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concentration-diagram the liquid curve of the region L-G (curve Fl in fig. 1) going through F, has in the P,T-diagram the same tangent in F as the evaporationline of the liquid F starting from F.

If we compare the P,T-diagram of the solutionpaths of a binary compound F (fig. 2) with those of a ternary compound F [fig. 4 (IV) and 1 - 3 (V)], then we see very great differences in the vicinity of the point F. We find these differences also in the concentration-diagrams. When viz. in fig. 1. in the point F we construct tangents to the curves Fl, Fk and Fs going through the point F, three different tangents arise. If F is a ternary compound, as e. g. in fig. 1 (IV), then these curves touch one another in F and the three tangents coincide in the line XFY.

All this is based on the following. When F is a binary compound, a new substance must be added, in order to trace a ternary solutionpath from F. When, however, F is a ternary compound, we add no new substance in order to trace a solutionpath, from F, but substances, which are already present in the melted F.

(To be continued).

Physics. *"An apparatus for the determination of gas isotherms up to about* 3000 *atms."* VAN DER WAALS-fund researches N°. 5. By Prof. PH. KOHNSTAMM and K. W. WALSTRA. (Communicated by Prof. VAN DER WAALS).

(Communicated in the meeting of December 27, 1913).

As is known the material for testing the theory of the equation of state at very high pressures consists almost exclusively of what AMAGAT has published in his famous papers. It seems desirable for different reasons to extend this material. Quite apart from the desirability to get to know the behaviour of other gases than those examined by AMAGAT — we think in the first place of the mon-atomic gases — AMAGAT's work itself gives rise to different questions, which can only be decided by means of new experiments.

First of all it is known that AMAGAT does not give the direct results of his observations; he only publishes the results of a graphical interpolation between these observations. The question rises how great the deviations are between the interpolated and the real observations, and whether another way of interpolation had been possible. Nor can the probable experimental error of AMAGAT's observations be inferred from his experiments. And it has finally appeared that there are discrepancies between some of AMAGAT's results inter se, as well as between AMAGAT's observations on hydrogen at high pressures on one side, and SCHALKWIJK's very accurate observations for low pressures on the other side[1]).

For all these reasons it seemed desirable to construct an apparatus with which gas-isotherms might be measured up to the highest attainable pressures. And as it is self-evident that the cost of such a set of apparatus could not be defrayed from the ordinary means of a laboratory, the board of the VAN DER WAALS-fund resolved already in 1904 to grant money for this purpose. It is owing to the strong support given by the VAN DER WAALS-fund all these years that we are now able to communicate the first results. Our cordial thanks are due to the board of the VAN DER WAALS-fund, and further to all who helped to support the fund.

In the following pages we shall of course not give an account of all the difficulties that confronted us, and the way in which they were finally surmounted. We shall confine ourselves to a description of the arrangement in its present form, and only mention in a few words now and then what considerations have led to this final form. We shall successively discuss the measurement of the pressure, the volume, and the temperature.

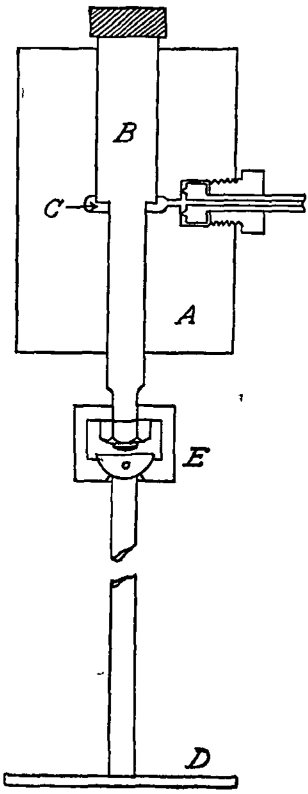

Fig. 1.

A. *Measurement of the Pressure.*

The measurement of the pressure in absolute measure takes place by means of SCHAFFER and BUDENBERG's pressure balance. In principle this apparatus consists of a steel piece A (fig. 1) with cylindric boring, which at about half the height passes into a wider cylindric boring. A differential piston B fits in this boring, which piston is ground into the two cylindres with the utmost care. By means of a side tube the cavity C can be connected with the space where the pressure is to be measured. This side tube and the space under the piston are filled with machine oil. By means of a mould,

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[1]) BRINKMAN, Thesis for the Doctorate, Amsterdam p. 34.
SCHALKWIJK. Thesis for the Doctorate, Leiden 1908, p. 120 et. seq.
KEESOM. Thesis for the Doctorate, 1904, p. 57.

which has been prepared and measured with the utmost care, the two apertures in the steel piece A and the two sections of the cylindre B are ground in such a way that the difference between the larger and the smaller section has a definite size, e.g. 1 cm². If we now suppose a pressure e.g. of 800 kg. per cm² to prevail in the space C, and no friction to be present, the piston B would be forced upwards with a force of 800 kg. If on the plate D, which is connected with B by means of the socket joint E we put so many weights that they together with B, D, E and the joining-rod F weigh exactly 800 kg., the whole apparatus is exactly in equilibrium. If the total weight amounts to 801 kg. — we still suppose absence of friction — the piston descends till the liquid in C and the space in connection with it is compressed so much that there prevails a pressure of 801 kg. per cm² in C. If the total weight amounts to 799 kg., the piston rises till the pressure in C has fallen to 799 kg. per cm². On account of the strong friction of the piston very tightly fitting in the cylindre nothing, however, is to be observed of these movements. In fact the plate D can easily be loaded with 10 or 20 kg. too much or too little without any movement being perceived on a manometer connected with C. If, however, the piston B with the plate D and all the weights lying on it are made to rotate round their axis, it appears that this rotation has practically annihilated all the friction. It will appear from the description of our experiments that the remaining friction will lie far below 10 gr. at low pressures, and that it can certainly not be so much as 50 gr. for pressures of 2500 kg.

We cannot account for this most remarkable property, though it is of course clear that the fact that C is filled with machine oil, and that this oil penetrates between piston and cylindre wall plays an important part in this. It is known that also in AMAGAT's manometer the great decrease of friction when the piston moves with respect to the cylindre wall is utilized. But in AMAGAT's manometer [1]) the piston must be moved to the left and the right by hand, also during the measurement. The mode of construction of SCHÄFFER and BUDENBERG's pressure balance evades this by making the whole mass of the weights, for the large model up to 1250 kg., for the small one up to 250 kg. rotate with the piston B. After these

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1) This manometer is generally called after DESGOFFE; according to AMAGAT, however, the first idea came from GALLY—CAZALAT. And we owe to AMAGAT the great improvement, which rendered the instrument for the first time adapted for really accurate measurements, nl. the free movability of the pistons.

weights have once been set rotating by the hand or in another way, the apparatus may be left to itself. The kinetic energy of the rotation is so great that the apparatus continues rotating for a considerable time, at any rate long enough to perform a pressure measurement. Only on account of this circumstance it is possible fully to avail oneself of the absence of friction in consequence of the rotation, for it appears that any, also the lightest, touch of the apparatus brings about increase or decrease of the pressure in C, as it is not possible in doing so not to exert a force on the piston B in vertical direction. If the space C is connected with a sensible manoscope (and the volumemeter itself served as such in our experiments) every touching of the piston, also the slightest, betrays itself immediately by a deviation of the manoscope. Measurements may, therefore, only be made when the apparatus is in rotation, and entirely left to itself.

A second circumstance, on account of which in our opinion SCHÄFFER and BUDENBERG's pressure balance may claim to be considered as an improvement compared with AMAGAT's manometer, is this that the differential piston as well as the cylindre consist of one piece, and can therefore be completely finished as a whole on the lathe. As is known AMAGAT's manometer makes use of two pistons of different section, which are connected with each other. In the vessel where the great pressure which is to be measured, prevails, there is a small piston, accurately ground in, and the force with which it is expelled is transmitted to a large piston, which can move in a second vessel; the pressure in this latter vessel is measured by means of mercury. In this construction it is, however, not to be avoided that the axes of the two pistons are not entirely each other's prolongation, which must give rise to wrenchings and frictions. To prevent these the pistons must, of course, not be so tightly ground in as would otherwise be possible. It is known that AMAGAT therefore uses molasses as transmission liquid in his manometer, because else the transmission liquid would flow away too quickly, whereas in SCHÄFFER and BUDENBERG's pressure balance thin machine oil suffices.

On the other hand SCHÄFFER and BUDENBERG's pressure balance shares a drawback with AMAGAT's manometer, which as far as I know, WAGNER ¹) was the first to point out in his investigation of an AMAGAT manometer. AMAGAT himself took as effective area of the piston, i. e. as area on which the pressure acts to the outside, simply the section of the piston itself. WAGNER, however, points out that the liquid which is pressed through between piston and cylindre

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¹) Thesis for the Doctorate. München 1904. Ann. d. Phys. (4) 15, p. 906.

wall exerts a friction force on the cylindrical surface of the piston, and that in consequence of this the force which drives the piston out must really be greater than the amount which can be calculated from the section of the piston and the pressure. Or in other words the effective area of the piston must be greater than the real section. By means of hydro-dynamic considerations WAGNER now comes to the conclusion that the difference will depend on the width of the cylindre in which the piston moves. Half the difference between piston and cylindre section will namely have to be added to the piston section to determine the true effective area. Hence WAGNER did not only very accurately determine the piston section, as AMAGAT did, but also the cylindre diameters (at least for the two small steel pistons which he used). The difference between the two diameters amounted to about 0,01 mm.; it is therefore by no means insignificant for a total amount of about 5 mm.

WAGNER has, however, also determined the effective area by a direct experimental way, by namely ascertaining with what weights the pistons must be loaded to balance a pressure which is directly measured by means of a mercury column. And he then arrives at a very remarkable result. For whereas the measurement yielded 5,128 resp. 4,076 mm. for the piston diameters, 5,138 resp. 4,088 for the cylindre diameters, which according to the above would give 5,133 resp. 4,082 for the effective area, the direct experimental equation yielded 5,127 resp. 4,076, i. e. exactly the sections of the pistons without any correction. Evidently WAGNER has not pointed this out, because in his first investigation the direct experimental determination of the effective area of the large piston of the AMAGAT-manometer yielded 40,189, whereas the section of the piston itself amounted only to 40.176.[1]). In a later investigation, however, which was undertaken in collaboration with P. P. KOCH[2]), WAGNER repeated these determinations. He now finds in measurements which he considers more accurate than the earlier ones again 5,128 for the effective area of the small piston, but 40.164 for that of the large one, i. e. even a little less than the real section. Accordingly these determinations cannot give support to the theory of the increase of the effective area in consequence of the friction on the cylindrical surface derived hydrodynamically. [3])

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[1]) l.c. p. 919.

[2]) Ann. d. Phys. (4) 31, p. 48.

[3]) Some particulars in BRIDGMAN's interesting experiments (Proc. Amer. Acad. XLIV p. 201) seem to point in the same direction, but whether this supposition is true cannot be inferred from the communication with certainty. We shall, therefore, not enter any further into this.

This question which is of fundamental importance for all absolute pressure measurement, cannot be considered as decided as yet. Nor can our experiments at this moment give a decision, because we have not yet been able to compare one of our pressure balances directly with an open manometer with transmission for sufficiently high pressures (60 to 100 atm.). The indirect comparison obtained by the very close agreement of our hydrogen-isotherm with that of SCHALKWIJK, seems to point in the same direction as WAGNER's experiments, that namely actually effective and real area coincide. Nevertheless a direct comparison remains, of course, a matter of the highest importance for all our measurements and we greatly hope, therefore, to be able to carry out a comparison before long.

In what precedes we have discussed the principle of SCHÄFFER and BUDENBERG's pressure balances. We should now discuss for a moment the execution of it in practice. For the lower pressures — up to 250 atm. — this is very simple indeed. The cylindre A (fig. 2) rests on a heavy cast tripod, which again is supported on a stand,

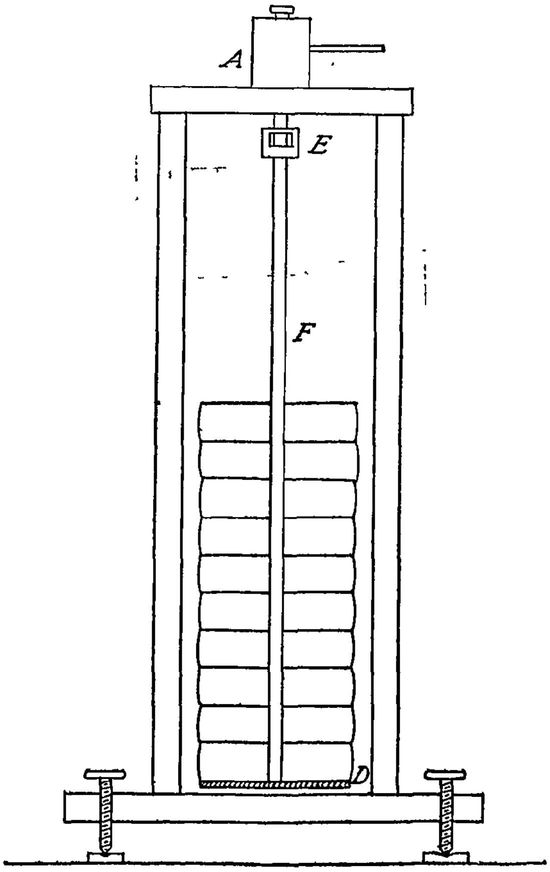

Fig. 2.

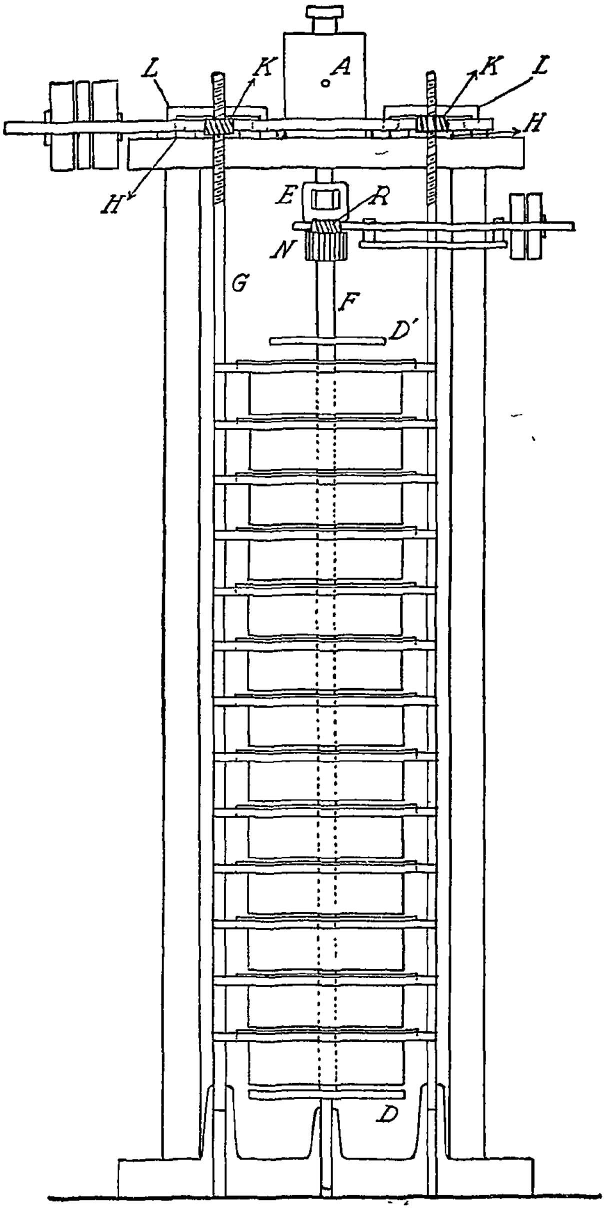

Fig. 3.

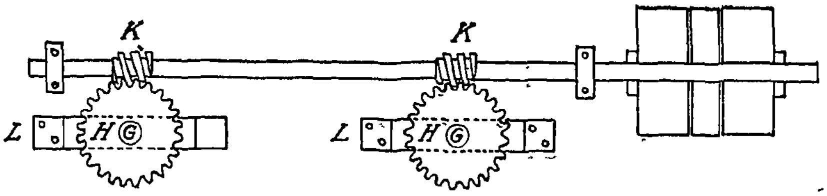

Fig. 3*a*.

which can be put in the required position by means of adjusting screws. On the plate *D* an iron weight is placed, weighing with *B*, *E*, *F*, and *D* together exactly 25 kg. Then plate-shaped weights of 25, 10 etc. to 1 kg. and lower are put on it with a slit, which enables them to slide round the rod *F*. The whole apparatus is set rotating by hand.

For higher pressures the gauge cannot be worked solely by the hand. The "head" of the pressure balance (the piece *A* with the piston *B*, fig. 1) is mounted here on an iron stand 2 m. high, which by accurate levelling has been adjusted, and rests on a separate heavy stone foundation. Weights of 100 kg. lie round the rod *F* (fig. 3) in rings, on which they rest. These rings are connected by means of two bars *G* and the distances between the rings are taken so that between two weights there always remains a space of 2 cm.

The rods *G* are provided at their upper ends with screw thread, and are in this way carried by the nuts *H* (fig. 3*a*) [1]), which rest on the top plate of the iron stand, and are fixed by bent pieces *L*. The nuts *H* are provided on the outside with teeth, in which a worm *K* catches. By means of this the nuts *H* can be turned, and in this way the rods *G* and all the rings attached to them can be adjusted higher or lower. When the rods are turned down, first the lowest weight will get to lie on the plate *D*; this weight has been taken so that together with the plate *D*, the rods *F* and *E*, and the piston it weighs exactly 100 kg. If the rods *G* are turned still lower down, another weight of exactly 100 kg. will rest on this weight etc. In this way the piston can in all be loaded with 1150 kg. If the worm is turned in the opposite direction, the ring-system rises, and lifts up the weights one after another, which relieves *D*. By means of a transmission with two loose pulleys and a fast pulley the worm is driven from a shaft, which in its turn is set going by an electromotor of 1 H.P. Two belts run over the loose pulleys, a crossed one and a straight one. By a simple adjusting apparatus either the one or the other can be transferred to the interjacent fast pulley, by which weights are put on or taken off. Smaller weights are put on by the hand on the plate *D'*, which is fastened on the rod *F*.

In the second place it is necessary to get a mechanical arrangement to set the pressure balance rotating. For this purpose a toothed wheel *M* [2]) (Fig. 3*b*) has been fixed on the rod *F*, which engages

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[1]) Fig. 3*a* gives a view from below, omitting the plate on which everything rests. In Fig. 3 the nuts *H* are hidden behind the worm *K* and the rod on which it is fastened.

[2]) In Fig. 3 *M* is hidden behind *N*.

a second toothed wheel *N*. *M* is about 32 mm. high, *N* only 23 mm. This is necessary because the toothed wheel *N* is rigidly adjusted at a fixed height, whereas *M* moves up and down with the rod *F*, and therefore with the piston *B* in the cylindre *A*, for so far as the cylindre *A* leaves room for it, i e. about $2^{1}/_{2}$ cm. The toothed wheels *M* and *N* must be able to engage each other at every position made possible by the space left.

By the plate *O* turning round *P*, *N* can now be put in two positions: so that its teeth catch in *M*, and so that the two toothed wheels are clear of each other. When once the weights have been well set rotating, *N* is placed in the latter position, and fixed, so that the toothed wheels no longer catch into each other, and the piston *B* therefore with the weights attached to it rotates perfectly freely, and no other forces act on it than gravity and the pressure of the liquid. *N* is driven by the worm *R*. The latter receives its motion by means of a transmission with fast and loose pulleys from the shaft, which is set going by the electromotor. To prevent the toothed wheels from breaking, or connections from being strained when the belt should be transferred from the fast to the loose pulley, the toothed wheels catching into each other and the weights being in strong rotation, *N* is provided with a free-wheel *S*, as is also in use for bicycles. It is therefore possible by setting the worm in motion, to make *N* and with it *M* and the weights rotate, but a rotation of *M* only sets *N*, and not the worm going.

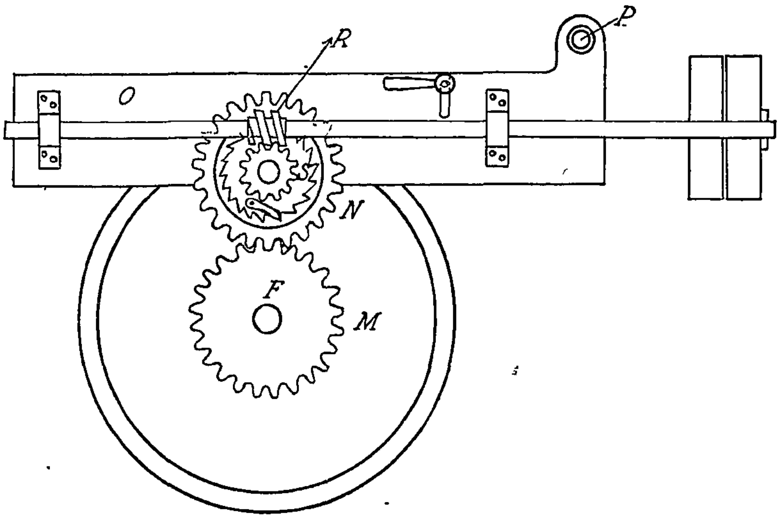

Fig. 3*b*.

It is self-evident that the pressure indicated by the pressure balance, is the pressure at C (fig. 1). The pressure at the place where one wants to know it, in casu at the place where the isotherm measurements take place, must be derived from that in C by means of a correction for the hydrostatic pressure difference in C and the first-mentioned place.

The measurement of the pressures above 1250 kg. takes place in exactly the same way, only then the "head" A is exchanged for another cylindre and piston whose effective area is only $^1/_4$ cm.^{2} instead of 1 cm^2. With this "head" therefore pressures of 5000 Kg. per cm^2 might be attained. The firm SCHÄFFER and BUDENBERG, however, informed us in 1906 when they prepared the apparatus, that already at about 4000 atm. a permanent change of form of the cylindre A was to be feared in consequence of a transgression of the limit of elasticity of the steel, so that this pressure could not be exceeded for the pressure balance. Since then BRIDGMAN has succeeded in far exceeding this limit of pressure by means of apparatus of newer kinds of steel. The question, however, remains whether his apparatus could be modified for the determination of gas isotherms. Apart from the much greater complexity and dimension of the apparatus also the question of a transmission liquid which could be used in the absolute pressure gauge, is to be considered. The machine oils, which we always used as transmission liquid in the following investigations, because they best remove the friction between the cylindre and piston, begin to be so viscous already at room temperature and 3000 atm., that the pressure gauge begins to be slow in its indications, and also the transmission of the pressure in the narrow channels becomes highly uncertain. For this reason we have for the present confined ourselves to pressures below 3000 atm.

The very great value of the viscosity of the mineral oils at high pressures is ascribed by TAMMANN and BRIDGMAN to the solidification of these substances. With the apparatus, however, described in N°. 4 of these communications (These Proc. XV p. 1021) nothing is to be perceived of a deposition of solid substance at these pressures. The oil remains as transparent when this pressure is approached as it was at first, nor is anything to be observed of crystallisation. We have, therefore, only to do with a very viscous fluid, possibly a continuous transition into an amorphous solid phase.

B. The volume measurement.

For the measurement of volume we have made use of a somewhat modified method of the electric contacts. Just as with AMAGAT, platinum wires about 1 mm. thick were originally sealed into a glass tube. It appeared, however, that such sealing places were no longer to be trusted after the tube had been compressed to e. g. 2500 atm. Sometimes they lasted some time longer, often however they already came forth cracked from the pressure apparatus, and in any case the reliability was exceedingly slight. AMAGAT too complains of the great fragility of his tubes. An investigation undertaken specially for this end showed that the cause of the phenomenon will be found in the difference of compressibility between enamel glass and platinum, in consequence of which the connection between the wire and the glass is lost at high pressures.

This gave an indication of the way in which improvement was to be expected. If only the platinum wires are taken exceedingly thin, the change of volume cannot be so great that detaching is to be feared. Glass tubes in which capillary wires of 0.0356 mm. of HARTMANN and BRAUN were sealed, appeared really not to lose anything of their strength, not even when they had been kept at 3000 atm. for a long time. It is, however, not possible to seal in these wires in such a way that the mercury forms contact against a loose point of them, it is self-evident that they are too limp for this. This difficulty can be overcome by not letting a bit of wire stick out in the tube, but by sealing in the wire at both its extremities. The whole tube is therefore made as follows. A thick-walled capillary tube of Jena enamel glass is blown out to small reservoirs in 15 or 20 places. At the top there is a somewhat larger reservoir, above which the tube is drawn out to a very narrow capillary. Under the said widening there are a number of very small reservoirs, which pass into reservoirs that become gradually larger, to distribute the points as uniformly as possible over the isotherm that is to be determined. Now the tube is cut through at the places between the reservoirs, which have kept their normal thickness of wall; a platinum wire of the said strength is laid between the two ends, so that the wire projects outside on either side, and then the glass is fused together again. In this the wire is bent downward in a point to get a sharper contact with the mercury. Then the projecting ends are connected with a spiral of the same platinum wire, which is attached to the tube by means of "zapon"-lac and gelatin. (See Fig. 4. For clearness' sake the wire is drawn beside the tube. Fig. 5 gives the real position). If the mercury is quite at the bottom of the tube, the resistance between the two leads is the total amount of the platinum spiral, e. g. 150 Ohms. As soon, however, as the mercury has risen to the second contact B, the resistance AB e. g.

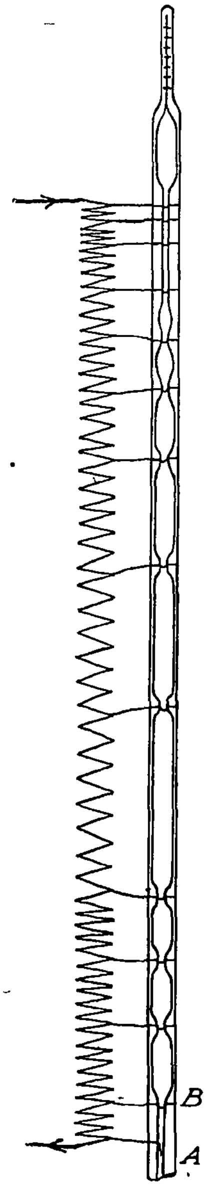

Fig. 4.

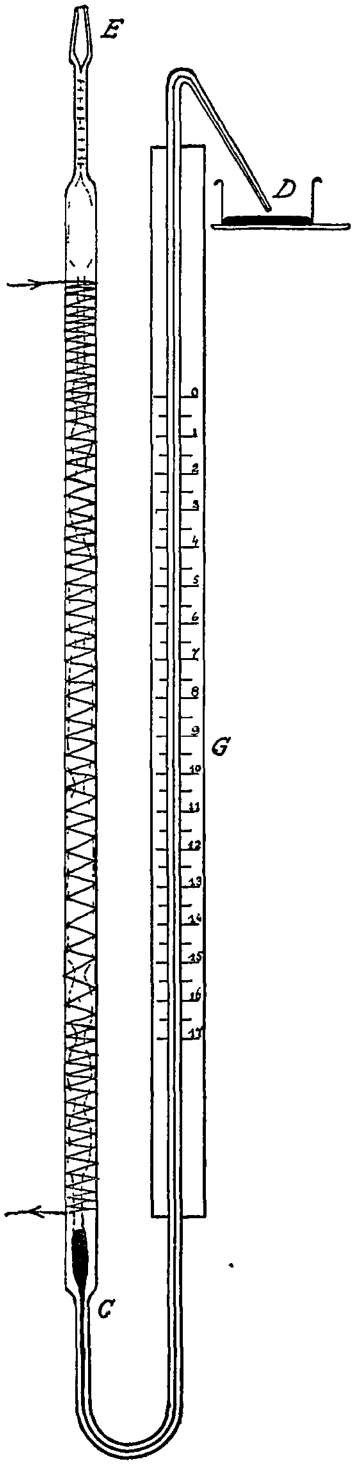

Fig. 5.

10 Ohms, is short-circuited, and so on at every following contact.

If we place the whole of the platinum wire in a Wheatstone bridge, it is clear that when the gas is compressed, so when the mercury in the tube rises, the resistance will be subjected to abrupt changes. This is observed by replacing the galvanometer needle of the bridge at zero, whenever a part of the platinum resistance has been shunted out by the mercury. At the outset of the experiment, when the measuring tube is still entirely filled with gas, the resistance of the whole platinum wire, which we shall call the volume wire, is in the bridge. Whenever a reservoir has been filled with mercury, the part of the volume wire wrapped round that reservoir, is short circuited.

The resistances of the different parts of which the volume wire consists, are known by the gauging of the measuring tubes. We shall now proceed to a discussion of this gauging.

An exceedingly narrow capillary *CD* is sealed to the measuring tube. This capillary has the same length as the measuring tube and is bent somewhat further round. The measuring tube is still open at the top, and has a prolongation *E*, to which a rubber tube can be fastened. An accurate scale-division *G* is attached to the narrow capillary. The capillary is drawn out thin at the top and bent.

If the end *D* is put in a vessel with mercury, the tubes will be filled with mercury, when the air is sucked off at *E*. When the mercury in the measuring tube is close to a point of contact, the mercury can be made to move to and fro past it by suction or pressure with two pumps[1]) connected with *E* by means of a three-way cock. The volume wire is then again inserted into a WHEATSTONE bridge. The galvanometer needle deviates whenever the place of contact is passed. At the same time the mercury in the narrow capillary tube passes up and down along the scale After some practice it is not difficult to read the position of the mercury in the latter tube at the moment that the galvanometer needle deviates. The best way to do this is of course when the mercury in the measuring tube rises, because the meniscus has then the same position as during the measurements.

If this has been done at a place of contact, the mercury may be pressed from the reservoir under it by increase of pressure of *E*, and the quantity that flows out at *D* may be received in a weighing bottle then the level of the mercury in the capillary tube is again observed at the moment that the galvanometer deviates. It is clear

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[1]) Two cycle pumps, in one of which the leather valve has been put reversed.

that in the meantime the resistance has changed, and the resistance in the resistance box must also be changed.

It is simple to determine the volume that was occupied by the mercury between the two places of contact. Let G be the weight of the expelled mercury, S_1 and S_2 the scalar heights which have been read, and f the weight of one scalar division of mercury, then $\{G + (S_1 - S_2)f\} : \Delta$ is equal to the required volume. (Δ is the specific weight at the temperature used). In this way the great advantage is reached that in the measurement any cocks and other movable parts are avoided.

Thus the different reservoirs are calibrated. The upmost reservoir is in an exceptional case. First of all there is no place of contact in it. It would not be practicable to make one there. Besides, to clean the tube after contamination the upmost point must be knocked off. In order to enable us yet to accurately know the volume of the upmost reservoir every time, the tube is drawn out very thin at the top On this narrow part lines are etched at some millimeters' distance. When the tube is quite filled with mercury, the positions of the mercury at the etched lines can every time be compared with the position of the mercury along the scale. Thus the volumes can be expressed and calculated from line to line in scalar divisions, and also those from one of these lines to the upmost contact, after a quantity of mercury has been expelled.

To determine the weight of a scalar division of mercury, we make use of one of the places of contact. When the deviation of the galvanometer needle has been compared with the level of the mercury along the scale, we press out a drop of mercury, and again compare the mercury level with the same place of contact. The decrease of height agrees with the expelled drop of mercury, which is weighed, and then the scale is at least partially gauged. This can be done for different parts of the scale. Care can further be taken always to work within a certain, pretty small part of the scale. And the tube being very narrow, the differences of position are only to be taken into account as a correction.

During the measurements the whole tube is of course placed in a thermostat. On account of the length of the tube the thermostat is thus constructed. A glass tube of ± 6 cm. diameter passes at the bottom into a narrower tube, which is connected by a rubber tube with a large copper mixing vessel, where the water is kept at the desired temperature by means of a toluol-thermoregulator, stirrer, and burner. The glass tube is placed so high with respect to the liquid level in the mixing vessel that the measuring tube which is to be gauged, is quite immersed in the water; only the bent point D, in which there is no mercury during the measurements, projects above the water. By means of a water-jet air pump the water from the glass tube is sucked up, and conveyed to the mixing vessel, in the same way as the mercury is sucked up and thrown over (by air being sucked up at the same time) in the well-known KAHLBAUM air pump. The water from the mixing vessel flows of its own accord to the thermostat through the connection at the bottom, which secures a strong water current. Thus the required accuracy, at the utmost 0°.1, is easily obtained. Eventual variations in temperature can be taken into account, when the weight of the total quantity of mercury in the two tubes is known. This quantity is every time determined by pressing the remaining mercury from the tubes and weighing it when the last reservoir has been gauged. As a rule the temperature variations were not worth mentioning, and it was not necessary to apply temperature corrections.

When a measuring tube must be cleaned on account of contaminations, a piece may every time be knocked off at the top. After the cleaning the tube is fused to at the next line. This can be done so accurately, and the capillary is so narrow here, that it may be assumed that the volume of the tube is diminished by the known volume between the lines.

It is unnecessary to apply more than ten lines. After so many cleanings, the volume wire is damaged as a rule, if the tube was not broken before, and to repair the volume wire is very difficult. A newly wrapped tube is, indeed, always rubbed with zapon lac, but in the long run this measure is no safeguard for the thin volume wire.

That in this way an exceedingly accurate calibration is obtained, may appear from the following example. The values give the total volumes from the upper end of the tube to the different places of contact at two different calibrations.

7.0561	7.0554	20.0667	20.0590
7.4276	7.4281	25.0062	25.0078
8.0137	8.0121	34.5016	34.5005
8.8849	8.8843	43.7536	43.7516
11.5623	11.5595	85.4267	85.4287
14.9740	14.9709	87.5029	87.5008
		90.3264	90.3269

The differences are at most $^1/_{4000}$ of the values themselves, mostly however much smaller, and for the large volumes they are even of the order of 1 to 100.000. The mean error may safely be put at no more than one to 10.000, an accuracy which is certainly not reached for other sources of error in these measurements. Of course the values directly give only the volumes at the temperature and the pressure of the gauging. For other temperatures and pressures corrections must be applied, which we shall discuss in one of the following papers.

Amsterdam. *Physical Laboratory of the University.*

Geology. — *"Elephas antiquus Falc. from the river Waal near Nijmegen."* By Dr. L. Rutten. (Communicated by Prof. Dr. A. Wichmann).

The dredging-works in the river Waal in the neighbourhood of Nijmegen have brought to light already many a finding of diluvial mammals.

By much the greater part of the bones found belong — as indeed nearly all remains of mammals dredged from our rivers — either to animals of the mammoth fauna[1]) or to animals of the postglacial fauna.

An exception to this rule is the fragment of a molar of *Elephas meridionalis* from the river Waal near Nijmegen,[2]) and this finding proved that in the sub-soil of the neighbourhood of Nijmegen also pliocene deposits must be found.

Mr. G. M. Kam of Nijmegen, who collects with laudable ardour all remains of mammals that are found in the neighbourhood of this town, showed me a short time ago a number of newly found typical molars of *Elephas primigenius Blum.* and moreover a molar belonging doubtlessly to *El. antiquus Falc.*, and which had been dredged from the river Waal, as were likewise the mammoth teeth.

Though the great stratigraphical value formerly ascribed to *Elephas antiquus*, has somewhat depreciated, because it is supposed from later discoveries that the *antiquus*-fauna and the *primigenius*-fauna, differ more facially than stratigraphically from each other,[3]) it seems however that, for our country, the rare fossils that are known of the *antiquus*-fauna are older than the remains of the *primigenius*-fauna.

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[1]) L. Rutten. Die diluvialen Säugetiere der Niederlande. Diss. Utrecht, 1909.

[2]) L. Rutten. Ibid., p. 15—16.

[3]) A.o. W. Soergel. Elephas trogontherii Pohl. und Elephas antiquus Falc. Palaeontographica. LX. 1912.