



The standard length unit being *a b*, the lower part will furnish this length cut off, or what is called in French "à bout," projecting from its back about two-thirds of an inch, or more. The upper part presents a long notch, exactly fitting over it, and thence sheltering it, by lying over it, and close, so as to contain exactly the same length between the projections; it is proper not to let this come up entirely in the corner of the standard's cut, that some space may be left at the two ends, between the two pieces, to separate them gently, and gradually, by the insertion of some wedging tool, without laying any strain or force to the standard itself, or its matrix.

The thickness of the bars must never be less than half an inch, and the breadth of the two together should be rather more than three inches.

It is evident that the line of contact of the two measures is well observable by a microscope, in the same manner as a divided scale, and that, therefore, for the unit length, the arrangement serves equally like a scale; to trace or adjust measures from it, without the aid of microscopic arrangements, it is evident that either a measure cut to length can be fitted into the matrix, or a matrix, to be used for other standarding, be fitted over the length measure, with equal ease. It is possible to make this fitting by the touch to a very great accuracy; when the metals are of the same kind, and of equal temperature; and with precautions, as all such works require, I have, by my own experience, found the same accuracy attainable as by any other method; it is necessary in all this that the parts joining must be worked to a very nice perpendicular, and to full contact over their whole length and breadth.

UPON THE COMPARISON OF WEIGHTS.

75. In all applications of mathematics to subjects of natural philosophy, it is always necessary to determine the operation to be made, or the phenomenon to be observed, by a distinct definition, equally as well as in theoretical mathematics.

Having a number of operations of weighing to make, and to select the best means within my reach, I defined weighing "*to produce the same mechanical momentum by means of different masses.*" This definition is general, and extends the field of the means to select wider than only the solid lever, habitually applied to that aim, admitting evidently all the principles and means of the equilibrium of liquids, and even of elastic fluids, for cases when they might be appropriated to the peculiar nature of the experiments.

76. The solid lever, in its habitual form, requires very accurate and delicate workmanship, if it shall be very sensible; it has friction, causing a resistance proportional to the weight, that tends, of course, to its own destruction, in proportion to the masses to be weighed, and the delicacy of the work required for the accuracy aimed at. The strength must be, at the same time, sufficient for the double of the weight to be weighed, on account of the necessary counterpoise; the very nice weighing is in general an operation of more delicacy, and minuteness, than might be thought at first sight.

77. A solid body, immersed in a liquid, will displace a quantity of the liquid equal in weight to its own weight, whether it be entirely or only partially immersed in the liquid, and the liquid forms the counterpoise to the weight and the apparatus together; thence, two solids, displacing the same weight of liquid, will have the same weight, all physical influences upon the experiment being the same. These influences are, therefore, here, like in any other philosophical experiment, to be ascertained, and their laws of action to be determined.

The state of equilibrium of fluids is affected by the temperature, the barometric, and even the hygrometric, state of the atmosphere. Thence, in making use of hydrostatic principles *to produce equilibrium*, that is, weighing, the thermometer and the barometer must be observed, simultaneously with the experiments; and to render different weighings comparable, they must be reduced to what they would present under exactly equal circumstances and influences.

78. The aim of the present comparison—to determine weights of different magnitude, and also the contents of capacity measures, by the weight of distilled water, that they may hold, which for some is considerable, both exceeding, in most instances, the reach of the accurate balances habitually made and employed, the balances upon the principle of the hydrometer are evidently more appropriated to the case, for the reasons already stated in my report. The different dimensions in which they were constructed, and their capacity of weighing, degree of sensibility, their weight, and the dimensions of their parts, are all brought in a table, (§ 127,) for easier inspection. It is proper to give here a full description of them, with their variety, to adapt them to their different purposes.

Description of the Balance.

79. An ellipsoidic glass, or metal, bulb, *a, b, a, b*, fig. 6, 7, and 15, forms the principal part of the apparatus; at the one end of the larger axis is fixed

a metal mounting, in form of a cap, which shuts it up hermetically. This mounting bears one, or three, perpendicular stems; their middle part is a small cylinder; they have square parts below, to afford a hold for screwing them in the cap mounting of the bulb, and the same above, to give rest to the upper frame of the mounting, through which their prolongation passes; they hold fast to this frame by means of square mothers, screwing the frame and the bulb together.

80. Glass is the best material for the bulbs, on account of its smoothness, and the consequent entire freedom of friction, when regularly blown; by its rigidity, it yields less, or not at all, to the pressure of the fluid; it applies equally to mercury, water, and other liquids; but the fastening of the mounting requires a good cement. The size of these bulbs must of course be appropriated to the capacity of weighing, because the reductions of the weights from one temperature to the other, when there is any difference between two weighings, as is more generally the case, applies in full to the weight determined, and is proportional to the whole mass; the less, therefore, this weight is below the whole mass, the less the result suffers by this over correction, in case any error or uncertainty should rest upon the principle of it, or upon the temperature, which latter is affected by so many accidental circumstauces. I had also a copper bulb made, and one of sheet tin, with which experiments upon the expansion of water were made, but their use rather was to determine the relative expansion of these metals and glass, with a view to determine the influence of the expansion of the capacity measures made of these different materials, that are commonly used indiscriminately; the pliability of the thin sheet of metal made three stems here necessary, they could of course not be immersed in the mercury.

81. For the mercury balances, of which the larger went in weight near 226 lbs., the glass bulbs must have considerable strength; they require very good glass, which no window glass factory can afford. The glass house of Brooklyn, on Long Island, opposite New York, furnished all the glasses, bulbs, and large jars, used in the present work, of a very satisfactory quality and workmanship.

82. It would be very desirable, if possible, to have the bulb entirely free of air and moisture, but I had no convenient arrangement for this, and the exhaustion even leaves easily dampness behind, particularly in a climate within the influence of the sea atmosphere; this dampness will show itself by a light precipitation in the upper part of the bulb, when this is left to float somewhat out of the water, so that the increase of the temperature of the water vapors within occasions their distillation, which, being cooled by the atmosphere, precipitates to the part reaching above.

To avoid this as much as possible, the bulbs were heated over a coal fire, when their caps were cemented upon, which served at the same time as a partial exhausting and drying, and the means of making the cement hold well to the glass; when it was not considered dry enough, a small hole was made in the top mounting, and the bulbs heated, the hole being stopped by a brass screw when found proper. The copper bulb was buried into sand, heated as much as could be, without melting the soldering; and in this state, when no more air showed itself, the hole made to let the air escape was soldered up again while in this heated state.

Ultimately these circumstances may be considered as without influence in the weighing, there being no absolute quantities, but only relative, or differences of weights to be determined; and we may suppose the weight of air enclosed as the same, whether the dampness it contains is in a state of invisible dissolution, or in the form of visible vapors, provided the effect of all external influences, other than the temperature, (which cannot be excluded,) be avoided.

83. The caps of the bulbs must of course have a solid hold of them; they were made in the following manner for the glass bulbs: A cap, *a, a,* fig. 8 and 9, of steel for the larger, and of brass for the smaller, bulbs, is adapted to the outer form of the bulb, having the upper plate even and thick enough to give good hold to the screws of the perpendicular stems,; it rests upon the rim of the opening of the bulb, which is ground flat, for the purpose of close adjustment. In the middle of this plate is a square hole, fitting to the square stem, that reaches through it, from the middle part of the mounting within the bulb, *b, b,* fig. 8; this is of brass, adapted to the inner shape of the glass bulb, and is hollowed out from below, to make it as light as proper strength will permit, so that it presents in that part the form of an inverted basin. This part is made of three pieces, divided in the direction of three radii, as seen in the central part in fig. 9, and presented by the vertical partition line, in fig. 8, at *d;* the three pieces united present the square form fitting in the central square hole of the steel piece above: the upper part above this has a screw, by which, with the square mother above the steel plate, the two pieces are screwed together.

The fitting of the two pieces is such, that while the steel cap fits to the glass from outside, and the brass piece from within, they admit yet about 0,02 of an inch for the cement to come between them.

84. It may not be amiss, though perhaps rather much entering into details, to state particulars of the means of placing these caps. For the inner brass pieces, there are, first, three brass pieces prepared, fitting together by three radii, so as the pieces shall be afterwards; these pieces are then soft soldered together, turned off, and worked to their proper shape; the screw part above is left about one inch too long, tapered off in form of a sugar loaf, upon which already the screw threads begin; the pieces are then again unsoldered. To cement these pieces to the bulbs, the bulb is hung, with the opening downwards, over a coal fire, with the three parts of the inner pieces within, and held from without by threads, to enable to guide them; the steel cap is made warm also; when all is as hot as can be, without hindering its being worked, the warm cement is put in the mouth part of the bulb, the three brass pieces pulled to, and placed properly, the threads passing through the square hole of the steel cap; this is put up to its place, and fitted over the square formed by the union of the three inner pieces and the mother, which is also already passed over the threads; it is now screwed fast, to such tightness as will leave the cement to fill all the inequalities that may be between the parts that must join, without exercising any unequal or too strong pressure upon the glass; thus suffered to cool down again, the cap will be well secured, without any strain upon the glass, which might occasion it to spring in the use.

85. As, by the principle of the apparatus, the centre of the figure of the bulb, and the centre of gravity of the whole mass, must be in the same perpendicular, the parts uniting the stems and the bulb must present sufficient resistance to the occasional lateral pressures; when the bulb has but one stem, the base upon which this action takes place is only the diameter of the stem; this dares, therefore, be trusted only to smaller weights, as I had it, for instance, in bulb No. 4. Three stems present the base of the triangle, which

they form as what might be called play room for this resistance, and affords a kind of angular lever action to each stem, for the direction of the perpendicular line; it is, therefore, best adapted to any balance for heavier weights, and the three stems may be of so small a diameter, as to displace less water than a single thick stem would. As it is this that gives the measure of the sensibility of the balance, without regard to its weight, the smallness of these stems is desirable.

These steel stems must be well hardened, and placed well perpendicular, and parallel; for the water it is proper to blue the steel, because then a light cut, made by the chisel, upon the turning lathe, or by the sharp edge of a file, will show, as well as possible, a bright stroke; these strokes are made about in the middle of the stems, and determine the points of immersion, in all the weighings, for once and all.

But for the immersion in mercury, the galvanic effect of it upon the steel occasions a constant oxydation, which must be prevented by insulation, that is easily obtained by covering the whole steel mounting with a varnish of black sealing wax, dissolved in alcohol; the strokes for the coincidence of immersion are then made upon them by white paint, or by red sealing wax varnish.

Upon this oxidation first showing itself, with the naked steel stems, and my stating it to Dr. Ellet in New York, who came to see the preparation of my arrangements, he immediately suggested the idea that there was likely a pretty strong galvanic action in the case, which of course indicated to me immediately the above mean of preventing it, that has been fully successful.

86. The top frame, to which the bulb is adjusted by means of the one or three stems that join them together, consists of a piece with three radii, fig. 6, 7, and 15, *c*, *c*, *c*, uniting in one central piece, which part I made first circular, presenting near its circumference the places for the stems, against which they rest by a plate from below, and the upper flat part of the radii above, as seen in fig. 8.

A still lighter form of this central part, and of rather more strength, I applied to some water bulbs, mounted here in the arsenal of the United States; it is shown in fig. 10 and 11. The whole frame being composed of three horizontal radii, having the edges perpendicular, and fastened upon a horizontal flat piece, upon which they stand edge-bared, as usually termed, as upon a plate of brass covering the lower triangle; these radii were made passing each other alternately, as tangents to a small central circle, forming a small triangle around the centre; the three holds thus presented uniting each time two bars, hold very strong against each other, and allow to make the whole of thin hammered brass, favoring both lightness and solidity, which in this apparatus it is necessary to unite. In the corners of the meeting of the three radii, were placed three tubes, that receive the upper parts of the three vertical stems of the bulb; and, if only one stem was applied, this was screwed in a triangular central piece, fitted within the crossing of the radii. The outer end of the radii presents perpendicular holes or tubes, through which pass the three vertical steel rods, *e*, *e*, *e*, intended to unite this upper frame with the lower, that shall receive the weights.

For a mercury balance, intended to weigh to fifty and some pounds, these frames are made of cast iron, the others were of brass, each appropriated to its special purpose, and applying in several instances to several bulbs. The length of the radii of these frames is so calculated, that they outreach the glass jar, or the buckets, (as was the case for the largest mercury balance,) sufficiently to allow full free play, but still so, that, in case of a side motion, the perpendicular rods would touch the glass outside, before the bulb touched inside; by this, the adhesion of the bulb with the jar was avoided.

87. The three round steel rods, *e*, *e*, *e*, fig. 6, 7, and 15, descend perpendicularly down from the end of the radii of the frame, and are held to it by screw mothers from above; they are of sufficient length to bring another three armed frame, similar to the upper one, to a proper depth under the vessel, holding the liquid, and the stand supporting it, to receive easily the weights, or other objects intended to be weighed, give proper room to the observer, and bring the centre of gravity between the bulb and the weight to a proper depth for stability. Mothers from below hold again up the lower corresponding frame, *d*, *d*, upon which a plate of sheet tin, or sheet iron, is laid, that receives the weights, so distributed as to produce exact perpendicularity, with the best stability; this is favored, as shown in the figures, by placing three equal and principal weights towards the ends of the radii of the frame, near the perpendicular rods, where they resist, of course, the most to any upsetting, by overweights on the other side; for the same reason, it is necessary to place them simultaneously, and hold the upper frame in hand, well supported, during the time they are placed; after which, the further laying up of the weights can go from the centre with more ease.

The *perpendicular rods must be of round steel*, because it is desirable that they should have the least weight possible, and still they must be able to guide the perpendicularity of the bulb, and whole apparatus, by means of the weight below, which requires them to have considerable rigidity and elasticity. With a view to lightness, I had used for the small water bulb with one stem, No. 4, only thin brass wire; this proved not to afford the essential quality just stated. I made, therefore, three very light channelled pieces of straight pine wood, in which the wires were embedded, fastened to it by very light twists of copper wire; the whole was then strongly varnished, to fill up the interstices, and prevent moisture; thus it served extremely well, and was lighter, with the same rigidity and elasticity, than even steel wire would have been.

88. The glass jar, holding the water, is placed upon a piece of board of circular form, of the proper size, fig. 6 and 15, *g*, *g*, adapted to its diameter; this projects, with a support under it, from the upright part of a stand, which gets its bearing from the corresponding lower part, projecting parallel to it under the jar, as is easily seen by the figures. For more security, I always tied the top of the upright part of this stand to the wall behind, by means of some proper arrangement. The same arrangement on a smaller scale, but with proper strength, was made for the small mercury balance, fig. 15.

The size of the vessels in each case is appropriated to that of the bulb, so as to give it sufficient play in it, and not to put it under direct influence of the outside temperature, communicated to the jar.

For the large mercury balance, some peculiarities of arrangement were necessary, which will be described in their place.

89. Each of these balances has evidently its limit of weighing, as above stated; it is proper, for greater accuracy, to use such a one as will give the least dead weight, that is, weight which remains the same with and without the body to be weighed, to have least superfluous correction for the influence of temperature. This temperature, and also the stand of the barometer, are to be observed every time immediately, when the equilibrium is established; the water balances have two thermometers in a nearly horizontal position,

h, h, the one at the level of the upper part of the bulb, the other about that of the lower part; these can be observed through the glass. In the mercury, this part was not so convenient, but I had also, as much as I could, two thermometers at an unequal depth.

Manner of weighing with this Apparatus.

90. The principle of the apparatus itself indicates, that the operation to be performed is to procure the immersion of the bulb to a certain determined and constant point, indicated by the fixed marks upon the vertical stems, between the cap of the bulb and the upper frame, by means of the weights or masses, known or unknown, that are placed upon the lower frame. These stems must be perpendicular in the water, when there are three stems, the marks being made at exactly equal distance from the upper frame; the bulb being well adjusted to this frame, they will appear and disappear simultaneously.

Looking at the stems through the water, from the outside of the glass jar, the part immersed in the water will be seen directly, and also by reflection from under the surface of the water; viewing them under an angle of about 12° to 15°, with the surface, the direct and the reflected image will appear in the same straight line, when the stem is in a perpendicular position, therefore at right angle upon the surface of the water; when that is not the case, it is necessary to shift the weights, so as to procure this perpendicularity, when viewed from two sides at right angles with one another.

The same reflection takes, of course, also, place for the marks made upon these stems; they will appear double when under the surface of the water, and disappear entirely when above it. The point where this mark will appear in one, exactly presenting its actual size, is evidently that where its middle exactly coincides with the surface of the water. It is, therefore, by the observation of these direct and reflected images that the perpendicularity, and the coincidence must be observed; above the water, this can be done but imperfectly, because of the capillary effect of the stems, which occasions them to be surrounded by the water, according to a curve appropriated to this effect.

91. This adhesion is of no influence otherwise, because it is the same in every weighing, and acts therefore as a dead weight, like any other part of the apparatus; this will generally be the case, as the stems will always be wet, which is the condition of this equality of effect for equal stems, for the case, as in higher temperatures sometimes, that the part of the stem, long out of the water, should be dry, I had always a camel hair brush at hand, with which I wetted the stems, and often also the whole of the cap mounting of the bulb, which is apt in the same case to take air bubbles around it, that must be taken off.

92. The vessel, conveying the apparatus, made in New York, (in the fall 1830,) having shipwrecked on the eastern shore of Virginia, the large jar intended for the largest water bulb was broken, in saving the objects from the wreck; another one could not be procured, but from the same factory of Brooklyn, which from here was not accessible in the winter. Wishing to make use of the mahogany bucket, that had been made to use the same glass bulb in mercury, and had been saved, I supplied the visibility of the reflection, which could not be seen through the bucket, by the following arrangement:

The visual rays from the stem, and its mark, being supposed to meet the eye at *h*, fig. 12, from *b*, and by the reflection from *c*, I placed a mirror in the bucket, in an inclined position, the section of which being *f*, *g*, the visual rays are directed up to the point *p*, so that the observation could be made, and the coincidence at *a* be observed, with the greatest ease and accuracy; indeed, it appeared to present a full picture, rather more advantageous than the direct vision through the glass, which is apt to suffer distortion from the inequalities of the glass vessel, necessitating often a shifting of the eye.

93. The great influence of the change of temperature upon these observations renders it desirable to proceed in such a manner, as to avoid the errors that might result from any uncertainty in the law of its action, by reducing all reductions, arising from that circumstance, to the smallest possible. This dictated to me the following method:

I first produced equilibrium, at the coincidence of the marks of the stems, entirely by known weights. To this, the indications of the upper and lower thermometers were immediately red; for, when the temperature undergoes a change, which is generally progressive, this coincidence of equilibrium and temperature is immediately changed, and the influence of one-tenth of a degree Fahr. is already more than it is possible to fail in the weight producing the equilibrium. The barometer is then also read off; and, after this, the weights were taken down, and each individual weight that had been used noted in the journal, leaving the calculation of their amount for the future, so much more, as all the weights which I had were differing more or less from their nominal value; and I had to use for any weight that amount which I had determined for them in Troughton's grain weights, these being the only English weights that I had agreeing within themselves.

These known weights were then removed as much as needed to admit the mass of unknown weight, which was now placed upon the sheet serving as basin, and the whole operation, to obtain equilibrium, was now repeated, placing the well known or ascertained weights upon, for all that was needed to produce a second equilibrium; when obtained, the thermometer, barometer, and weights, were read off, and noted down, as has been just stated for the first equilibrium.

Then the mass of unknown weight was removed, the identical weights used in the first equilibrium replaced, and a third equilibrium produced, which would at most only vary in the grain weights, according to the effect of the change of temperature. Equilibrium being obtained, the details of it were again written down, as in the two preceding observations.

94. It will at once strike that it is the weights that were taken off, that determine the weight of the unknown mass; that, therefore, if a choice should be between the different accuracy of determination of the weights, the best determined must be those removed, as the others that are the same in the second as in the first and third equilibrium, act like mere dead weights.

I used all only brass weights, in order that, if any reduction for buoyancy to the vacuum, or otherwise, should be desired, this would refer always to the same metal.

95. In respect to the reductions for effect of temperature, it will be observed, that the temperature changing somewhat regularly, that of the second equilibrium will, by a regular steady process in the operation, fall very near in the middle between that of the first and third equilibrium. Taking, therefore, a mean of the weights of the two, it will also represent that weight which would make equilibrium to the unknown mass, at a temperature near

the second equilibrium; thereby the uncertainty of the principles of reduction will have little or no influence. For the small differences between these means, it was allowed to take the variation proportional to that given by the first and last equilibrium. I speak so decidedly, however, only for such a small change of temperature, as will generally be the case, within which the variation of the expansion of the water may be considered uniform, which, in many cases, cannot be extended to a whole degree; in all other cases, the reduction must be made according to the indication of the law ascertained for each point of temperature.

96. These circumstances evidently indicate the point of temperature at which the bulb takes the greatest quantity of weight for the equilibrium, as the most favorable to accurate weighing, exactly in a similar manner as the observation of the meridional altitude of a celestial body is the most favorable for the determination of the geographical latitude, for in both cases the curve of the variations is most parallel with the result to be determined.

In the higher degrees of temperature, and in those approaching 32° Fahr., this influence is great, and varying very rapidly; therefore, also these temperatures are far less advantageous to accuracy in any determination depending upon water.

97. The accurate ascertaining of the law of expansion of water by the temperature is in general a subject of interest in a scientific point of view. It is, for instance, singular, that hitherto it has always been omitted to precise this in stating the specific gravity of different materials, taking the water as unit, by stating the temperature at which this is supposed taken. I do not know that the circumstance has been even attended to in making experiments; still it is evidently of great influence.

These balances are eminently qualified to ascertain this interesting fact, it was necessary for me to have these experiments originally, from determinations of my own, purposely made, and not merely an effect calculated, by circuitous route from determinations of others, because not only the reduction of the weighings at different temperatures to the same required it, but also the capacity measures, to be determined by the weight of distilled water, at a certain temperature, absolutely required it, as it forms there the principal element of determination and accuracy. I instituted, therefore, regular and extensive series of experiments upon this subject, by keeping all my water balances constantly loaded, during many months, and observing daily, and many times a day, according as circumstances favored it, the weight they bore to equilibrium, under the existing temperature, and stand of the barometer, the thermometers being placed as stated for the weighing, and each observation being a full weighing, with all determined known weights in the manner as above described; I used constantly distilled water, which was frequently renewed. They form a particular part of my work, of which a special account will be rendered; it is a preparatory element for the construction of standards.

I may here only quote the general results; they show evidently that the material of the vessel of which the standard of any capacity measure is made, is a necessary determination in the statement and settlement of it. For this, these experiments were entirely direct to the point in their result, for it is evidently the same whether the water is contained in the vessel, or is excluded by it; the results apply, therefore, directly. The temperature at which vessels of different materials will hold the greatest weight of water, is different for each metal, or other material, expansible by heat; for glass, it is

41°,6; for copper, 44°,6, &c., while, absolutely taken, the maximum density of water is at 39°,8; though I have seen different determinations, which I suspect to be affected by the effects of the temperature upon the vessels that may have been used in the experiment.

It was besides, also, for the ease and the accuracy of my weighing the most advantageous mode of determining the influence of temperature, for the reduction of the weights, to have this effect determined directly for each of my balances individually; every doubt upon the element of the reductions was thereby more removed, than by calculations from other sources, as these results gave at once the sum of all the influences in the case.

Peculiarity of the Mercury Balance.

98. The balances immersed in mercury do, of course, not allow the same mode of observing the coincidence of the mark on the stems with the surface, as the water; the stems occasion a cavity around them, presenting about the inversion of the curve of capillarity; no direct observation can be made there; the observation of the coincidence of the lines drawn round the stems, with certain marks dependant on the surface of the mercury, must be obtained by means of some light body swimming upon its surface. The following were my arrangements to that purpose:

For the smaller mercury balance, I turned an ivory ring, surrounding the three stems very close, but yet so loose as to always lie upon the mercury, by its own weight, presenting, as seen in fig. 13, a rounded section to the mercury below, and an edge to the upper part, parallel to the mercury; upon this, a very thin ivory disk was laid, cut in, to admit the free passage of the stems of the bulb, with the surface thus presented, or rather the line presented by the meeting of the ring and this disk, the marks of the stems were brought in coincidence to designate the point of equilibrium.

On account of the great pressure which the stems of the large mercury balance had to bear, they were made short; they did, therefore, not easily admit such an ivory ring. I supplied the mark of coincidence, by placing in the middle of the frame, and through a hole made for it, a glass tube, (see *n*, fig. 14,) around which a thread of black silk was fastened; within this, moved, perfectly free, a thin ivory stem, at the lower end of which is an ivory disk, flat at the bottom, which stands upon the mercury; at the proper place of the upper part of it, a black stroke is made around it; the coincidence of it with the black silk thread around the glass tube is very nicely observable, and furnishes the point for the observation of the equilibrium.

99. The smaller mercury balance is floated in a strong glass jar, supported by a stand of proportional size, exactly similar to that for the large water balance. On account of its smallness, it presents a compact and very solid arrangement, easily manageable, (see fig. 15.) However, the laying on and taking off of weights, to the amount of upwards of fifty pounds, with a glass bulb floating in glass again, under the pressure of the heavy weight of mercury, rendered some precautions against accidents very necessary. To secure the bulb during the changing of weights, there was an iron hook put to the centre of the lower frame; to the upright back of the stand, a piece of plank, *l*, *l*, was tied fast, stemming exactly between the upper and the lower horizontal parts of the stand, with a square hole at *m*, so placed, that, by a lever, *m*, *m*, placed in it, that had a rope noose taking in this hook, the bulb

was kept immersed, and under the guide of the lever, during the changing of the weights. The thermometer was immersed in the mercury, by attaching it to a piece of wood that hung over the side of the jar, having a weight, *g*, fixed to it, to press the thermometer down in the mercury.

The rest of the arrangement was exactly similar to the water balances.

It sometimes occurred, that some object to be weighed could not be placed upon the basin below, between the vertical steel rods, as, for instance, gallon and peck measure, and some of the glass bulbs of the balances, that had to be weighed; these were placed upon the top, the bulbs in an inverted position, their upper frames being tied to the upper frame of this balance, as indicated by the dotted figure upon the top. This, however, required evidently peculiar care, and the condition that this weight be not so large as to destroy the stability of the whole, that is, that the centre of gravity was not brought too high by it.

100. The largest mercury balance was principally intended for the weighing of the larger capacity measures, and also for the 56 lbs. weights, to which the smaller one did not fully reach, as in general glass bulbs cannot be obtained exactly of a given size, and the excess of a size over the weight intended to weigh by these balances is not advantageous, these accidentally fell a few pounds short of their intended weight, including the weight of the apparatus.

A glass jar, capable to hold with safety the great weight of mercury required for it, could not be expected obtainable; therefore, a wooden bucket was made for the purpose, thus:

A solid block of well seasoned mahogany, (as this is obtained the driest and longest seasoned in this country,) *x*, *x*, *y*, *y*, fig. 7, was turned to the proper size outside, and so tapering as to admit good hold to the iron hooping; when in that state, and well dried before the fire, iron hoops were heated on upon it. Then it was put in the turning lathe again, to be hollowed out in the shape and size adapted to the bulb intended to be floated in it, so as to leave all around about one and a half or two inches vacant, that the bulb should not touch the side; the lower part is, of course, equally rounded to the same form, which spared so much weight of mercury, at the same time that it increased the strength, and the impediment to the filtering of the mercury through the wood, in the direction of its fibres. When thus turned out, it was well dried, and soaked, in and out, with boiled linseed oil, before the fire. Lastly, glaziers' putty, thinned with the same oil, was rubbed in, inside and outside, as far up as the pores of the wood presented themselves perpendicularly, and pounded with an iron pestle inside and outside, to fill well the pores, and crush the wood in over the putty. Lastly, it was well dried before a fire.

101. This bucket was placed upon a stout, four-legged stand, of sufficient elevation to admit under it all the arrangements and weights necessary for the largest bushel measure, and the top of the bucket was levelled by a spirit level, so that the arms of the upper frame of the balance mounting would always set up equally when loaded down.

The three inch plank forming the top of the stand has nearly the breadth of the bucket; the one of the perpendicular steel rods passes on the one side of it, the two others on the other side; and there are notches cut in the stand at the places where they come, to give them more freedom.

102. The heavy mass put in a floating equilibrium, under the constant pressure of so considerable a mass of mercury, acquires a very great momen-

tum, by the slightest force applied to it; it is, therefore, necessary to be able to arrest it entirely, at any notable change of weight, besides proceeding with the utmost caution in the proper distribution of the weights, and making no great changes at once.

Three iron hooks, *m*, *m*, fig, 16, were made, exactly of the proper length to reach from above the arms of the upper frame till under the plank, the hooks above and below being so directed, that each fitted its peculiar place, by the angle they made with each other, these projecting arms being always perpendicular to the bar itself; their use gave perfect security. When the balance was intended to set in operation, the hooks were removed, and the upper frame held under the direction of my assistant, the balance being at first before always fully laden down; the weights were gradually taken off, and shifted, according to what was found needed, to make all three radii of the upper frame set up equally, so that, when, gradually, weight enough was taken off to float the bulb, it hung free in an exact perpendicular position, and the nicer final adjustments, to the coincidence of the mark, on the swimmer, and on the glass tube, were then made.

103. The general arrangement of the mounting of this balance was the same as that of the largest water balance; it was the same as had been used to the first bulb, which broke in the attempt of using it in mercury, except that a new lower three-armed iron frame was made, to obtain more strength without increasing the weight, as it had to receive heavier weights. Upon this a triangular sheet iron plate was placed to receive the complementary smaller weights; the triangular shape of this did not come in the way in any work about the bushel below. But the size of the large metal bushels required a widening of the lower parts, at the same time that, for the proper filling of it under the glass cover, it was necessary to place it exactly level. The following arrangement answered these purposes.

Three iron pieces, *g*, *g*, of sixteen inches long, were made, having at the upper end, at right angle, projecting arms, *r*, *r*, of about three and a half inches long, the end of which presented at *k* a cylindrical widening, with a hole in the perpendicular direction, just to admit the steel rod of the upper part to pass through; at the lower ends, other pieces projected about two inches, with stronger cylindrical parts, through which passed an iron screw, having its milled head downwards. Upon these three screws rested again an iron frame of three radii, that had its ends formed in an elliptic larger resting place, for the rim of the largest metal bushels, and below a deepening, to receive the screw just mentioned, so that it could not slip out. In the middle of this frame was again an iron hook, to which heavy weights were hung.

This arrangement just admitted the largest bushel, with sufficient space for the overreaching of the ground glass cover, with which the bushels were shut up in the filling, with space enough above for the necessary manipulation. At the lower parts of these, lengthening pieces were also hung, by brass wire hooks, certain of the heaviest of the dead weights occurring in a weighing.

Smaller capacity measures, as half bushels, &c., were, of course, easily adapted to a central position upon the lowest frame, and the low situation of the heavy weights gave the whole apparatus considerable steadiness in its suspension.

Two thermometers were again put in the bucket, by means of pieces of wood, with weights fastened to them outside, as in *q*, *q*.

104. These arrangements were not the first that I had made; several were tried, that failed from accidental weakness of parts, leaking of the mercury bucket, &c. In one of these, a circumstance occurred, worth mentioning, with the details that accompanied it, on account of its novelty.

I had prepared, in the largest mercury apparatus, one of the glass bulbs, with all arrangements, ready to weigh the large capacity measures, filled with water, when other works, and an absence of some time, occasioned me to leave it for upwards of a month immersed in the mercury, fastened down by a wooden frame. During my absence, a loud report was heard, that appeared to proceed from this apparatus, so that it was suspected the bulb had broken; but no diminution appearing in the mercury, no further attention was paid to this. When, on my return, we were trying to put the apparatus in activity, the bulb suddenly fell upon one side, so that we had to fasten it down again with great trouble, and dismount all, when it showed itself, that one of the vertical stems had just broken in a place where there was a flaw in the steel, and another showed an old break, with the *steel amalgamated upon the two parts of the break of the stem.* This showed, therefore, that the report heard during my absence had proceeded from this breaking of the stem under the mercury, which having no contact with the air, the steel was always acted upon by the mercury at the fresh break. This being the first instance, to my knowledge, of *steel being amalgamated,* it is proper here to record the fact, the other stem, that broke only then, though also under mercury, came soon after to the air, and suffered no amalgamation.

I must yet state the necessary precaution in placing the bulb in the bucket. This operation must be done so: The bulb must be hung in the bucket when the mercury in it is no more than to its bottom; the weight must be added always corresponding to the mercury poured in, so as to keep it always equally pressed in it, and somewhat overladen, always minding the proper distribution of it, to maintain the due verticality, at last the hooks being put on to fill up entirely. For use, the overweights are then taken off gradually, and proceeded as described in the weighing. When the bulb is to be taken out, the mercury must be drawn off by a hole in the side of the bucket, and the weight gradually taken off, gradually to relieve the apparatus until it can be lifted out free. Without these precautions, the operation is more likely to break the bulb than to succeed.

Description of Troughton's Lever Balance.

105. It has been already stated, that when I was in Europe for the purpose of procuring instruments for the survey of the coast, I considered it proper to incur the small additional expense to procure also accurate English and French weights, and litres modèles. Thus I procured also a balance, constructed by Troughton with great care and accuracy, and in general principle similar to that employed by Sir George Shuckburgh in his comparisons; the weights accompanying it are English troy grain weights, from 10,000 grains to 0,01 of the grain; they proved the only consistent small weights upon which I could ground my comparison, the collection of the State Department being neither detailed enough in this part, nor consistent enough within itself, thence it proved the only means that enabled me to proceed immediately in this part of my work. The procuring of weights from London would have been very long and precarious.

The peculiarities of this balance, though simple, are not much known;

and, as they are very well appropriated, I think it will be proper here to give a full description of it.

106. The general appearance of this balance is represented by fig. 17. The beam is solid steel, blued, of one foot in length, one-quarter of an inch thick; its middle breadth, forming its height of beam, is a little over one inch, tapering out to half an inch at the ends; all edges and ends are rounded. The axis between its supporting knife edge part is 1,4 inch; this is, therefore, also the distance of the steel palettes, upon which it oscillates.

The form of the parts *a*, *a*, fig. 18 and 19, of the axis, which rests upon the palettes *b*, *b*, is not a simple knife edge; a part, of about one-tenth of an inch, is formed by the edge left between the sides of two cones, intersecting one another, forming a concave knife edge, much better supported than a straight one, therefore better and more lasting. The palettes are rounded off on the top edge, so as to present the form of a half cylinder, of a diameter somewhat smaller than the excavation presented by the knife edge. By this means the oscillations take place, from a section of a larger cylinder, upon the curved surface of a smaller one, thence with very little contact, and of greatest sensibility, and the strength of these parts is increased.

The axis and the palettes are both of well hardened steel, highly polished; the axis rests fully free, without any lateral friction, or stop, therefore, in the use, the beam must be properly placed, so that the knife edge is perpendicular to the axes of the cylinders of the palettes, and all lateral motions, in the changing of the weights, must be avoided.

The palettes are screwed fast to parallel perpendicular plates, cut out at the top in form of Y, wide enough to occasion no touching of the axis; these are fast upon a brass column of proper height, screwing in a ring, that is fastened upon the box, containing the weights, but which I screwed, for my use, upon a square block sufficiently large to admit the placing of a spirit level upon it, outside of the ring, by which the balance is properly placed.

When the balance is not in use, the beam is simply taken off, to prevent useless wear.

107. Upon the circular part of the axis, within the above described knife edges, is, on the front side, a brass ring, *c*, holding by friction only; this bears on the top a perpendicular tubular part, in which revolves a small cylinder, *t*; to the top knob of this is fixed a very light brass wire, reaching out horizontally about one and a half inch, that may be placed in any direction. By the horizontal revolution of this wire upon its axis, its very light weight is thrown on either side, or, when placed in the middle, neutralized, by which means the empty beam is adjusted to the nicest equilibrium, at the beginning of any weighing operation. Fig. 18 and 20, which are in full size, show this, as well as the other parts of the arrangements about the axis, in full.

A disk of ivory, of about 0,05 of an inch in diameter near the one end of the beam, presents a horizontal black line, to which the divisions of an ivory arc is presented, by an arm fitting by friction in an upright piece, *g*, fast upon the top plate of the column, to which, also, the palettes are fixed. The coincidence of the middle division of the arc with the line upon the ivory plate gives the observation of the equilibrium. In this coincidence, the balance, when laden with a kilogram in each basin, will be well sensible to about 0,01 of a grain.

108. The knife edge for the suspension of the basins at both ends are pieces of steel, fastened in the arm, and going fully through the thickness of

the beam. A small steel plate, with a hole through, that is rounded out, hangs over the knife edge part within the beam; this inner knife edge is formed in a similar manner as the central knife edge above described. The hole through the lower part of the small steel plate receives a thin brass hook, in form of the figure 8, open on one side, while to the other are tied three strings of Indian grass, the lower ends of which pass through three holes, in the thin brass basins, that receive the weights. These grass threads, which are commonly used for fishing lines, I have found the strongest, and far preferable to silk threads.

109. When the basins are laden, the balance is set free by an arrangement similar to that of Sir George Shuckburgh's balance; the elevation of the beam by the supports of the central axis, by means of a rakwork, is a very bad arrangement. The present consists in the following:

At rest each basin is supported by a small stand, *e*, *e*, the upper plate of which has a perpendicular tube under it, that slides in a corresponding tube fast to the stronger lower plate. A spiral steel wire spring, within these two tubes, presses the upper plate against the basin. Two arms of brass wire on opposite sides, passing through slits in the lower tube, and fast to the upper, present a hold for two fingers, by which the upper plate is lowered from the basin, by the compression of the spiral spring; this can be done much more gently than a rakwork acts, and the weight needed for the equilibrium is in some measure felt by the rapidity of leaving, and following, of of this motion by the basins; thus the balance is then left to its free motion, and in the operation of weighing.

110. The experiment of weighing with the lever balance, apparently simple, is by no means so when the greatest attainable accuracy is desired, on account of the many precautions needed in that case; evidently all draughts of air, and unequal temperature of the parts, are to be carefully avoided. I had, therefore, a glass case made for the above balance, entirely close on the sides and top, the front part, towards the observer, being an entire glass in a frame, that could be hooked to its place. I rejected doors; they are in the way when the case is open, and, in shutting, they occasion a motion of the air within the case, which I avoided by sliding the frame gently up to its place from below.

When I had made the most careful equilibrium, I tried it by shutting the balance up entirely, letting it come to rest, and ultimately observing through the glass. In making the equilibrium, the balance being, by preference, placed with the back towards the light, I held a quarto sheet of white paper between the balance and my face below the eyes, for the double purpose of sheltering the balance from the influence of my breath, and to reflect the light upon the reading of the divisions, as this mode furnishes the best light.

111. However good the balance may be, it is not allowed to weigh, by placing the object to be weighed in one basin, and the weights it represents in the other; the full error of the balance, if any, would be included. It is absolutely necessary to make what is called in French "double pesée," *double weighing*, namely, the object to be weighed must be placed in one basin, and in the other weights or masses, such as to produce perfect equilibrium, for which I always used the subdivided French kilograms; then the object to be weighed, in my case always a weight, that was to be compared, is removed, and equilibrium is again produced, by substituting for it all well known and determined weights; the amount of these is the weight of the body, or, in my case, of the weight compared. It is not proper to load the

balance with more weight than absolutely necessary; the sensibility of it is of course diminished, in proportion to the weight which presses the knife edge to its support, still also this has its limits, according to the power of the balance. A balance, well fitted for heavier weights, will become too lightly oscillatory, when not sufficiently laden to give it steadiness; and the observer will ultimately take an approximate esteemed equilibrium, perhaps not in its proper resting point, by accidental inequalities in the oscillations.

This double weighing is evidently intended to neutralize the balance; for if even unequal armed, the weights producing equal effects upon the same basin, and under exactly equal circumstances, will be equal, according to the very definition given of weighing at the first outset of this part of this paper; the only requisite remaining is the equal and delicate sensibility. For the same reason, it is not proper to lay complementary weight in the basin serving as counterpoise; this must remain entirely unaltered in the two corresponding weighings. In a series of comparisons, of weights nearly equal, I always established a counterpoise to the heaviest of them, and, for the lighter ones, the equilibrium was made by the addition of the necessary determined weights, including this variation always within comparatively small limits, to use the least compensating weights.

In these weighings, like in those with the water or mercury balances, I always wrote down the full details of all the weights engaged in an equilibrium, all reductions being made afterwards, in calculating out the results.

112. This balance being ready at hand, in good order, while my glass balances, upon the hydrometer principle, were not yet mended again from the shipwreck, and the proportional reductions for the temperature not yet determined by direct experiments, it has been used exclusively for the smaller weights, up to the kilogram, and two pound A. de P. weights.

In some instances, I have even applied to the weighing the principle of the binary combination, that I have used in the determination of the metres, "à bout;" so, for instance, for the Chinese weights of Mr. Adams, &c., where my principal aim was to determine the value of their unit, the tale. This evidently applies with full advantage to the weighing with the water balance, by its lessening proportionably the influence of the reduction for temperature.

Before any series of weighings, I always verified, or adjusted, the empty beam, by means of the small arm upon the top, described above, and then hung on the basins, placed weights and contre poises, thus considering the basins as dead weights in the equilibrium, and I generally verified this equilibrium again at the end.

Results of the Weighings.

113. The preceding descriptions of the balances, and of the methods made use of in their application to my work, give evidently a full account of the operations, to which it would be entirely without interest to add the details of the individual weighing of so many weights, that in fact were never intended to stand the test of such a minute scrutiny. The most essential weights, in fact, the only ones intended for such minute accuracy, were the troy pound of the United States' Mint, and the different kilograms; and it will be seen by the results given in my report, that these latter are very perfect. The small difference exhibited by the platinum kilogram, after reduction, may just as well be ascribed to the elements of the reduction for the

different buoyancy of the brass and platinum, as to any actual difference in the weights, as the note made upon that subject in the report clearly shows.

The accuracy of the subdivided kilograms, considering that they consist of twelve different pieces, is indeed very satisfactory, and the brass kilogram copy, of the same form as the original, may be considered as fully exact. What relates to the troy pound of the mint, is detailed in its proper place, in the report itself.*

The weights next in interest after these were the foreign weights, lent to me by the late President, John Q. Adams. If any more of them were on hand, duly authenticated, it would be of interest to enter into more minute discussions, as well as details, upon the individual results of their comparison, as would also be the case with the coins, if any other had been on hand, but those kindly lent to me by Baron Sacken, chargé d'affaires of Russia.

114. The preceding descriptions of the different balances that I have made use of, and the methods employed in their use, give evidently a full account of my operations in this part of my work. A few examples, exhibiting the details of a weighing with each of them, will be all that can be of any interest to add hereafter.

115. The great disparity between the grain weights of Mr. Troughton, the troy pound derived from him, which I had brought with me to this country already in 1805, and found again in exact coincidence with them; when compared with the United States' Mint troy pound, made with peculiar care by Mr. Kater himself, form in this comparison the most striking feature; this difference, repeatedly determined in presence of Dr. Moore, Director of the Mint, to be 2,41 grains, constitute, therefore, the element of reduction of all the weights from the grain weights of Troughton, that naturally were my standard for comparison, upon this Mint troy pound, which has been adopted as legal standard for the coinage by act of Congress of 19th May, 1828; this necessitated the double statement of all weights whatever, that appears in the statements additional to my report, and which exhibits, in a striking manner, the wavering of the English weights of the State Department collection, between these two weights, the more modern rather favoring the weights of Troughton, the old weights of New Hampshire, of the time of George I., alone supporting fully the new Exchequer weight, now legal standard of Great Britain.

After this, it is not to be wondered that a still greater, but, in general, similar, result should be exhibited by the coarse iron, or other weights, sent in by the custom-houses, which besides, on account of their great mass, could not be adjusted but upon common balances; and it will not be expected that a minute account shall here be given of what was never intended for so minute investigation.

116. But already Sir George Shuckburgh found in 1797, by weighing the standard troy pound of 1758, made by Mr. Harris, then chief assayer of the Mint, which is kept at the House of Commons, as follows:

		Grains of Troughton.
One troy pound of 1758 - - -	-	= 5763,745
One duplicate in a box marked B - -	-	= 5763,685
Mean	-	5763,715.
The two pound weight corresponding to the first	-	= 11527,84
The two pound weight corresponding to the second	-	= 11527,55.
Mean	-	= 11527,70.

These two pound weights would give single pounds as follows:

The first	-	= 5763,92
The second	-	= 5763,775.
Mean		5763,847

The mean adopted by Sir G. Shuckburgh - - = 5763,75
shows a difference still greater than I found, by - = 1,37.

Since the time that I handed into the Treasury Department my report, and the accompanying statements, the Journal of the Royal Institution of London, No. 4, 1831, has made known to us a similar result of an investigation made in Holland by Dr. Moll, of Utrecht.

The British troy pounds obtained from the mint, and certified by it to be 5760 grains, weighed with grain weights of a Mr. Robinson, gave as follows:

	Grains.
The one at the Mint of Utrecht - - -	= 5758,57
The other, in the possession of Dr. Moll - -	= 5758,40
Mean -	= 5758,485

An imperial troy pound weight of Bates gave - - = 5759,935
This giving an excess of the new British standard weights, which it is evident the grains of Robinson mean to represent, of 1,515, while the weights of Bates, who made the new standard weight under the direction of Captain Kater, gives only such a difference as may be attributed to want of proper minute accuracy, though this is better than the agreement between the two weights of the mint.

Of the collection of English weights in the State Department, which are all well certified, it will be observed, that the Tower troy nest agrees with the grain weights of Troughton so much, that, allowing duly for the general want of minute accuracy, which they all betray, they may be considered as intended for the same. The Mint of London being an appendage of the Tower, this Tower troy nest may be considered as referring to the Mint weights.

117. Here are, therefore, four testimonies, all independent of one another, and concurring in point of direction, or side of the error, that certify a difference in the English standards between the Exchequer, and, most likely, the Mint weight, which appears so much more astonishing, as the maker of the weight of 1758, that has served to establish the new British standard, was at the time the chief assayer of the Mint. They stand as follows:

By Sir George Shuckburgh, in 1797 - -	= 3,78
— Troughton, grain weights used by me -	= 2,41
— Dr. Moll's mint weight - - - -	= 1,515

Of the Tower troy nest here compared, only the 64 oz. and the 128 oz. came up to the new British standard; the others all differ from one to two grains, and the smaller weights cannot be considered with this view. None of all the English weights of the State Department have more than common sealers' accuracy, where the whole grain supplies the place of its hundredth part in scientific investigations.

118. It is proper to conclude from this, that the ratio of the British troy pound to the kilogram must vary according to the origin from which the British weights that has been compared, is derived. The various kilograms which I have compared, of different origin and different dates, gave such a coincidence, as *screens them from all accusations* of giving any cause to

difference, *provided they are made for standards*, and not for common commerce, having the legal "tolerance," as is the case with the nest of late President Adams, and fully explained by the report of the Minister of the interior of France, upon the demand of the British Commissioners of Weights and Measures.

Though I stated in my report the degree of coincidence between my result and that of a comparison made in France of an English troy standard, the results stated by Dr. Moll make it proper for me to place here all in one view of comparison:

	Kilogram in English grains.	Eng. troy pound in grammes.
My comparisons give in mint weight	= 15433,15902	373,2223
— ——— — in Trought. grains	= 15439,619	373,0661
The French Minister of the Interior	= 15432,719	373,233
Dr. Moll, Van Swinden's kilogram with Robinson's grains - - - - -	= 15432,265	373,244
Dr. Moll's pound from the British mint -	= 15437,035	373,1286
Weber, in Berlin, by platinum - -	= 15432,08222	373,2484

118. Among the notices communicated to me by Mr Tralles, on his return from the Committee of Weights and Measures of Paris, I find also the following:

"The troy pound brought to Paris by Mr. Van Swinden was found = 9266,1168 grains (French)."

This, reduced to the new French grammes, by the statement of the Almanac du Bureau des Longitudes of 1831, giving the kilogram = 18827,15 old French grains, makes this weight = 492,16802 grammes; and this, reduced to English grains by my determination of the kilogram, gives = 7595,706 grains of the mint weight.

Dr. Moll states, that the same weight of Mr. Van Swinden had been religiously preserved, and, carefully compared by him, gave of Mr. Robinson's grains = 7594,975; the difference from the above result, = 0,731, is most likely again owing to the difference between overweights, as referred to the new British troy pound, as he makes the kilogram in these same

grains - - - - - - - - = 15432,265,
My determination being - - - - - - = 15433,159,
Giving a difference in the same direction, of - - 0,894.

So we may be considered agreeing about within the limits of the difference of the English troy standards taken for guide, namely, he the weights of Robinson, and I the troy pound of the United States' Mint.

119. The Almanac du Bureau des Longitudes being the authority most generally resorted to for weight and measure values, it will be proper here to give in a tabular form, for comparison, its statements, together with mine, without any comment, which the above deductions evidently forbid.

	Indication of the almanac.	My results.
The English imperial troy pound in grammes	373,0956	373,2228
—— ——— ——— avoirdupois pound gr.	453,4148	453,5685
The kilogram in English grains troy, according to the U. S. Mint pound - - -	15438,36	15433,15902

The statement of the almanac evidently disagrees with that given by the Minister of the interior of France to the British Commissioners of Weights and Measures, who states the result of the comparison of a British imperial troy pound sent there, to have given as above 373,233. See, in the British parliamentary paper on weights and measures, the letter dated Paris, 28th February, 1821.

120. The notices upon the comparisons of Dr. Moll also give a mean of confronting the result I obtained for the nest of the Amsterdam pound, lent to me by late President Adams, which I have stated, reduced to the United States' Mint weight = 7630,76.

Dr. Moll gives for it in avoirdupois pound -	- =	1,0892347.
This, reduced to grains, gives - -	- =	7624,6429.
The difference is - - - -	- =	6,1171,

in excess for the weight of late President Adams, probably again an allowance for use and wear.

121. It does not belong to this place to carry those investigations and comparisons farther. I may only advert to some simple conclusions, which they lead to, namely: We must not be astonished to find large differences in the English weights from sealers, and in the standards of the capacity measures, that depend on them, when we find differences as here appear in the original units.

A system of weights and measures, and its proper establishment, must be a careful scientific operation, in which the *accuracy aimed at* must far exceed that which may be considered required for practical use, otherwise this less accuracy will even not be obtained, by the unavoidable fate of human exertion: to remain always yet at some distance behind the ideal proposed. What is done in such a work is done for the future, the improvement of science always spreading more in common life, if such an establishment is not ahead of its time, even, if possible, of the science of it, it very soon drops back, behind even the wants of the nicer social intercourse, and such an epoch approaches always more rapidly, with the greater means of science.

Not long since we were considering the works of Sir George Shuckburgh, with the conviction of their superiority; and now, what they really were then lies in many respects already far behind the needful of our present time, and so it is to be hoped my own work will be in proper time.

UPON THE CONSTRUCTION OF WEIGHTS.

122. A few words may suffice upon the principles of constructing weights, when the unit weight has been determined, in either way, as stated in its proper place in my report. The utmost care, and attentions of all kind, are indispensable requisites; and the task is rather a tedious than a learned one. The choice of the metal must be the best against oxydation. A certain proportion of copper and tin, or zinc, appears to be the best in the absence of perfect brass, that is, copper exactly saturated, by cementation, with pure zinc, neither over nor under saturated. For this, to my knowledge, we would have to resort to Calcutta or China; the European, and especially the English, art appears, in this point, to be behind the old eastern art. One caution is to be given against the old, bad habit of making a mass finished off and polished, with a hole in it, in which small pieces of another metal are enclosed, to satisfy the equilibrium; this occasions, by the galvanic action between the metals, an oxydation, that changes the weights, by the process of time, more than their wear in use would do; therefore weights, to be accurate, must be made of one mass and metal, and ultimately rubbed down to the full adjustment; if by that they become too light, they must simply be rejected.

Brass is only to be chosen, on account of its cheapness, and the almost general habit of its use for that purpose, by which, therefore, other weights are made equal to the standards, without the influence of their different buoyancy in the atmosphere, as would be the case if the standards were made of platinum, which would evidently be the best metal now known for this purpose, if sufficiently common.

123. SPECIMENS OF WEIGHING STATEMENTS.

Weighing with the balance of Troughton.

1831, *February* 15.—Equilibrated 16 oz. piece of the Tower troy nest by parts of subdivided square kilogram No. 1.

	Grammes.		Resulting value. Gr. Tr.
1st equil.	497,575 = 16 oz. Tow. troy		= 7680,07
2d equil.	1 lb. Swedish victualling weight, brass nest		= 6542,07
	+ Tr. gr. { 1000, 100, 30 | 5, 2, 1 }	= 1138,0	
3d equil.	Brass nest of Amsterdam		= 7633,95
	+ Tr. gr. { 40, 4, 2 | 0,1, 0,02 }	= 46,12	
4th equil.	Brass Russian Mint pound nest		= 6309,97
	+ Tr. gr. { 1000, 300, 40 | 30,0, 0,1 }	= 1370,1	
5th equil.	Russian iron pound standard		= 6314,05
	+ Tr. gr. { 1000, 300, 40 | 20, 4, 2, 0,02 }	= 1366,02	
6th equil.	All only Troughton's grains laid up to verify		= 7680,07

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124. *Weighing of the four lb. bellform, of New Hampshire standard, upon the water balance with one stem No.* 4.

		Tr. gr.		Barom.	Thermom. Upper.	Thermom. Lower.
1st equil.	2 lb. bellf. St. Dept. 2 lb. Philad. 2 lb. New Orl. 1222 grains	207 3 1 0,1	= 43444,35	30,344	35,2	35,9
2d equil.	4 lb. bellf. of New Hampsh. 2 lb. New Orl. 1222 grains	207 2 0,7	= 15429,25	——	35,8	36,1
3d equil.	2 lb. bellf. of St. Dept. 2 lb. Philad. 2 lb. New Orl. 1222 grains	207 6	= 43446,25	——	35,9	36,5

The results of the above are as follows:

Mean of 1st and 3d equil. - - = 43445^{gr},3 at temp. 35,875
Weight supplement to 4 lb. of New Hampshire = 15429 ,25 ——— 35,95

Differences - 28016 ,05 0,075

The difference between the first and third equil. gives
Difference of weight = 1^{gr},9
Difference of temperat. = 0 ,65

Proportional change of weight from the difference of temperature of the mean of first and third equil. from that of the weighing of the 4 lb. New Hampshire, which is to be subtracted from the above = 0^{gr},22.

Resulting 4 lb. New Hampshire = 28015,83.

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125. *Weighing of the largest weight of the Tower troy nest, being the 256 oz troy, by the smaller mercury balance.*

			Grains.		Mean weights, omitting equal.	Thermometer centigrade. Mean.	Thermometer centigrade.
1st equil.	All the A de P pile All Tow. troy nest	½ lb. New Orl. ½ oz. def. tr. nest	40 20 5 2	67	3542,0	23,275	23,2 23,35
2d eq.	Idem	Idem	40 10 4	54			
3d eq.	All A de P pile All Tow. troy nest under the 256 oz.	4 lb. } bellform 2 lb. } State Dep. 4 lb. } Philad. 2 lb. } 4 lb. } New Orl. 2 lb } ½ oz def. troy	300 40 30 2	372	126443,87	23,6	23,5
4th eq.	Idem	Idem	300 40 20 4	364			23,7
5th eq.	All the A de P pile A l the Tow. troy nest	½ lb. New Orl. ½ oz. def troy	30		3520,0	23,925	23,9
6th eq.	Idem	Idem	20 4 2 1	27			23,95

The mean of the temperatures of first and second and fifth and sixth equil. is here exactly the same as the mean between third and fourth; thence the mean weights will also correspond, without reduction.

The weights being therefore stated, with omission of those that are equal in all, this gives:

Mean of third and fourth equil. = 126443,87
Mean of two first and two last = 3531,0

Which, being deducted, leaves 256 oz. Tow. troy = 122912,87

126. *Comparison of* 4 *lb. and* 8 *lb. weights, by the water balance floating in the bucket, (the bulb of which broke afterwards.)*

		Weight to determ.	Grains.			Barom. 30",405.	Therm. Fahr.
						Sum gr.	
1st equil.	8 lb. 1 lb. 8 oz. 2 oz. } avoirdupois pile	4 lb. bellform of the St. Dep.	400 200 5	2 0,2 0,1	=	607,3	39,8
2d equil.	Idem	4 lb. avoirdupois pile	400 200 5 3	2, 0,4 0,2 0,1 0,05	=	610,75	39,8
3d equil.	Idem	4 lb. Philadelphia	400 200 0,4	0,3 0,2	=	600,9	39,7
4th eq.	Idem	4 lb. New York iron	400 200 5 1	0,4 0,3 0,2	=	606,9	39,7
5th eq.	Idem	4 lb. Baltimore iron	400 200 20	3 0,4 0,3 0,2	=	623,9	39,8
6th eq.	Idem	4 lb. Wilmington iron	400 200 100 20	1 0,4 0,3 0,1	=	721,8	39,9
7th eq.	Idem	4 lb. N. Orl.	400 100 40 30	20 5 0,2 0,1	=	595,3	39,8
8th eq.	4 lb. 1 lb. 8 oz. 2 oz. } avoirdupois pile	8 lb. avoirdupois pile	400 200 10	0,4 0,3 0,05	=	610,75	39,9
9th eq.	4 lb. 2 lb. 8 oz. 2 oz. } avoirdupois pile	7 lb. State Dep. bellform	400 200 4 0,4	0,2 0,1 0,05	=	604,75	40,0
10th eq.	Idem	7 lb. Philadelphia	400 100 40	30 20 5 0,2	=	595,2	40,1

These weighings are made so near the maximum density of the water, that, for the kind of weights to which they apply, the reduction upon the difference of temperature of the water, which amounts to less than 0,2 of a degree Fahr., may be omitted: it serves to ascertain the difference between those weights marked in the same column. Adopting the four lb. bellform as fixed, at which it was found on a first weighing, though since somewhat altered by a mean of more results; we obtain:

4 lb. bellform, accepted - - - - -	= 28016,74
4 lb. avoirdupois pile, by this weighing - -	= 28013,29
4 lb. Philadelphia - - - - - -	= 28023,14
4 lb. New York - - - - - -	= 28017,14
4 lb. Baltimore - - - - - -	= 28000,14
4 lb. Wilmington - - - - - -	= 27902,24
4 lb. New Orleans - - - - - -	= 28028,74
8 lb. avoirdupois pile - - - - -	= 56015,23
7 lb. bellform of State Department - - -	= 49014,38
7 lb. Philadelphia - - - - - -	= 49023,93

127. *A TABLE of the Balances, in dimensions, size, weight, capacity of weighing, &c.*

	Largest water balance No. 1.	Water balance No. 3.	Water balance No. 4.	Water balance No. 5.	Copper water balance.	No. 5, in mercury.	Smaller mercury balance No. 2.	Largest mercury balance.	Sheet tin bulb.
Diameter of the bulbs { Long diameter in inch.	15″,43	11″,3	10″,9	8″,0	13″,4	8″,0	8 ,45	12 ,1	15 ,5
Diameter of the bulbs { Short do. -	10 ,9	7 ,3	7 ,2	5 ,0	9 ,6	5 ,0	5 ,4	8 ,55	12 ,0
Diameter of top mounting - - -	2″,2	1″,3	1″,2	1″,1	1″,1	1″,1	1″,5	1″,4	2″,
Height of the stems - - - -	1″,3	1″,1	1″,25	1″,4	1 ,45	1″,4	1″,4	1″,15	13 ,
Distance of the stems from centre - -	0 ,95	0 ,5	only one stem	0 ,5	0 ,5	0 ,5	0 ,5	1 ,0	0 ,95
Diameter *of* stems - - -	0 ,08	0 ,07	0 ,1	0 ,08	0 ,08	0 ,08	0 ,09	0 ,16	0 ,07
Radius *of* Y frame, to the rod's middle -	8″,0	5 ,2	5 ,0	4 ,5	7 ,8	4 ,8	4 ,8	7 ,8	8 ,
Length of steel rods - - - -	42″,0	31′,	31 ,	22	39 ,4	29 ,	29 ,	38 ,	42
Weight of bulb and *mounting* in Troughton's grains, without basin - - -	118559,0	30900,5	30112,1	21777,3	72043,9	41108,2	50936,9	184117,7	59943,77
	At therm. 41°,6.	41°6.	41°,55.	41°,7.	44°,6.		40°.		
Capacity of weighing at max. in Troughton's grains, besides basins - - -	105214,5	44325,45	43457,25	7687,6	109379,25	-	362942,	1393649,2	
Weight of the liquid displaced, in Troughton's grains - - - - -	227847,	76781,3	75344,0	29464,8	181423,16	-	416150,	1577767,0	
Cubic content of bulb, deduced from weight	Cub. 901″,52	303,85	298,11	116,58	717,95	-	121,22	406,88	
Length of stem for 1gre Trought. variation -		0″,15	0″,12	0,068	0″,2	-	0″,1121	0″,00416	

UPON THE CAPACITY MEASURES.

128. As it is now habitual to determine the capacity measures by the weight of distilled water they contain, at a certain temperature, the investigation, or comparison, is reduced to the operation of weighing, like that of the comparison of the weights; therefore all my arrangements, described under that head, and the methods detailed there, have also been applied to this part of my work.

Though I also measured the dimensions of all the capacity measures, and calculated their cubical content in inches from those measurements, the accuracy now aimed at in such determinations not being obtained by that means, the results do not enter in the comparison, but as a kind of approximate estimate.

In my hydrostatic balances occurs already the reduction for the temperature of the liquid in which the weighing is made, but there the thermometer changes applied alone, because during the time of a weighing the barometer varies never for a quantity, the influence of which would be sensible.

In the weighing of capacity measures with water, the reductions must be made also for the water weighed in the vessel itself, that makes the element of determination, and that must be made for the barometer as well as for the thermometer, because the results obtained at different times refer to different stands of the barometer, as well as to different temperatures, and must all be reduced to one and the same for both.

129. Any mass that we weigh in the atmosphere suffering in it buoyancy in the inversed ratio of its specific gravity, the variation of the barometric state of the atmosphere becomes sensible in the weighing of water.

The element of this variation has been accepted, in the English establishment of the capacity measures, as for the specific gravity of the air $= \frac{1}{837}$ at the temperature of 62° Fahr., and the variation for other temperatures left out of consideration.

The French determination, made on the occasion of the establishment of the metric system, is $\frac{1}{770}$, at the temperature of the maximum density of the water.

The English determination rests upon the experiments of Sir George Shuckburgh, none having been made expressly on the occasion of the latter establishment of the British imperial weights and measures, and also none upon the expansion of the water by the temperature. Upon this latter, however, various other determinations have been made, but they are yet somewhat at variance with one another; and it was proper that I should establish this element myself, by means of my water balances, which are peculiarly adapted for that purpose.

130. The most of the standard capacity measures, that I had to compare, are, however, little adapted to yield an accuracy adequate to this minute scrutiny, for which they never were intended.

To procure exact filling of the standards of capacity measures, it is necessary to cover the vessel with a ground glass cover, and fill it so as to be free of air bubbles, and not overflowing; it must, of course, also be wiped dry outside. The French litres modèles have such a glass always with it. For the different English capacity measures, I made similar glass disks, of the proper diameters, adapted to their size; those for the bushels required large glasses. I made one of them with a hole in the centre, by which air bubbles, that might have remained, were disengaged, by means of a brass wire, bent at right angles, and turned round horizontally, so as to sweep the glass in its contact with the water, which led them to the hole, to escape. This glass not reaching to the largest size, the bushel of New Hampshire, and an old looking-glass, that could be procured easiest for the purpose, not having the necessary breadth, a piece cut from the length was applied to the side, and ground against it, so as to shut exactly; the separation that would thus be made proved to afford the best means to clear the bushel of air.

The stamps which the measures had upon the side rim were, of course, always taking up more or less water; and this difference is evident by the results which are related in the table. At last, in weighing the coal bushel, it was found good to fill up those stamps with glaziers' putty, even with the rest of the edge; but still too much inequality remained in the rim from the turning.

A thermometer was placed in the measure during the filling, or before shutting it up, and observed, and again after the weighing, before it was emptied.

131. In the determination of the new British standards of capacity measures, it has been omitted to state the kind of metal, of which they were legally to be considered. It is, however, evident that the expansion being different for different metals, the bushel holding 80 lbs. of water at 62° Fahrenheit, when made of another metal, will hold, of any other substance, a different quantity at another temperature, than a bushel made of the same metal as the standard. In the liquid measures, a greater variety is habitual in this respect than in dry measures, which latter are commonly made of wood, where, of course, the accuracy can never reach to this minute distinction, and only so far this may be considered negligeable; but, in the establishment of standards, it is not allowed to neglect this, because, in making other standards from them afterwards, uniformity can never be obtained, without proper attention to this consideration.

132. The choice of the standard temperature for capacity measures *must be* the temperature of maximum density of the water, as has been stated above to be the most favorable also for the weighing, because there, at least, the one element of the determination, the water, may be considered in a settled state, and the kind of metal being determined, the actual determination is arrested by it, for this will always be of the same temperature as the included water, as near as determination can go; its variations thence in all directions are known by the laws of expansion of both the water and the metal. To give an idea of this effect, it may be stated here what would be the content of vessels of different materials at the temperature of 62° Fahr., that would hold, at the maximum density of the water, 1000 parts, according to the present knowledge of these expansions.

Mr. Van der Toorn, of the Hague, in Holland, gives for this, in a table:

		Parts.
The vessel of glass would hold	- -	= 999,18
The vessel of copper would hold	- -	= 999,49
The vessel of brass would hold	- -	= 999,56
The vessel of pewter would hold	- -	= 999,72

And these materials are indiscriminately used for liquid measures.

The sheet tin, which is also of frequent use, has not yet been inquired into, and I am now engaged in experiments relating to it. The difference in the above amounts to more than *half a hundredth part*, which, though in common neglected, must not be so in the *establishment of standards*.

The standard capacity measures which I had to compare were of cast bell metal; five from custom-houses were of hammered copper. The sheet tin gallons, sent in by some custom-houses, must not be considered as standards; they assist only the proof that there are not any standards.

133. The French standards of capacity measure are reduced to the vacuum for their ultimate determination. In the British standard, the barometer stand of thirty inches has been adopted. The first is scientifically more proper; the latter was more convenient for me to reduce the reductions to smaller quantities; and being the mean state of the barometer in this country, this mode may be also more convenient for practical use. The reduction is directed by the simple principle, that, the higher the barometer is, the greater must the buoyancy be.

To establish a comparison between the results that could be derived from the different data known to me at the beginning of my operations, I calculated a table of the resulting weight of the bushel and gallon, at the temperature of the maximum density, from the different data. Upon this, the determination of the content of the gallon and bushel, as standard capacity measures, has been grounded as ultimate result. The perusal of this table will show in one view the state of the data, and their diversified effect, which it would be too long to detail; I believe it will prove the necessity of the above investigation, that I have begun, but which by this time could not yet be finished. Since then, I have seen newer determinations, which I shall consider where needed.

It would, of course, have been agreeable for me already here to make use of the results of my own experiments, had they been finished; but, in fact, the state of the measures to be compared made it entirely indifferent. For the actual construction of capacity measures, these results will be used; as it is proper that the establishment of a system of standards be grounded upon results of determinations made for that purpose expressly, and entirely deduced from the very principles.

The following is this table.

134. ***COMPARATIVE TABLE** of data and results, for the reduction of the new and old English capacity measures from their capacity and weight of distilled water at 62° Fahr. to the temperature of the maximum density of the water, and from their absolute value to that in brass, and its relation to the troy and avoirdupois pound litre, &c.*

1. Reduction of the brass bushels according to the expansion deduced from my pyrometric experiments.

	For 1° Fahr.	For 22° Fahr.	Grains in 1 cubic inch water.	The new bushel.		The old bushel.	
				Cub. in.	Grains.	Cub. in.	Grains.
Ratio of lineal expansion of brass	1,00001050903	1,00023330		-			
Resulting ratio of cubical expansion	1,000031514	1,000700					
Weight of the cubic inch water, at 62° Fahr.	-	-	252,458				
Legal determinations of the bushel, at 62° Fahr.	-	-	-	-	560000,	2150,42	
Resulting capacity in weight of water at 62° Fahr.	-	-	-	2218,19		-	542886,0
Capacity of the brass bushel at temperature of max. density of water	-	-	-	2216,64	-	2148,9	
Diminution of capacity of the brass bushels	-	-	-	1,55	-	1,5	

2. Reduction of the above capacities and weights to the capacities and weights of the water at the maximum density, according to different data.

DENOMINATIONS AND AUTHORITY OF THE DATA OF REDUCTION.	Proportions given in decimals.	Weight of the cubic inch of water at max. density resulting.	Weight of the bushels of water at maximum density, by equal absolute space.		Capacity of the bushel contain'g equal weight of water at maximum density.		Weight of water of max. dens. cont'd in the brass bushel, reduced to temp. of max. density of water.	
			New bush.	Old bush.	New bush.	Old bush.	New bush.	Old bush.
By Gilpin, quoted in Young's Nat. Ph. from specific gravity	0,998858	252,748	560640,3	543506,5	2215,757	2147,94	560248,0	543125,5
By Gilpin, quoted in Young's Nat. Ph. observed expansion	1,001142	252,7462	560635,0	543506,0	2215,66	2147,947	560247,3	543125,5
By Gilpin, as quoted by Van der Toorn for the weight of one litre	0,998837	252,752	560652,0	543518,0	2215,61	2147,90	560259,7	543138,0
Mean result of the above	-	252,7487	560642,4	543510,2	2215,642	2147,929	560251,66	543130,0
Mean result adopted by Van der Toorn for the comparison with metal litres, by the weight of one litre	0,9988634	252,7453	560637,3	543503,6	2215,661	2147,956	560245,0	543123,4
By the new French tables { From volumen	1,0009125	252,6883	560511,0	543381,0	2216,168	2148,44	560119,0	543001,0
By the new French tables { From density	0,9990883							
By Van der Toorn's tables for the litre for density from Charles	0,99900	252,7107	560560,5	543429,0	2215,972	2148,250	560168,3	543049,0
his own experiment	0,99896	252,7211	560583,4	543451,0	2215,885	2148,164	560190,6	543071,0
Biot's formula	0,998967	252,719	560579,0	543447,2	2215,90	2148,171	560186,8	543067,0
Mean results of French determinations	-	252,7098	560558,48	543427,05	2215,981	2148,256	560166,18	543047,0
Mean of all Van der Toorn's indications together, in density	0,9989254	252,7295	560602,4	543469,6	2215,807	2148,09	560210,0	543090,0
Mean between the results of French and English determinations by this calculation	-	252,72925	560600,44	543468,625	2215,811	2148,0925	560208,92	543088,5
By Van der Toorn's indications for metal and glass, given by density { In brass	0,995734	252,5658	-	-	-	-	560239,0	543118,0
In copper	0,99949	252,5868	-	-	-	-	560285,7	543163,0
In glass	0,999147	252,6735	-	-	-	-	560478,0	543349,2

3. Differences between the means of the different determinations and results, as taken above.

		Weight of the cubic inch of water at max. density resulting.	Weight of the bushels of water at maximum density, by equal absolute space.		Capacity of the bushel contain'g equal weight of water at maximum density.		Weight of the water of max. density contained in the brass bushel reduced to temp. of max. density of water.	
			New bush.	Old bush.	New bush.	Old bush.	New bush.	Old bush.
Mean of Gilpin—mean of the French	=	+0,0389	+83,92	+83,15	—0,339	—0,327	+85,48	+83,0
Mean of Gilpin taken by V. d. T.—general mean of V. d. T. tables	=	+0,0157	+34,8	+34,0	—0,146	—0,134	+35,0	+33,4
General mean of French and English— do. do. do.	=	—0,00025	— 1,96	— 0,975	+0,004	+0,0025	— 1,08	— 1,5
Van der Toorn's results for brass. { — result of his own mean for Gilpin's	=	-	-	-	-	-	— 6,0	— 5,4
— result of my calculation for Gilpin's	=	-	-	-	-	-	—12,66	—12,0
— result of my calculation of the French	=	-	-	-	-	-	+72,82	+71,0
— result of my calculation of ult. V. d. T.	=	-	-	-	-	-	+29,0	+28,0
— result of my mean between English and French	=	-	-	-	-	-	+30,08	+29,5

All these results are under the supposition of equal stand of barometer and hygrometer, the reduction for these being taken into consideration only in the construction of standards, or in nice comparisons. Sir George Shuckburgh's determinations were not used, because they were made without the knowledge of a point of maximum density of water, and only vaguely stating the expansion, of about $\frac{5}{10000}$ in 2° Fahr., or, by his table, {= 1,00363 or 0,99637 evidently erroneous; the weight of a cubic inch of water he stated at 252,422. In the English determination of the gallon and bushel, the hygrometric influence was disregarded; it is, indeed, the smallest influence, and the hygrometer itself not yet brought to sufficient perfection; that of Sausure being the only one in which the application of a regular scale has succeeded.

According to Van der Toorn, the temperature at which, by the expansion of the water, and that of the litre, constructed of different materials, contains again an equal weight of water, as at the maximum density, is as follows:

For a glass vessel - - - - - - -	at 45°,2 Fahr.	
For a brass do. - - - - - - -	at 52 ,8	
For a copper do. - - - - - - -	at 51 ,8	
For a pewter do. - - - - - - -	at 56 ,3	(composed of 5. tin, 1. lead.)

4. Deduction of the data from some determinations made relating to the litre.

	Engl. inches.	Cubic inches.	Trought. grains.	Actual British weight of kilogram.	Absolute.	Reduced to 39°,8 of length in brass.	Max. density. Cubic inch in brass.
The authentic metre of the committee, compared twice by myself, is - - - - - -	39,3810327	-	-	-	-	39,3842349	
The cubic decimetre, which determines the litre by the weight of water at maximum density, becomes -	-	61,074664	-	-	-	-	61,09959
The authentic kilogram of the committee, which I compared, weighs - - - - - -	-	-	15439,6				
This is to be reduced to the actual English weights, by the difference found from the comparison of the troy pound of the Mint, at the rate of 2gr,4 per pound troy			6,4331			Deduced weight of one cubic inch of water in brass.	
Thence weight of kilogram in actual English weight of the Mint - - -			-	15433,1669		By Trought. grains.	By the Mint weight.
Resulting weight of the cubic inch distilled water at maximum density	-	-	-	-	252,6934	252,737	252,632
This *exceeds* the result of the new French determination only - -	-	-	-	-	0,0051	0,0487	0,0563
It is below the mean of French and English determination -	-	-	-	-	0,03585	0,00775	0,09725
It is below the mean of Gilpin, according to my calculation -	-	-	-	-	0,0553	0,0117	0,1167
It is below the mean of Gilpin, by the mean of Van der Toorn	-	-	-	-	0,0519	0,0083	0,1133

Remark.—The first determinations of the metre, kilogram, &c. were here suffered to remain, though somewhat different from the ultimate mean since determined, because it was found better to give the results upon which the determinations were grounded unaltered; the influence of the small difference between the two is, besides that, very little.

135. The results of the comparison of all the metal capacity measures may best be presented in one mass in the table of the following § 140; any comparison with other results would appear to me idle here, because none of the English standard copies, that I had, is such as to answer with satisfaction such a call upon it. It is evident that this was found to be the case in the old English standards themselves, on the last investigation for the establishment of new ones; no account being given of their comparison, and ultimately the eighty pounds for the bushel, and the ten pounds for the gallon, were accepted as convenient means in round numbers.

It will be observed how near the mean of the coal bushel of the State Department agrees with this acceptation, and thereby favors the idea, that this coal bushel was properly the original standard bushel.

136. The manner in which the results were obtained from the weighings is, in fact, evident from the table, and will be explained in detail by the specimens of it that will follow here, § 137 and 138.

The weighing of the full measures was always included between two weighings of the empty measure, in order to reduce, and even, as often occurred, entirely to avoid, the reduction for the change of temperature in the water, or the mercury, that floated the bulb, serving in the weighing, if not fully so the reduction was made for the difference, between the mean of the first and last empty weighing, and the weighing of the full measure, which never exceeded a few tenths of a degree of Fahrenheit's scale.

The reduction for the barometric influence was applied to the English measures by the English data, accepting the atmospheric air $\frac{1}{831}$ of the water, in specific gravity, and adopting for the brass eight times that of the water, which gives for the effect of one inch variation of the barometer $\frac{1}{831} \cdot \frac{7}{8} \cdot \frac{1}{30} = 0{,}0000350983$.

For the French litre I adopted the French determination of the specific gravity of the air, of $\frac{1}{770}$, the water being taken at the maximum density, which, treated for brass like the English, gives $\frac{1}{770} \cdot \frac{7}{8} \cdot \frac{1}{30} = 0{,}000037879$.

For the reductions for temperature, I made use of a table given by Mr. Van der Toorn, in a treatise upon the acetic acid, giving the weight of a litre of water at different temperatures, as well absolute as for vessels of glass and several metals in grammes and decimals, thereby affording an easy decimal reduction for any other measure.

137. *Weighing of the metal quart measure of New Hampshire, upon the largest glass water balance.*

Weights.	Object.	Grains	Sum, omitting equal.	Barometer.	Thermometer. Upper.	Thermometer. Lower.
1st eq. 4 lb. bellform St. Dep. 4 lb. Philad. 4 lb. N. Orl. 1 lb. } Provid. 1 lb. } Def. troy 8 oz., 4 oz. 2 oz. ½ oz.		150 1 0,2	151,2	30,340	34,29	35,15
2d eq. 4 lb. bellf. 4 lb. Philad. 1 lb. } Provid. 1 lb. } 4 oz. def. troy.	The New Hampshire metal quart standard, with ground glass cover.	450 250 2 0,7	28718,82	30,330	34,55	35,35
3d eq. 4 lb. Philad. 1 lb. bellform 1 lb. } Provid. 1 lb. } Defect. troy 8 oz. 4 oz. 1 oz. ½ oz.	The same quart filled with distilled water, temp. 36°,6 Fahr.	60 17 0,7 0,4 0,1	11638,32	——	34,80	35,55
4th eq. The same as in the first equilibrium, until		150 5 0,7 0,4	156,1	30,324	34,95	35,65

The above gives difference between first and fourth equilibrium, for proportional expansion of the water of the balance, for 0°,58 exp. = 4gr,9; thence For 1°, Fahr. at the mean of 35° = 8,45 grains.

Supplementary weights of the empty quart measure -	= 28718,82
Do. do. full do. -	= 11638,32
The difference is the unreduced, or observed, weight of the water - - - - - - -	= 17080,5
The reduction of this weight for 0°,225 proportionally to the above - - - - - - -	= + 1,9
The actual corrected weight - - - -	= 17082,4
Reduction of the barometric effect to 30 inches - -	+ 0,2
Reduction of the thermometric variation from 36°,6 to maximum density - - - - - -	+ 2,2
Weight at 30″ barom. and maximum density of the water	= 17084,8

138. *Weighing of the metal coal bushel of the State Department, with distilled water, upon the largest mercury balance.*

	Barom.	Thermometer. Upper.	Thermometer. Lower.
1st eq. The coal bushel empty, with the large glass cover in two parts. 1st. Hanged on below: 32 lb. Portsmouth, with hook. / 14 lb. bellform of State Dept. / 14 lb. Philadelphia. / 14 lb New Orleans. 2d. Upon the sheet tin plate: 7 lb. + 1 lb. bellform, St. Dept. / 7 lb. Philadelphia. / 7 lb. New Orleans. Of Tower troy nest. 256 oz. / 128 — / 64 — / 4 — / 2 oz. / ½ — / ¼ — Grains { 10 / 8 } 18 - - - -	-	57,9	58,28
2d eq. The bushel filled with distilled water at temp. 58°,0, with the same glass cover in two parts, barom.	29,538		
1st. Hanged on below: 14 lb. bellform of State Depl. / 14 lb. Philadelphia. / 14 lb. New Orleans. 2d. Upon the sheet iron plate: ½ lb. New Orleans. / 4 oz. avoirdupois pile. / All under 64 oz. of Tower troy nest. Grains { 450 / 60 / 6 } = 516 - - - -	-	57,4	57,8
means = 537 - -	-	57,35.	
3d eq. All as in 2d eq. until gr. { 450 / 100 / 8 } = 558 - - - -	-	57,3	57;65
4th eq. The coal bushel again empty, with the same glass cover, well wiped dry. All the weights as in 1st equil. until gr. { 80 / 8 } = 88 - - - -	-	57,4	57,65
Means for the empty weighing gr. 53 at temp. -	-	57,81	

Omitting the weights that were constant in all the four equil., and using the means indicated, there results:

Supplementary weight to the empty bushel - - - - -	=	596624,284
Do. do. full do. - - - - -		36502,187
Apparent weight, by balance - - - - - -	=	560122,097
Reduction for the expansion of mercury in the balance - - -	+	30,58
Actual weight of the water in the bushel observed - - - -	=	560152,677
Reduction to 30″ barometer - - - - - - -	= —	9,088
Value at 30″ barometer, and 58° temperature - - - - -	=	560143,594
Reduction to the temperature of the maximum density, by the tables of of Mr. Van der Toorn for brass - - - - - -	+	112,029
Weight of distilled water held by the coal bushel at maximum density, and 30 inch barometer - - - - - - -	=	560255,6[illegible]

139. *Upon the construction of standards of capacity measures.*

The standarding of the capacity measures being determined by the weight of distilled water which they contain, it is proper to give to the standards, from which all others are to be made, that form which will give the greatest accuracy in their filling, therefore the smallest top surface, that is well admissible with an otherwise convenient shape. This does not hinder that the measures for common use, that will be standarded from them, have the form most convenient for practical use; for instance, in the liquid measures cylinders, having the altitude and the diameter of the base equal, and in dry measures, that are often used heaped, the diameter of the base double the height.

It will be best to choose the metal, of which these standards are to be made, the same as that of the weights, and of the length measures The determination of the expansion of this metal by temperature will be one of the necessary experiments to be made with the length measures, and it will therefore, then, apply equally to the whole system. This uniformity, which has not been fully regarded in all the establishments of standards in other countries, is equally as proper as that of taking the water at its maximum density for the determination of the capacity measures; it equally serves to simplify the whole, and render all reductions and comparisons more accurate, by making all indications less dependant on calculations. Upon the kind of metal to be chosen, the proper remarks have already been made.

140. ***RESULTS** of the determinations of the Capacity Measures, with their reductions.*

1. State Department measures.

Date.	Denomination.	Capacity in cubic inches.	Weight of distilled water observed in Troughton's grains.	Barom. in Engl. inches.	Ther. mean Fahr.	Barom. reduction to 30″.	Thermom. reduction to max. density.	Weight at 30″ barom., and the temp. of maximum density of water. Of the measures compared. In Troughton's grains. Each observ.	Mean.	In Mint wt. Mean.	Reduced for comp. To the gall. Mint wt.	To the bush. Mint weight.	
Mar. 11	Wine gall.		58466,227	30″,177	39°,2	+0,3695	0,0	58466,596					
"	Do.	235,04	58468,107	30 ,130	39 ,7	+0,2668	0,0	58468,374	58484,63	58460,2	58460,2	467681,6	
Nov. 18	Do.		58506,78	29 ,573	49 ,8	—0,94	— 4,21	58501,63					
Feb. 24	Winchester pint	35,063	8814,74	30 ,087	41 ,5	+0,003	— 0,0441	8814,7	8814,89	8811,21	70489,68	563917,44	
28	Do.		8815,14	30 ,163	39 ,8	+0,050	0,0	8815,09					
Feb. 24	Winchester quart		17699,89	30 ,129	43 ,0	+0,0804	— 0,9204	17699,81					
25	Do.	71,654	17689,79	30 ,20	39 ,4	+0,124	0,0	17689,914	17691,61	17684,21	70736,84	565894,72	
Mar. 9	Do.		17686,62	29 ,83	43 ,8	—0,101	— 1,415	17685,1					
Mar. 11	Winchester gallon		68569,433	30 ,129	43 ,0	+0,310	— 0,686	68569,057					
May 5	Do.	274,325	68593,27		60 ,2		+ 21,264	68614,534	68599,7	68571,0	68571,0	548568,0	
Nov. 18	Do.		68621,587	29 ,573	49. ,6	—1,027	— 5,078	68615,482					
Jan. 4	Winchester bushel	2124,09	540232,81		42 ,2		— 34,03	540198,78	540208,45	539981,3	67497,66	539981,3	
7	Do.		540263,5	30 ,217	47, 95	+4,33	— 49,7	540218,13					
Jan. 11	The coal bushel		560177,8	29 ,800	47 ,95	+3,92	— 50,49	560123,39					
24	Do.	2211,26	560494,6	30 ,122	43 ,0	+2,24	— 40,35	560366,49	560249,3	560050,0	70007,1	560050,0	
Apr. 26	Do.		560155,0	29 ,538	58 ,0	—9,08	+112,03	560257,95					
Feb. 25	Litre of St. Dept.		15406,523	30 ,115	39 ,8	+0,0696	0	15406,5806				Reduction to vacuum.	Litre in value at maximum density.
"	Do.	61,07466	15408,623	30 ,105	41 ,0	+0,061	— 0,7704	15407,9136	15407,839	15401,33			
Mar. 9	Do.		15410,219	29 ,85	43 ,0	—0,0875	— 1,109	15409,0225			15403,2	+17,6645	15420,8645
	Litre of coast surv. No. 1		15411,319	29 ,984	40 ,0	—0,0092	0,0	15411,209	15411,527	15405,078			
	Do. do. No. 2		15412,719	29 ,85	42 ,0	—0,0875	— 0,786	15411,845					

Continuation of the results of the determinations of Capacity Measures, with their reduction.

2. New Hampshire standards.

Date.		Denomination.	Capacity in cubic inches.	Weight of distilled water observed, in Troughton's grains.	Barom. in Engl. inches.	Ther. mean Fahr.	Barom. reduction to 30″.	Thermom. reduction to max. density.	Weight at 30″ barom., and the temp of max. density of water.				
									Of the measures compared			Reduced for compar.	
									In Troughton's grains.		In Mint wt.	To the gallon, in Mint wt.	To the bushel, in Mint wt.
									Observed.	Mean.	Mean.		
Dec.	5	⅛ of a pint	3,56	957,35	30,087	35,4	0,0	+ 0,20	957,55		957,15	61257,6	490060,8
		Quarter pint	7,125	1914,19	30,100	35,5	0,0	+ 0,555	1914,745		1913,95	61246,4	489971,2
		Half pint	16,905	4440,146	30,100	35,7	0,0	+ 0,888	4441,036		4439,18	71026,88	568215,04
		Pint	33,861	8853,466	30,169	35,6		+ 1,806	8855,272		8851,57	70812,56	566500,48
Dec.	6	Quart	66,972	17082,404	30,330	36,6	+ 0,225	+ 2,647	17085,276	17089,947	17082,7	68330,8	546646,4
	13	Do.		17121,221	30,161	42,0	+ 0,11	0,0	17094,619				
	14	Half gallon	134,97	34228,6	30,455	39,9	+ 0,623	0,0	34229,223		34214,9	68429,8	547438,4
	12	Gallon	269,59	68777,472	30,180	41,0	+ 0,495	0,0	68777,967		68749,2	68749,2	549993,6
Jan.	10	The peck	537,35	136770,5	29,745	45,25	— 1,34	—13,13	136756,03		136698,76	68349,38	546795,04
	8	Half bushel	1074,2	271696,89	29,809	46,2	—19,659	—29,343	271647,981		271534,4	67883,6	543068,8
	12	The bushel	2099,2	543911,3	30,400	40,75	+82,67	0,0	543994,		543766,2	67297,077	543766,2

3. Metal measures from the custom-houses.

Jan.	8	Boston ½ bush.	1076,275	271521,0	29,697	45,4	—3,125	—21,722	271496,153	-	271382,6	67845,4	542765,2
	16	Philad. ½ bush.	1076,55	275422,327	29,823	43,8	—1,845	—28,336	275398,146	-	275284,2	68821,05	550568,4
	10	Provid. peck	539,704	136594,14	29,719	45,66	—1,45	— 1,09	136591,6	-	136537,6	68268,8	546150,4
		——— gallon	219,5	57809,38	-	-	The reductions for barometer and thermometer are omitted as useless proportionably to the construction of these measures.				57785,2		
		Boston gallon	-	58568,53	29,8	44,0					58544,0		
		Baltimore do.	224,08	58690,9	-						58566,36		
	18	Richmond do.	226,55	57826,89	30,096	54,2	+ 0,214	0,0	57827,1	-	57802,9	57802,9	462423,2

EXPERIMENTS UPON THE EXPANSION OF WATER AND MERCURY.

141. Though the full account and discussion of the experiments, which I have established, upon the expansion of mercury and water by the temperature, cannot be presented here, it may be agreeable, for whoever may take interest in the subject in general, that I place here yet a series of experiments made with the smaller mercury balance, and one made with the largest water balance of glass, from which the reductions were taken when needed; and, as relates to the water, the law of it may be calculated.

142. The observations give, of course, the difference between the expansion of glass and mercury, or water, by the effect upon the weight, which was required to make the equilibrium at different temperatures. I shall yet in time make the determination of the expansion of the glass. I found the specific gravity of a piece of the glass, taken from a bulb that had failed in the blowing, to be = 3,1314 by a first approximate experiment; this is lighter than the English flint glass: but I shall yet make more careful determinations.

As both these series of observations are made upon quantities of somewhat considerable weight, and with care, they may afford pretty satisfactory accuracy. How these observations were made, has already been stated. Their extent goes as far as the variation of the temperature in one year, in a room separated for the purpose, afforded. I should suppose this mode of observing, all being rested by the slow, natural effect, to be preferable to the production of artificial temperatures, that would be more transient, and under more accessory influences, from a surrounding medium of a different temperature.

143. To scrutinize these observations, with the view of clearing the calculations from error, I have projected the line which they represent, which for the mercury forms a straight line, as both mercury and glass expand uniformly. For the water, the expansion of the glass being uniform, and that of the water progressive, there results a curve with two unequal branches, as must be expected; because water expanding both above and below the maximum density, the curve presents below that point the *difference between the expansion* of the water and *the contraction* of the glass, and above that point the *difference between the expansion of both;* these lines are represented in a reduced scale, fig. 21.

144. Taking the results of the observation upon the mercury balance from the table of the following section, by combining the observations, giving about from 4° to 6° F. difference of temperature, in succession from the temperature of about 25° to that of 92°, which was the highest observed, they furnish a number of results, the mean of which gives 36.62 grains for the variation of weight in every degree of the variation of Fahr thermometer, and accepting the whole weight of mercury displaced at 32° = 416565 grains, the fraction $\frac{36,62}{416565} = 0,0000879094$, presents the resulting proportional difference of weight corresponding to the difference of effect of temperature, upon mercury and glass, for 1° Fahrenheit.

145. Of the experiments with the glass bulb No. 1 in water, I shall simply transcribe all the observations themselves, with the barometric correc-

tions, that these may be recalculated by whoever may wish to take results out of them upon another ratio of the barometric reduction.

The thermometers of Fisher were constructed purposely to give decimals of degrees; the degree is about one-fourth of an inch long, and they are divided to every two decimal parts of the degree.

These two examples of my observations upon this subject will suffice to give an idea of the manner in which they were all conducted, without entering into the details of their reduction; they will be all calculated and reduced to comparison and to one general result, in proper time, for the use, in the construction of standards, for which they are intended.

146. The water having no expansion at maximum density, while the glass, or metal, expands always uniformly the point of temperature at which any bulb takes the greatest weight, must be above the temperature of this maximum; this will be found by the table of § 127 to have occurred in all glass bulbs at 41°,6, the extreme variation between these different bulbs being only 0,15 of a degree Fahr., within which I suppose no thermometer may be said to be certain.

For the copper this temperature was given 44°,6, and bulbs of any other metal will of course indicate another temperature, according to their expansion; the temperature of the maximum density of the water, determined independently, I found to be, like indicated by Mr. Tralles, 39°,8 Fahr. Hence the temperature at which a vessel of any material holds the most distilled water, or displaces the most, which is the same thing, is different, and properly to be distinguished, from that of the maximum density of the water itself.

When the water in the jars had ice, the thermometers always stood at 33°, and even higher, without any decided regularity.

It will be observed that the curve has, at each side of the maximum, a place where it goes nearly parallel to the line of the degrees; this indicates the temperature where the material of the bulb and the water have the same expansion, between these and the maximum, the expansion of the water gains. It will also be observed that the expansion of the water, on approaching towards the ice point, is very rapid, and that in general between 32° and the maximum the expansion is as great as between this and about 54°. These experiments have given occasion to various peculiar observations and remarks, which will be noticed in their place when giving a full, detailed account of the experiments made with all the different balances.

147. *Data for the change of weight of mercury by the change of temperature, observed with the smaller mercury balance, in the order of temperature.*

Therm. Fahr.	Weight of the mercury displaced.	Therm. Fahr.	Weight of the mercury displaced.
24°,89	416805,75	60°,61	415513,18
31 ,64	569,75	61 ,38	475,75
32 ,18	551,75	61 ,88	458,76
33 ,37	503,56	62 ,24	453,76
33 ,98	484,15	62 ,6	434,13
34 ,50	460,25	63 ,00	417,86
35 ,42	4[illegible]1,15	63 ,23	408,77
35 ,78	415,15	63 ,13	380,75
36 ,77	383,45	63 ,49	357,76
37 ,61	355,52	65 ,66	329,10
37 ,94	340,75	66 ,45	291,10
38 ,05	332,75	67 ,64	254,76
38 ,48	322,75	68 ,49	2[illegible]4,28
38 ,61	314,25	69 ,48	179,44
38 ,90	303,75	69 ,80	172,44
39 ,20	295,75	70 ,45	135,10
39 ,53	281,25	71 ,55	102,10
39 ,74	275,95	72 ,51	415063,33
40 ,13	259,45	73 ,00	51,11
40 ,83	232,12	73 ,58	25,08
41 ,12	222,75	74 ,82	414985,28
41 ,34	214,08	76 ,87	907,41
41 ,90	195,15	77 ,00	896,42
42 ,44	175,75	78 ,35	859,77
43 ,16	152,15	80 ,24	780,41
44 ,24	105,75	81 ,78	715,25
44 ,75	416085,25	82 ,40	690,75
45 ,20	70,75	85 ,33	587,27
45 ,54	63,75	86 ,72	542,60
46 ,18	39,25	88 ,11	494,45
48 ,60	415950,42	89 ,96	424,68
49 ,46	919,75	92 ,19	414341,83
49 ,57	915,25		
50 ,04	891,75		
50 ,41	880,63		
50 ,54	880,75		
50 ,79	873,10		
51 ,00	860,75		
51 ,24	853,25		
51 ,66	841,75		
52 ,25	814,75		
52 ,44	810,75		
52 ,88	787,75		
53 ,35	780,42		
53 ,87	755,75		
54 ,33	735,42		
55 ,08	709,25		
55 ,94	415691,76		

148. *Collection of results of the loss of weight of the largest water balance No. 1, with basin No. 1, by the change of temperature, with the corrections for the barometer.*

Date.	Sum of balance and weight in Trought. grains.	Barometer.		Thermometers.				Weight at 30″ barom. in Trought. grains.
		Stand.	Reduc.	Upper.	Lower.	Differ. +	Mean. Fahr.	
1831.								
July 2	227391,93	30″,372	+3,390	74,8	73,7	1,1	74,25	227395,32
	81,73	,360	+3,233	74,9	74,3	0,6	74,6	84,96
	80,23	,355	+3,188	75,0	74,1	0,9	74,55	83.42
3	227403,63	,384	+3,443	74,0	73,4	0,6	73,7	227407,07
	371,23	,333	+2,986	75,3	74,7	0,6	75,0	374,22
	363,63	— ,—	+2,986	75,5	74,7	0,8	75,1	366.62
	363,23	,298	+2,672	75,6	74,8	0,8	75,15	365,90
4	374,23	,320	+2,869	75,0	74,5	0,5	74,75	377,10
	333,88	,300	+2,690	76,9	75,5	1,4	76,2	336,57
	264,22	,241	+2,238	79,0	78,0	1,0	78,5	266,46
	270,62	,200	+1,793	78,95	78,1	0,85	78,52	272,71
5	317 78	,150	+1,345	77,0	76,6	0,4	76,8	319,12
	271,22	,107	+0,959	78,7	77,9	0,8	78,3	272,18
	350,58	,047	+0,421	75,9	75,5	0,4	75,7	351,00
	347,58	—		76,0	75,4	0,6	75,7	348,00
	333,08	—		76,5	75,9	0,6	76,2	333,50
9	350,46	29 ,939	—0,628	76,0	75,5	0,5	75,75	349,83
	348,96	—		76,1	75,7	0,4	75,9	348,33
	335,46	—		76,4	75,8	0,6	76,1	334,83
	326,46	29 ,863	—1,227	76,9	76,2	0,7	76,55	325,23
10	465,97	30 ,169	+1,515	71,7	71,15	0,55	71,42	467,48
	472,64	—	+1,515	71,4	70,7	0,7	71,05	474,15
	479 67	,163	+1,461	71,0	70,4	0,6	70,7	481,13
11	527,27	,385	+3,452	68,9	68,4	0,5	68,65	530,72
4 therm.	545,77	,375	+3,363	68,3	68,1	0,2	68,2	549,13
19	236,30	,002	+0,002	79,9	79,92	—0,02	79,91	236,30
	210,80	29 ,976	—0,215	80,8	80,3	0,5	80,55	210.59
	155,44	,959	—0,448	82,65	82,22	0,4	82,43	154,99
	237,80	,961	—0,349	80,0	79,55	0,45	79,78	237,45
	212,80	,944	—0,502	80,85	80,23	0,6	80.54	212,30
	182,94	,891	—0,903	81,7	81,37	0,3	81,53	182,04
	133,44	,868	—0,932	83,4	82,9	0,5	83,15	132,51
21	257,10	,620	—3,406	79,5	79,25	0,25	79,37	253,69
	214,30	,932	—0,610	80,67	80,42	0,25	80,55	213,69
	189,80	,890	—0,985	81,55	81,35	0,2	81,45	188,82
23	224,80	,809	—0,977	80,4	80,05	0,35	80,22	223,82
	155,44	,784	—1,887	82,55	82,52	0,03	82,53	153,55
27	271,60	30 ,141	+1,344	78,85	78,6	0,25	78,72	272,94
	165.64	,088	+0,107	82,35	81,6	0,75	82,0	165.75
	151,94	,760	+6,814	82,72	82,42	0,3	82,57	158.75
28	185,44	,067	+0,601	81,67	81,27	0,4	81.4	186,00
	111,65	,036	+0,3 3	83,9	83,4	0,5	83,65	111,97
	030,65	,007	+0,063	86,2	86,27	—0,07	86,23	030,71
29	138,44	,200	+1,793	83,0	82,9	0,1	82,95	140,23
	227201,44	30 ,202	+1,811	81,2	81,1	0,1	81,15	227203,25

Largest Water Balance No. 1.

Date.	Sum of balance and weight in Trought. grains.	Barometer.		Thermometers.			Mean Fahr.	Weight at 30″ barom. in Trought. grains.
		Stand.	Reduct.	Upper.	Lower.	Differ. +		
1831.								
July 30	227203 80	30,161	+1,525	81,0	81,0	0	81	227205,32
	194,80	—,152	+1,363	81,45	80,8	0,65	81,12	196,16
August 5	488,80	—,020	+0,179	70,62	70,25	0,37	70,43	488,98
	491 80	—,—	+0,179	70,6	70,0	0,6	70,3	491,98
	511,44	,029	+0,269	69,8	69,4	0,4	69,6	511,71
	492,94	,020	+0,179	70,85	70,45	0,4	70,65	493,12
	463,94	,005	+0,045	71,95	71,4	0,45	71,67	463,98
6	465.44	,071	+0,717	71 65	71,65	0,0	71,65	466,16
	473,44	,113	+0,989	71,4	71,4	0,0	71,4	474,43
	480,44	—,094	+0,842	70,9	70,7	0,2	70,8	481,28
8	518,84	29,917	—0,744	69 67	69,27	0,4	69,47	518,10
	521,74	—,900	—0,896	69,32	69,2	0,12	69,26	520,84
9	523,27	30,117	+0,992	69,25	69,05	0,2	69,15	534,26
	506,77	,160	+1,434	70,0	69,5	0,5	69,75	508,20
	459,32	,168	+1,506	72,05	71,45	0,6	71,75	462,75
10	442,94	,351	+3,227	72,75	72,25	0,5	72,50	446,17
	393,11	,290	+2,600	74,77	74,02	0,75	74,40	395,71
4	384,01	,071	+0,717	74,8	74,65	0,15	74,72	384,73
	397,65	,065	+0,583	74,25	74,10	0,15	74,17	398,23
	227404,65	30,011	+0,099	74 0	73,90	0,1	73,95	404,75
				All Fisher's thermom. large basin No. 1.				
October 1	227714,22	30,302	+2,710	58,85	58 42	0,43	58,65	227716,93
	701,02	,274	+2,459	59,8	59,4	0,4	59,6	703,48
	678,38	,207	+1.858	61,27	60,55	0,72	60,91	680,24
2	680,48	,103	+0,924	61,55	61,30	0,25	61,42	681,40
	645,36	,088	+0,790	63,25	62,37	0,88	62,81	646,15
3	602,36	.047	+0,421	65,5	64,1	1,4	64,8	602,78
	603 38	29,974	—0,233	65,18	64,95	0,23	65.06	603,15
4	509,72	,811	—0,977	69,5	69,3	0,2	69,4	508,74
	434,36	,680	—2,781	72,7	71,9	0,8	72,3	431,58
5	614,36	,711	—2,594	64,45	64,17	0,28	64,31	611,77
6	728,39	30,033	+0,296	57,87	57,8	0,07	57,83	728,69
	728,39	,070	+0,628	57,75	57,8	—0,05	57,77	728,92
	728,39	—,097	+0,870	57.8	57,8	0,	57,8	729,26
7	770,39	,507	+4,540	54,32	54,28	0,04	54,3	774,93
	738,51	,177	+1,588	57,17	56,58	0,59	56,87	740,10
10	684,03	29,825	—0,964	60,25	60,02	0,23	60,13	683,07
	786,03	,748	—2,262	52,2	52,19	0,01	52,2	783,77
11	809,53	,794	—1,849	50,85	51,0	—0,15	50,92	807,68
12	811,19	30,129	+1,157	50,08	50,1	—0,02	50,09	812,35
	799,69	,100	+0,897	51.8	51,2	0,6	51,5	800,59
13	792,19	,235	+2,109	52.32	52,21	0,11	52,26	794,30
	774,53	,090	+0,808	54,7	54,51	0,19	54,60	775,34

Largest Water Balance No. 1.

Date.	Sum of balance and weight in Trought. grains.	Barometer.		Thermometers.			Mean.	Weight reduced to 30″ barom. in Trought. grains.
		Stand.	Reduct.	Upper.	Lower.	Diff. +		
1831.								
Octob. 14	227743,39	30,138	+1,238	56,52	56,28	0,24	56,4	227744,63
	708,53	,123	+1,103	58,53	58,21	0,32	58,37	709,63
	697,03	,135	+1,235	60,5	59,0	1 5	59,75	698,26
15	709,03	,382	+3,427	59,3	59,25	0,05	59,28	712,46
16	687,78	,335	+3,006	60,35	60,21	0,14	60,28	690,79
	681,03	,293	+2,630	60,8	60,6	0,2	60,7	683,66
17	651,76	,259	+2,270	62,6	62,4	0,2	62,3	654,03
18	619,88	29,972	—0,251	64,3	64,07	0,23	64,18	619,63
	575,36	,940	—0,538	66,8	65,9	0,9	66,35	574,82
20	724,36	30,235	+2,109	58,0	58,0	0,0	58,0	726,47
	723,36	,217	+1,791	58,2	57,9	0,3	58,05	725,15
	714,36	,164	+1,472	58,72	58,5	0,22	58,61	715,83
21	726,03	,195	+1,750	57,83	57,83	0,0	57,85	727,78
	694,03	,130	+1,166	60,52	60,48	0,04	60,50	695,20
24	600,38	29,937	—0,565	65,2	65,2	0,0	65,2	599,82
	618,00	30,033	+0,296	64,51	64,62	—0,11	64,56	618,30
25	809,69	,218	+1,956	50,6	50,5	0,1	50,55	811,65
30	808,19	,010	+0,090	50,81	50,77	0,04	50,79	808,28
31	786,53	29,729	—2,504	51,22	51,01	0,21	51,11	784,03
	789,03	,639	—3,320	52,17	51,8	0,37	52,0	785,71
Novem. 1	784,03	,827	—1,552	53,2	53,19	0,01	53,2	782,48
2	809,03	30,049	+0,440	50,6	50,6	0,0	50,6	809,47
3	808,53	,199	+1,785	50,62	50,62	0,0	50,62	810,31
	807,53	,151	+1,435	50,7	50,65	0,05	50,67	808,96
	805,03	,147	+1,319	51,1	51,03	0,07	51,06	806,35
4	824,53	,110	+0,986	48,4	48,39	0,01	48,4	825,52
	816,53	,053	+0,476	49,65	49,3	0,35	49,34	817,01
5	822,03	,242	+2,172	48,81	48,8	0,01	48,80	824,17
	811,03	,215	+1,929	49,15	49,0	0,15	49,07	812,96
	815,03	,195	+1,750	50,02	49,79	0,23	49,40	816,78
6	829,23	,309	+2,774	47,7	47,8	—0,1	47,75	832,00
	826,43	,217	+1,947	48,15	48,1	0,05	48,12	828,38
7	828,53	,152	+1,365	47,7	47,65	0,05	47,67	829,90
	821,53	,079	+0,709	49,2	48,56	0,66	48,38	822,24
8	812,03	,299	+2,684	50,35	50,3	—0,05	50,32	814,71
	802,53	,251	+2,333	51,5	51,2	+0,3	51,35	804,86
14	812,53	29,831	—1,516	50,2	50,3	—0,1	50,25	811,01
15	821,53	,916	—0,754	48,82	48,98	—0,16	48,9	820,78
	821,03	,844	—1,391	49,2	49,1	+0,1	49,15	819,64
16	828,03	,980	—0,179	48,15	48,25	—0,1	48,2	827,85
	824,03	,880	—0,916	48,75	48,7	+0,05	48,72	823,11
17	836,03	,929	—0,718	46,35	46,35	0,0	46,35	835,31
	834,43	,875	—1,122	46,7	46,6	0,1	46,65	833,31
18	824,73	,670	—2,962	48,7	48,4	0,3	48,55	821,77
	819,03	,549	—4,049	49,4	48,95	0,45	49,17	814,98
21	826,23	,425	—5,163	48,4	48,25	0,15	48,32	821,07
	844,53	,371	—5,648	42,17	42,3	—0,13	42,23	838,88
	844,03	,448	—4,957	41,8	41,8	0,0	41,8	839,07
	843,53	,520	—4,310	41,2	41,4	—0,2	41,3	839,22
	842,53	,675	—2,918	40,4	40,66	—0,26	40,53	839,61

Largest Water Balance No. 1.

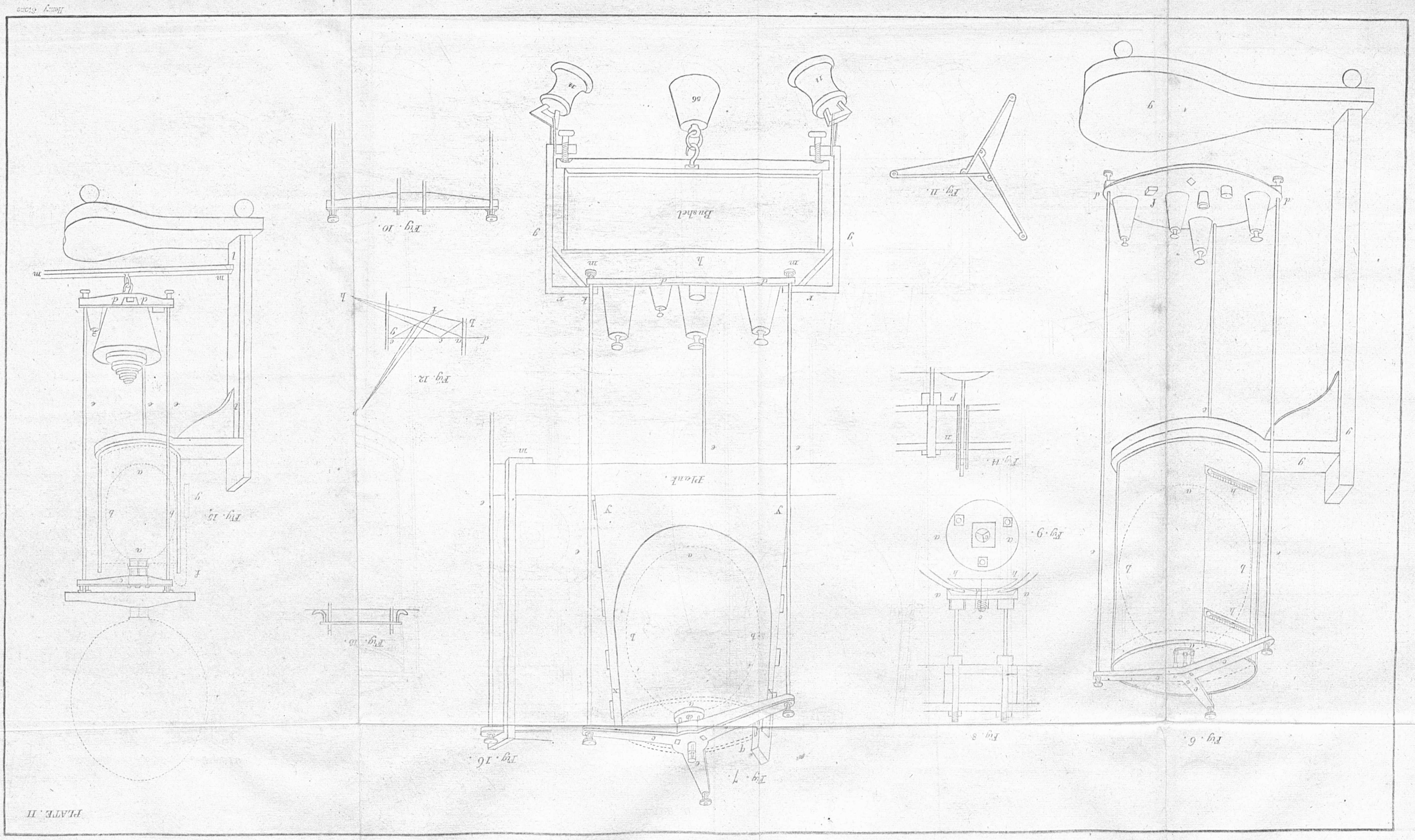
Date.	Sum of balance and weight in Trought. grains.	Barometer.		Thermometers.				Weight at 30″ barom. in Trought. grains.
		Stand.	Reduct.	Upper.	Lower.	Differ. +	Mean Fahr.	
1831.								
Nov. 23	227835,03	29″,971	—0,260	38,0	38,8	—0,8	38,4	227834,77
	835,73	30 ,032	+0,287	38,51	38,93	—0,42	38,72	836,02
	832,73	29 ,976	+0,215	38,6	39,2	—0,6	38,9	832,94
	838,73	30 ,154	+1,392	39,2	39,95	—0,75	39,57	840,12
24	838,53	30 ,260	+2,335	39,4	39,9	—0,5	39,65	840,86
27	842,83	30 ,037	+0,332	40,97	41,32	—0,35	41,14	843,16
	842,16	29 ,597	—3,619	42,3	42,27	+0,03	42,28	838,54
	842,15	,591	—3,673	42,6	42,4	0,2	42,5	838,48
	842,83	,581	—3,689	42,8	42,67	—0,13	42,73	839,14
	843,83	,659	—3,142	43,35	43,03	—0,32	43,19	840,69
28	843,23	,888	—0,989	41,67	41,9	—0,23	41,8	842,24
	842,03	,876	—1,113	40,35	40,12	+0,23	40,23	840,92
	841,53	,857	—1,284	40,1	40,27	—0,17	40,20	840,25
	839,53	,818	—1,634	39,25	39,35	—0,1	39,30	837,90
	838,93	,793	—1,859	39,05	39,47	—0,42	39,26	837,07
29	Icecoat { 817,03	,925	—0,673	34,46	36,25	—1,79	35,33	816,36
	33,6 { 812,73	,998	—0,018	33,85	35,75	—1,9	34,8	812,71
	811,33	30 ,021	+0,269	33,8	35,4	—1,6	34,6	811,60
	809,73	,104	+0,934	33,65	35,57	—1,92	34,61	810,66
	799,73	,253	+2,272	33,0	34,0	—1,0	33,5	802,00
30	Ice { 784,18	,319	+2,864	32,2	32,2	0,0	32,2	787,04
	coat- { 786,43	,280	+2,514	32,2	32,6	—0,4	32,4	788,94
Dec. 1	ing { 788,43	,280	+2,514	32,24	32,9	—0,66	32,57	790,94
	799,03	,280	+2,514	32,9	34,15	—1,25	33,52	801,54
	806,53	30 ,160	+1,437	33,35	34,8	—1,45	34,07	807,97
	817,43	,151	+0,951	34,92	35,87	—0,95	35,4	818,38
	825,03	,084	+0,915	36,25	36,9	—0,65	36,57	825,94
2	825,53	,122	+1,095	36,07	37,1	—1,03	36,58	826,62
	827,13	29 ,978	—0,195	36,27	37,21	—0,94	36,74	826,94
3	826,73	,719	—2,603	36,35	37,2	—0,85	36,78	824,13
	829,63	,667	—2,990	37,11	37,85	—0,74	37,48	826,64
4	833,03	,589	—3,691	37,7	38,4	—0,7	38,05	829,34
	836,73	,500	—4,490	38,57	39,17	—0,6	38,87	832,24
	838,73	,553	—4,014	38,82	39,5	—0,68	39,16	834,72
	838,73	,570	—3,861	38,97	39,6	—0,63	39,28	834,87
5	Ice { 797,33	30 ,097	+0,871	32,2	34,12	—1,92	33,16	798,20
	light { 793,63	,087	+0,781	32,32	33,9	—1,58	33,11	794,41
	809,53	,340	+3,053	34,29	35,15	—0,86	34,72	812,58
6	824,03	,354	+3,179	36,05	36,85	—0,8	36,45	827,21
	815,13	,324	+2,909	35,45	35,65	—0,2	35,55	818,04
	821,03	,319	+2,864	35,4	36,2	—0,8	35,8	823,89
7	818,23	,262	+2,353	34,8	35,75	—0,95	35,27	820,58
	821,43	,216	+2,939	35,4	36,3	—0,9	35,85	824,37
8	817,63	,220	+1,975	36,0	37,0	—1,0	36,5	819,60
	819,63	,250	+2,245	36,17	37,3	—1,13	36,73	821,87
	830,43	,197	+1,769	36,8	38,0	—1,2	37,4	832,20
10	839,03	,429	+3,852	38,7	39,6	—0,9	39,15	842,88
	842,03	,417	+3,744	39,07	40,0	—0,93	39,53	845,77
	841,23	,430	+3,861	40,27	40,25	+0,02	40,26	845,09
	227842,43	,427	+3,834	40,35	40,33	+0,02	40,34	227846,26

Largest Water Balance No. 1.

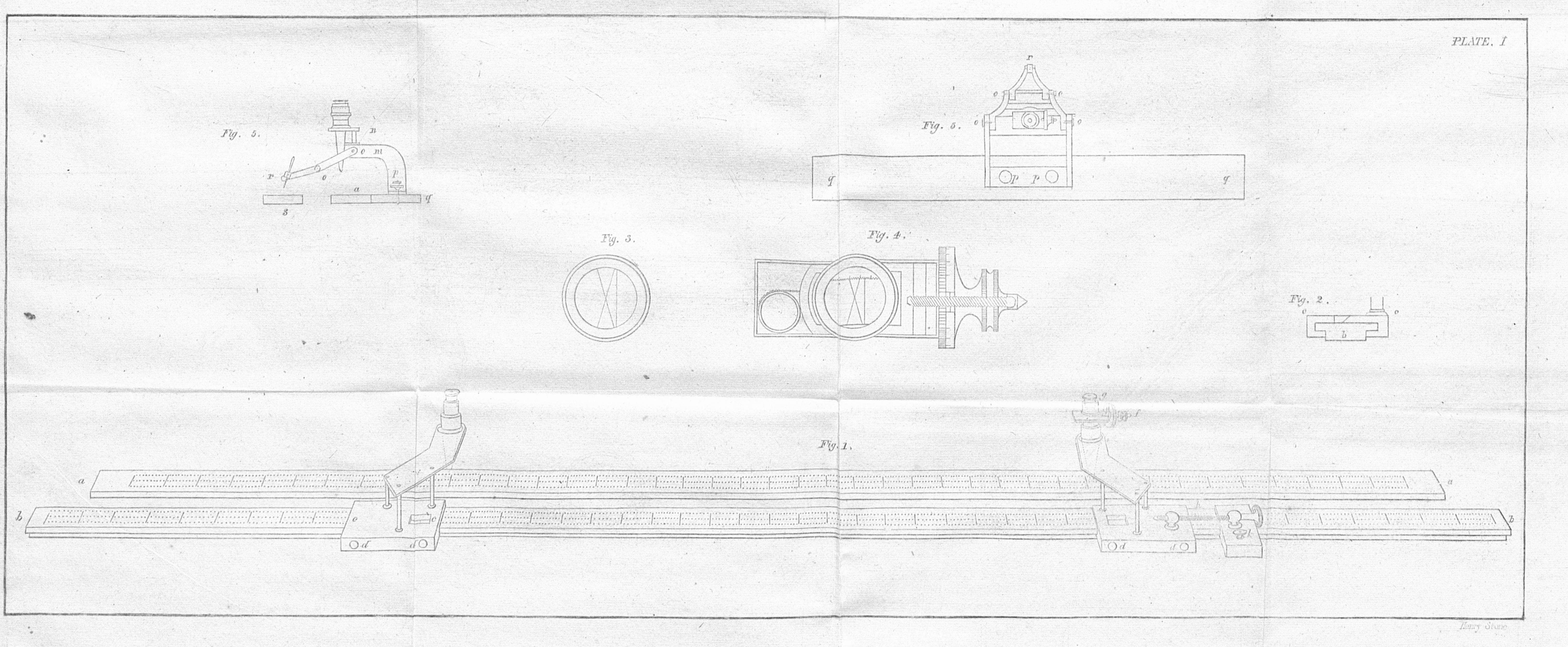
Date.	Sum of balance and weight in Trought. grains.	Barometer.		Thermometer.				Weight at 30″ barom. in Trought. grains.
		Stand.	Reduct.	Upper.	Lower.	Differ. +	Mean.	
1831.								
Decem. 11	227841,33	30,473	+4,247	40,4	40,4	0	40,4	227845,58
	843,83	,353	+3,170	41,7	41,52	+0,18	41,61	847,00
12	841,03	,390	+3,502	40,0	40,2	—0,2	40,1	844,53
	842,23	,364	+3,269	40,3	40,4	—0,1	40,35	845,50
15	842,03	,391	+3,591	41,21	40,4	+0,81	40,80	845,62
16	823,73	,097	+0,871	35,0	37,17	—2,17	36,08	824,60
	824,03	29,921	—0,709	35,3	37,25	—1,95	36,27	823,32
17	833,33	,692	—2,765	36,02	39,0	—2,98	37,51	830,47
	832,73	,750	—2,245	36,95	38,6	—1,66	37,77	830,49
	820,53	30,163	+1,464	34,7	36,52	—1,82	35,61	821,99
18	Ice 802,03	,450	+4,041	32,55	34,4	—1,85	33,47	806,07
	812,03	,358	+3,218	34,15	35,6	—1,45	34,87	815,25
	818,03	,300	+2,694	34,85	36,1	—1,25	35,47	820,72
19	819,63	,042	+0,377	35,05	36,2	—1,15	35,62	820,01
	825,53	,188	+1,688	36,55	36,87	—0,32	36,71	827,22
21	835,33	29,654	—3,107	39,12	39,35	—0,23	39,23	832,22
	839,53	,896	—0,934	40,6	40,17	+0,43	40,38	838,60
22	839,73	30,336	+3,017	39,8	40,17	—0,37	39,98	842,75
	817,73	,350	+3,143	34,37	36,27	—1,9	35,32	820,87
24	823,93	29,793	—1,859	36,55	36,92	—0,37	36,73	822,07
	827,03	,757	—2,182	37,05	37,4	—0,35	37,22	824,85
25	844,53	30,112	+1,006	41,35	41,0	+9,35	41,17	845,54
	843,03	29,928	—0,646	41,9	41,62	+0,28	41,76	842,38
26	844,83	,862	—1,239	40,9	41,0	—0,1	40,95	843,59
27	844,93	,855	—1,302	40,17	40,25	—0,08	40,21	843,63
28	842,23	,523	—4,283	40,20	39,66	+0,54	39,43	837,95
	843,23	,468	—4,777	40,50	40,32	+0,18	40,41	838,45
29	227844,73	,667	—2,99	40,85	40,61	+0,24	40,73	227841,74

WASHINGTON CITY, *29th June*, 1832.

F. R. HASSLER.



Harry Stone



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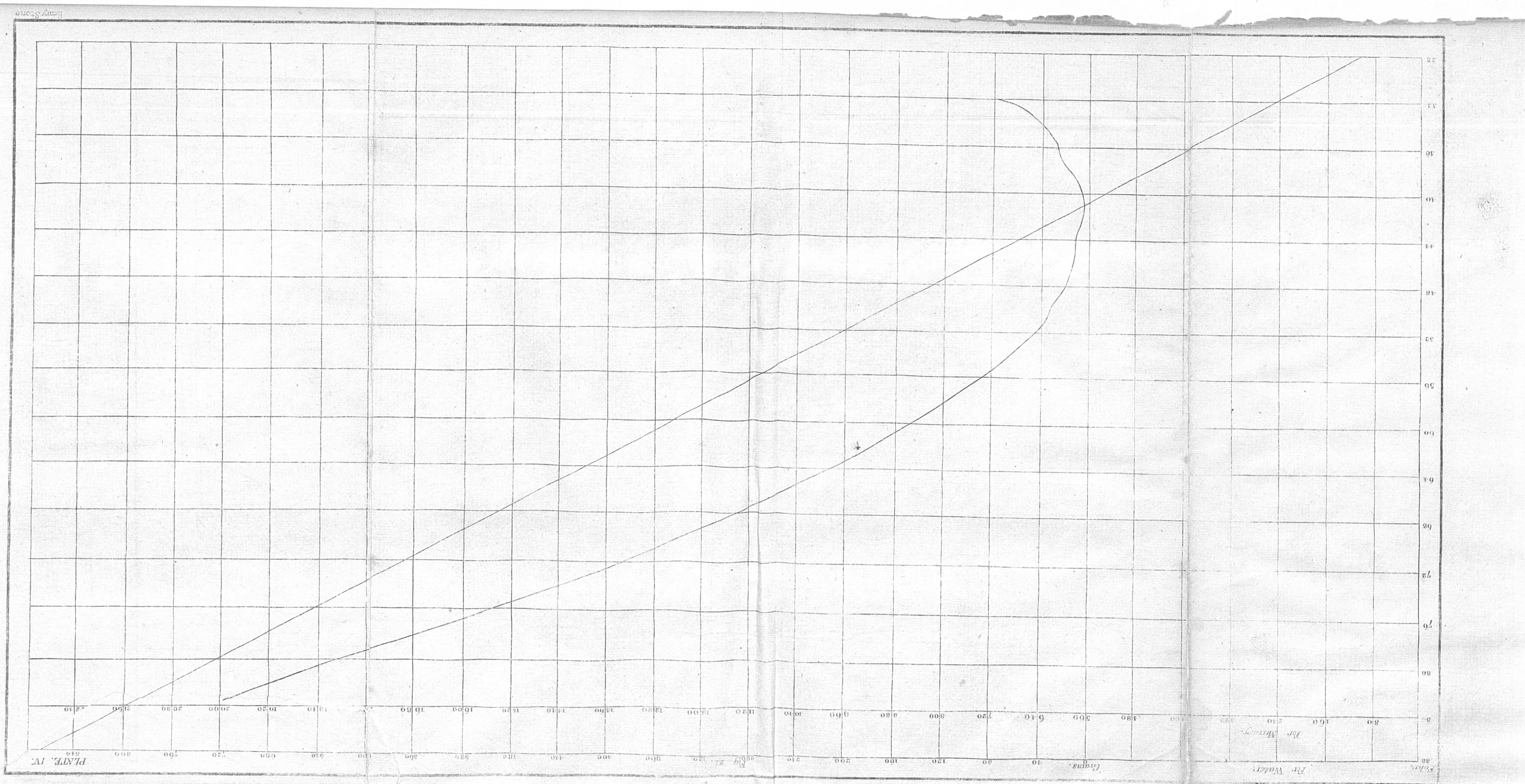

PLATE. III.