# XXXVIII. *A Deſcription of ſome Thermometers for particular Uſes. By the Right Honourable the Lord* Charles Cavendiſh, *V. P. R. S.*

Read June 30, 1757.

THE thermometer (TAB. XI. *fig.* 1.) is deſigned for ſhewing the greateſt degree of heat, which happens in any place during the abſence of the obſerver. It conſiſts of a cylinder of glaſs joined to a tube, and differs from common thermometers only in having the top of the ſtem drawn out into a capillary tube, which enters into a glaſs ball C, joined on to the ſtem at the place where it begins to be contracted. The cylinder, and part of the tube, are filled with mercury; the top of which ſhews the common degrees of heat as uſual. The upper part of the tube above the mercury is filled with ſpirit of wine, and ſome of the ſame liquor is left in the ball C, ſo as to fill it almoſt up to the top of the capillary tube.

Now when the thermometer riſes, the ſpirit of wine will be driven out of the tube, and will fall into the ball C. When the thermometer ſinks again, as the ſpirit cannot return back from the ball, the top of the tube will remain empty, and the length of the empty part will be proportional to the fall of the thermometer. Therefore, by means of a proper ſcale, the top of the ſpirit of wine will ſhew how many degrees it has been higher than when obſerved; which being added to the preſent height, will give the greateſt degree of heat it has been at.

To

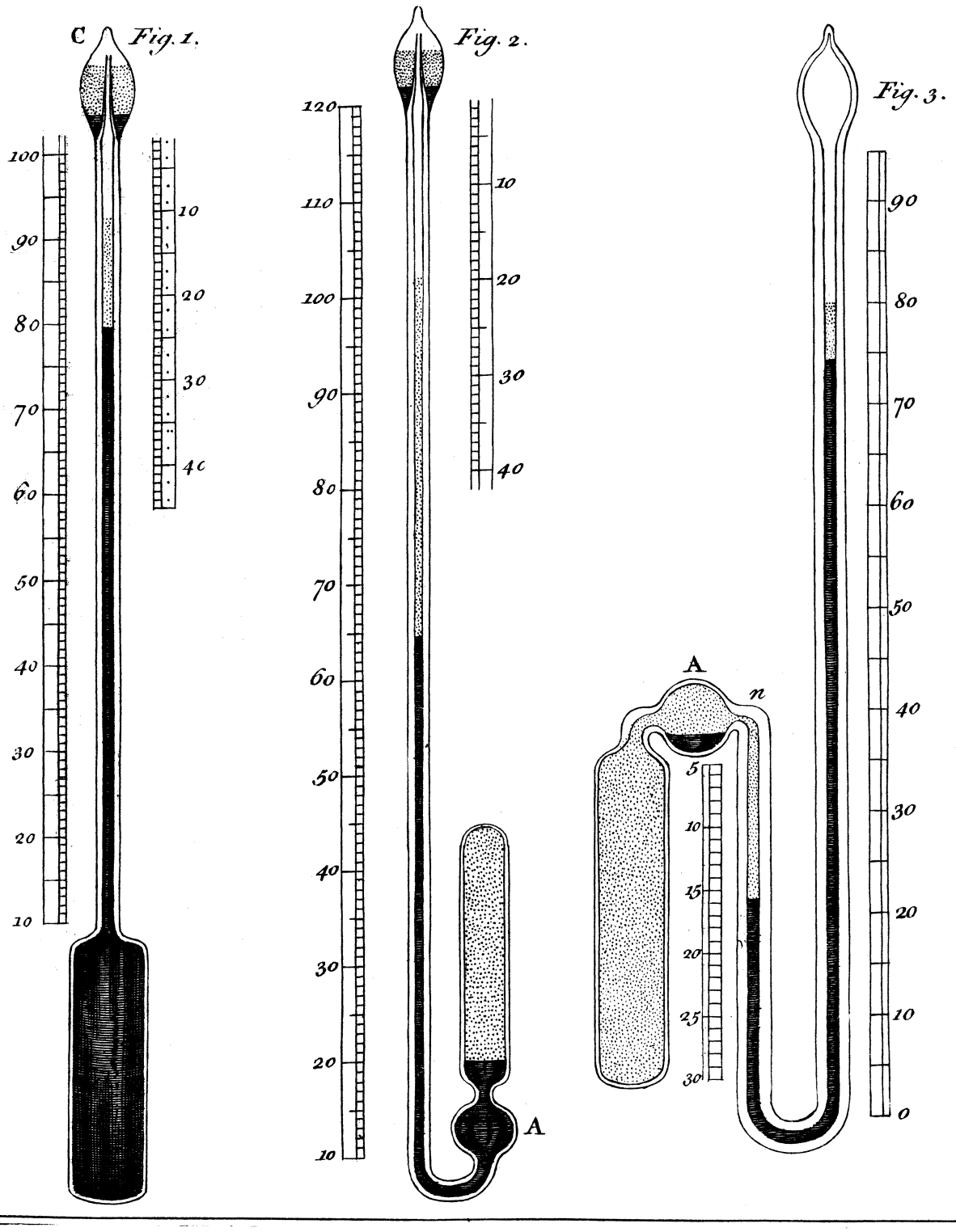
C
Fig. 1.
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Fig. 2.
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Fig. 3.
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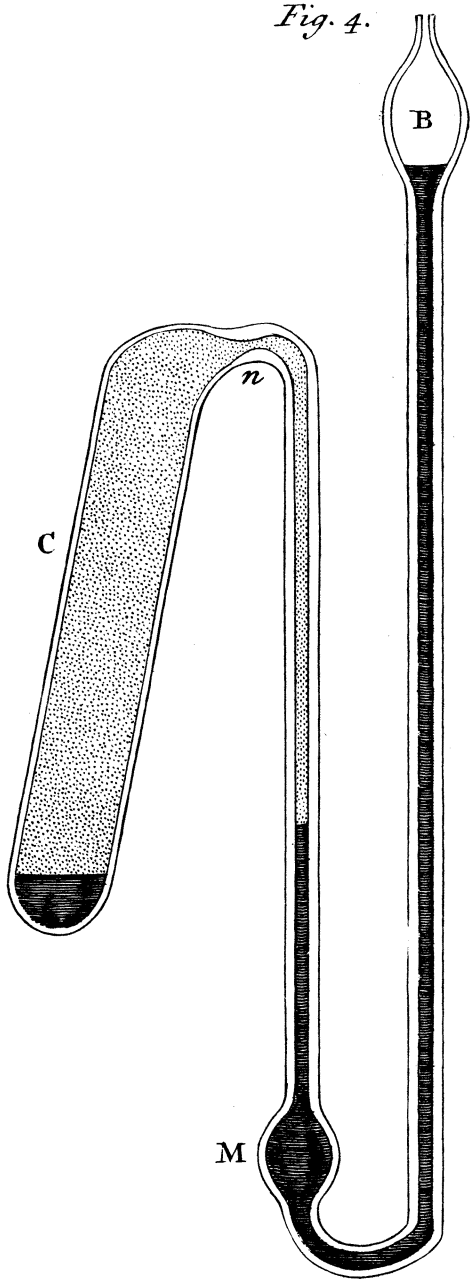
*Philos. Trans. Vol. L.* TAB. XI. *p.300.*

*Fig. 4.*




*J. Mynde sc.*

To fit this thermometer for a new obſervation, it is neceſſary to fill the upper part of the tube with ſpirits; which may be done, by inclining the inſtrument till the ſpirits in the ball C cover the end of the capillary tube. For if the cylinder is then heated, by applying the hand to it, or by the flame of a lamp held at ſome diſtance, till the ſpirits riſe to the top of the tube and run over into the ball C, and is then ſuffered to cool in the ſame poſition, the tube will remain full of ſpirits, and the thermometer will be fitted for a new experiment.

The top of the capillary tube is made to ſtand pretty near to one ſide of the ball, and alſo to the top of it, that a leſs inclination of the inſtrument may be ſufficient to make the ſpirit of wine in the ball cover the end of the tube.

The ball C is joined on as high as poſſible, ſo as to hide no part of the tube, except that, where the bore is contracted. By this means, the top of the ſpirit of wine begins to appear before the thermometer has ſunk one degree.

It will be convenient to leave ſome mercury in the ball C, which may be made to cover the end of the capillary tube, by inclining the thermometer more than what is neceſſary to make the ſpirit of wine cover it. By this means ſome mercury may be got back into the tube, in caſe any of it ſhould happen to be driven into the ball by the thermometer's being expoſed to too great a heat.

The ſcale of degrees at top, which ſhews the deſcent of the thermometer from the higheſt point it has arrived at, ought not, in ſtrictneſs, to be the ſame at all times of the year; for thoſe degrees exceed the

the common degrees of heat pointed out by the top of the mercury, as much as the column of ſpirit of wine expands, and therefore are greateſt when that column is ſo; that is to ſay, when the greateſt heat to which the inſtrument has been expoſed is leaſt. A difference of 30 degrees of Fahrenheit's ſcale, in the greateſt riſe of the thermometer, would require the ſcale to be altered one ſixtieth part: and the error ariſing from making uſe of the ſame ſcale will be about one ſixth of a degree, if the thermometer is obſerved when it has fallen ten degrees.

In the inſtrument here deſcribed, the bore of the tube is about 0.027 inches; and one inch of it contains two grains of mercury, and anſwers to about ten degrees, the cylinder containing about 2280 grains. If a much ſhorter tube was made uſe of, a conſiderable error might ariſe from too great a quantity of ſpirits adhering to the ſides of the tube, in that part, which is filled with mercury; eſpecially when the thermometer riſes faſt. This makes it neceſſary to employ a cylinder of a conſiderable bigneſs, if it is deſired to have the ſcale of degrees pretty large.

If the weight of the mercury is thought inconvenient, it may be avoided by the conſtruction deſcribed in fig. 2. where the bottom of the tube is bent ſo as to point upwards, and is joined to a ball A, which communicates with a cylider placed above it. In all other reſpects it is the ſame as the inſtrument before deſcribed.

It is filled with ſpirit of wine and mercury; the quantity of the latter being ſufficient to fill the whole tube and the ball A.

No

No part of the ſpirit, with which the cylinder is filled, can get into the tube, as long as the inſtrument is kept in an erect poſition, or even if it is carefully laid down flat on a table. For tho' in this laſt caſe ſome of the ſpirits may get into the ball A, it will riſe to that part of the ball, which is then uppermoſt, and will not touch the orifice of the tube *n*; which was the reaſon for adding this ball, which would be unneceſſary, if the inſtrument was kept conſtantly erect, or nearly ſo. If the ſpirit ſhould come to touch the orifice of the tube *n*, it would work up between the mercury and the glaſs; which would put the inſtrument out of order.

The thermometer fig. 3. is deſigned for ſhewing the greateſt cold, which happens in any place during the time the inſtrument is left in it. The tube is bent into the ſhape of a ſyphon of unequal legs ſtanding parallel to one another, the bend being at the bottom. The top of the ſhorter leg is bent to a right angle, and immediately opens into a ball A, which, by means of a ſhort bent tube on the oppoſite ſide, communicates with a cylinder ſtanding parallel to the legs of the ſyphon, and pointing downwards. This cylinder contains the greateſt part of the fluid; and is added only to make the thermometer more ſenſible than it would be, if the ball A was made of a ſufficient bigneſs to contain the proper quantity of fluid. This inſtrument is filled with ſpirit of wine, with the addition of as much mercury as is ſufficient to fill both legs of the ſyphon, and about a fourth or fifth part of the ball A.

The

The common degrees of heat are ſhown by the top of the mercury in the longeſt leg, or by the top of the ſpirit, in caſe any of it is left above the mercury.

When the mercury in the longeſt leg ſinks by cold, that in the ſhorter leg will riſe, and will run over into the ball A; from whence it cannot return back when the thermometer riſes again, as the ſurface of the mercury in the ball is below the orifice of the tube *n*. Therefore the upper part of the ſhorter leg will be filled with a column of ſpirits of a length proportional to the increaſe of heat; the bottom of which, by means of a proper ſcale, will ſhow how much the thermometer has been lower than it then is; which being ſubſtracted from the preſent height, will give the loweſt point that it has been at.

If no further contrivance was uſed, the mercury would fall into the ball A in large drops; which would make the inſtrument leſs accurate. For the thermometer's beginning to riſe immediately after a drop is fallen, or juſt as it is going to fall (in which caſe it will return back into the tube), will make a difference of ſuch part of a degree nearly as that drop anſwers to. To prevent this inconvenience, the top of the ſhorter leg, cloſe to the ball, is contracted, by being held in the flame of a lamp; and the paſſage is further ſtreightened by a ſolid thread of glaſs placed within the tube, and extending from the bottom of the ſhorter leg to the part near the ball A, where it is moſt contracted. By this means, as ſoon as any ſmall portion of mercury is got beyond the end of the thread of glaſs, it breaks off, and falls into the ball

ball in very ſmall drops. This thread of glaſs is faſtened by the heat given to the tube in making the bend next to the ball. In order to fill the ſhorter leg with mercury, to fit the inſtrument for a new experiment, it muſt be inclined till the mercury in the ball covers the orifice of the tube *n*. The cylinder being then heated, the mercury will be forced into the ſhorter leg, and will run down the thread of glaſs in drops, which will ſoon unite. By this means, ſuch a quantity of mercury muſt be got into the ſhorter leg, as, upon the cooling of the inſtrument, will be ſufficient to drive all the ſpirit of wine into the ball with a leſs degree of cold than what the thermometer is likely to be expoſed to.

The ball A muſt always have ſome mercury in it, but never enough to fill it up to the orifice of the tube *n*. It muſt therefore be made of ſuch a ſize, as to contain all the mercury, which can come into it from the tube without being too full. If it ſhould happen to be made too ſmall, ſo as to be too full in cold weather, any part of the mercury may eaſily be driven into the cylinder, and got back again into the ball when wanted in warmer weather.

It will be better to leave a little of the ſpirit above the mercury in the longeſt leg; in which caſe the top of the ſpirit will ſhew the common degrees of heat. For the filling the tube, ſo as to leave none, is attended with ſome trouble; and more of it will be apt to get up there, if the inſtrument ſhould happen to be held in an improper ſituation, or if it be kept in too warm a place without filling the ſhorter leg with mercury by the method above deſcribed. If too great a quantity ſhould get up, tho' it would

not affect the ſcale for the common degrees of heat, it would however cauſe ſome error in the degrees on the ſhorter leg; inaſmuch as the expanſion of that portion of ſpirits, which has got up into the longer leg, exceeds the expanſion of the mercury, which muſt ſupply its place. It may be got back at pleaſure, by expoſing the thermometer to ſuch a degree of cold as will make the ſpirit get beyond the bend of the ſyphon; for then it will run up along the thread of glaſs in the ſhorter leg till it gets above the mercury there. For this purpoſe the point of 0 degrees of Fahrenheit's ſcale ſhould be near the bend; by which means, any part of the ſpirit of wine may be got beyond it by an artificial cold; and there will be no danger of the whole getting beyond it by any natural cold; in which caſe the air would get up into the ball.

The ſcale of degrees on the ſhorter leg will, in different ſeaſons, be liable to an error of the ſame kind as that, which was explained in the firſt-mentioned thermometer; but in this it will be leſs conſiderable, as the ſpace between the two ſcales is filled with mercury, whoſe expanſion is about ſix times leſs than that of ſpirit of wine.

In the thermometer, which I have, the bore of the tube is about 0.054 inches; and one inch of it contains eight grains of mercury, and anſwers to ſeven degrees of Fahrenheit's ſcale. The drops of mercury, which fall into the ball A, anſwer to about one eighth of a degree.

If inſtruments of the nature of thoſe above deſcribed, were to be uſed for finding the temper of the

the ſea at great depths, ſome alteration would be neceſſary in the conſtruction of them, principally upon account of the great preſſure of the water; the ill effect of which can, I believe, be prevented no other way, than by leaving the tube open. For if the thermometer was made ſtrong enough to reſiſt the preſſure without breaking, yet it would be impoſſible to be ſure, that the figure of the glaſs would not thereby be altered, which ſhould make the experiment uncertain.

The inſtrument for finding the greateſt heat might be made juſt like that of fig. 1. only leaving the top open. It is to be filled with mercury only, as is alſo the lower part of the ball at top, but not near ſo high as the end of the capillary tube. The upper part of that ball, being left open, will in a great meaſure be filled with the ſea-water, which will be forced into it by the preſſure.

If this inſtrument (the tube being quite full of mercury) is plunged into any part of the ſea, where the heat is greater than that of the air above, part of the mercury will be driven out of the tube; and, upon bringing it into a colder place, the ſea-water or air in the ball will enter into the tube, and will fill the ſpace left by the mercury.

As this thermometer does not ſhow the common degrees of heat, it muſt be placed in a veſſel of water with another thermometer, and the ſcale of degrees at top will ſhew how much the heat it has been expoſed to is greater than that of the water in the veſſel.

The ſea-water getting into the glaſs will corrode the mercury, and thereby foul the glaſs; which

will make the experiment leſs exact: and therefore it would be much more convenient, if the ſea-water could intirely be kept out; which probably may be done by tying a bladder full of air to the neck of the ball C, which will contract by the preſſure of the water, without letting any of it get in.

If this can be done, the inſtrument may be filled with mercury and ſpirits, juſt like that at fig. 1. But it would be more convenient to fill it with mercury only: in which caſe it may be made with as ſmall a tube and ball as common mercurial thermometers: or it may be filled with ſpirits only. The inſtrument will thereby become much leſs bulky; which will compenſate the want of the common ſcale of heat.

It is better to put but little mercury into the ball at top, for fear of its getting into the capillary tube by the motion of the inſtrument.

The thermometer for finding the greateſt cold, if applied to this purpoſe, muſt alſo be left open at top. There is another inconvenience to be avoided; which is, that the mercury in the ball A, by the toſſing of the inſtrument, might ſometimes get into the ſhorter leg of the ſyphon; which would ſpoil the experiment. To prevent ſuch an accident, the moſt convenient conſtruction, which occurs to me, is that of fig. 4. which differs from fig. 3. in having the ball A omitted; ſo that the mercury running out of the ſhorter leg will fall to the bottom of the cylinder, and will not be ſo liable to get back into the tube by motion. The cylinder is made to ſtand not quite parallel to the legs of the ſyphon, that the mercury contained therein may more eaſily be brought to touch

touch the end of the tube, in order to fit the inſtrument for a new experiment.

If, by means of a bladder, the ſea-water can be kept out of the glaſs, this inſtrument may be made to ſhew the common degrees of heat; but even then, in order to render it leſs bulky, it may be better to ſupply the want of them as in the laſt inſtrument. The longer leg of the ſyphon may in that caſe be made as ſhort as you pleaſe; only making the ball B big enough to receive all the mercury, which may be driven into it by heat.

If thermometers of this kind were to be ſent up into the air by means of a kite, they might be made like thoſe propoſed for the ſea; but it would not be neceſſary to leave them open.

As it would be deſirable to make them as ſmall as poſſible, they ſhould be made ſo as not to ſhew the common degrees of heat: and it would alſo, on that account, be convenient to omit the thread of glaſs placed within the ſhorter leg of the ſyphon in fig. 3. and 4. This thread of glaſs is placed there in order to make the mercury fall into the ball A. fig. 3. or cylinder C. fig. 4. in ſmaller drops, and alſo to facilitate the filling the ſhorter leg with mercury. The latter purpoſe may be anſwered by having a ball blown towards the bottom of the ſhorter leg, as marked in fig. 4. at M: for as ſoon as the mercury driven out of the cylinder by heat gets to that ball, it will paſs by the ſpirit of wine. The other purpoſe may probably be anſwered by having the tube contracted as much as poſſible at *n*.

In the foregoing inſtruments the tubes made uſe of were of a large bore, as moſt of the errors in them

them would increaſe by making uſe of ſmaller ones. Poſſibly leſs ones might be uſed without much inconvenience. The chief advantage will be, the making theſe thermometers more ſenſible of the changes of heat, than when large cylinders are uſed. This will be of ſervice when the greateſt degree of heat or cold continues but a ſhort time.

It is better to uſe plain ſpirit of wine, than what is tinged, which ſeems more apt to cauſe a foulneſs in the tube, and thereby makes the ſurface of the mercury leſs well defined. I am induced to believe ſo, from obſerving, that the portion of ſpirits above the mercury in the tube fig. 3. which at firſt was ſtrongly tinged with cochineal, in ſome months became perfectly colourleſs, the tinging particles being depoſited in different parts of the tube, and cauſing a foulneſs there. The colour of the ſpirits in the cylinder does not appear to be altered.

The dark-ſhaded part in the ſeveral figures repreſents mercury, the dotted part ſpirit of wine.

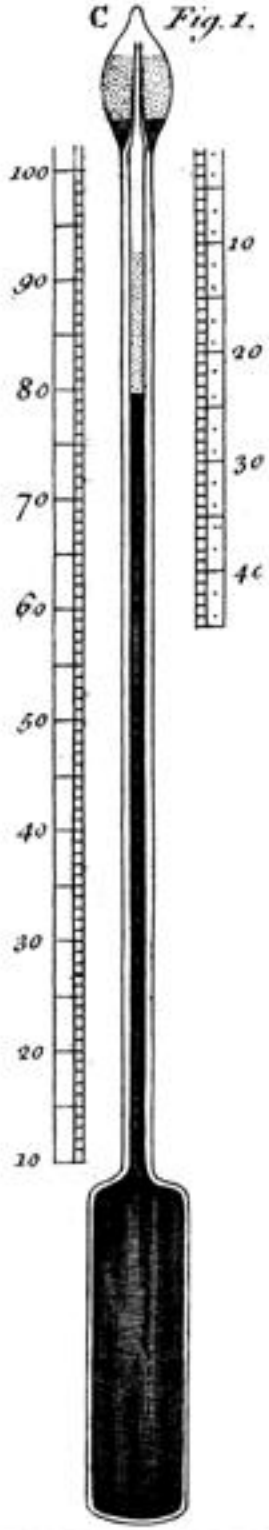



Fig. 1.

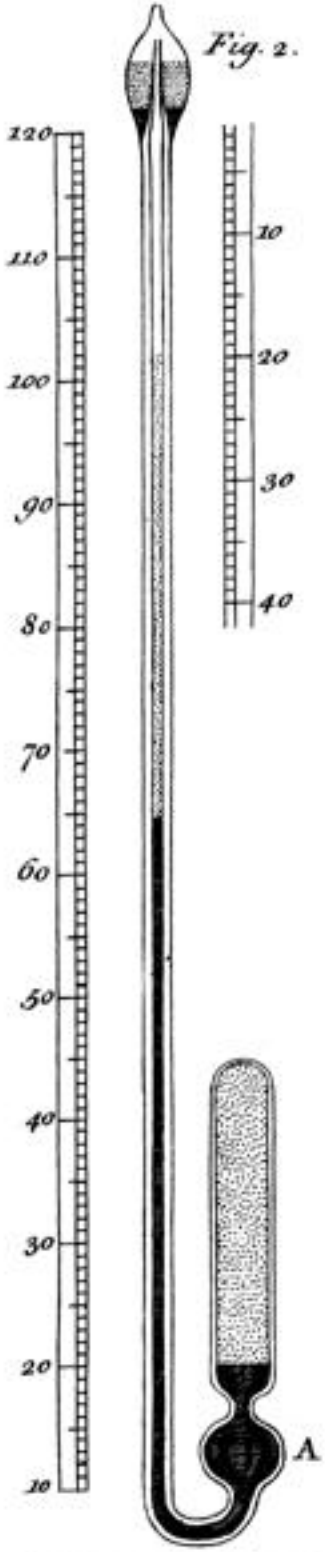



Fig. 2.

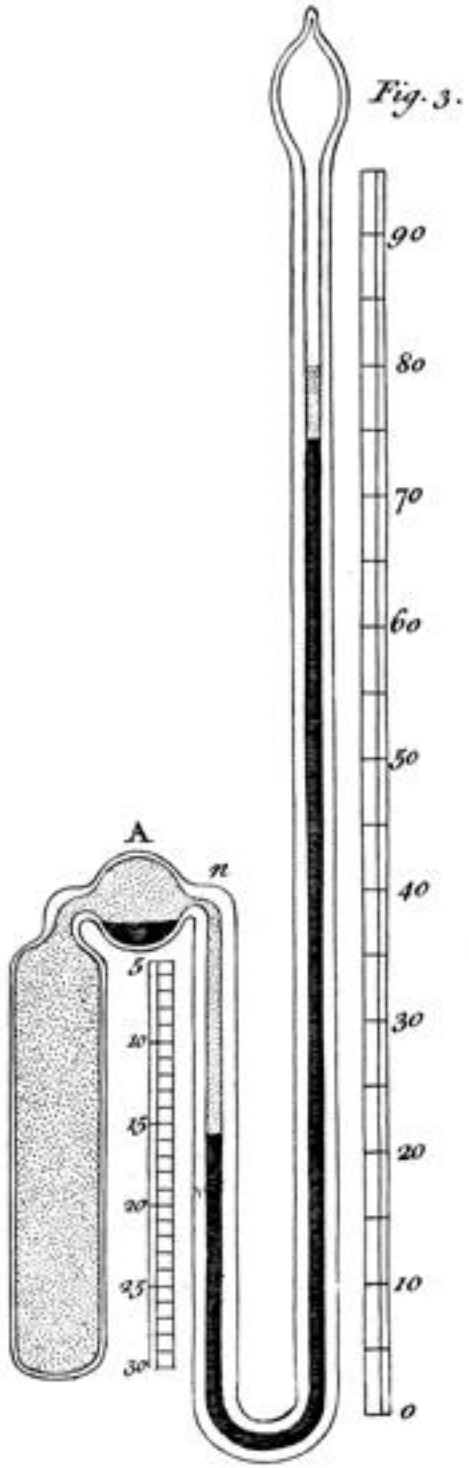



Fig. 3.

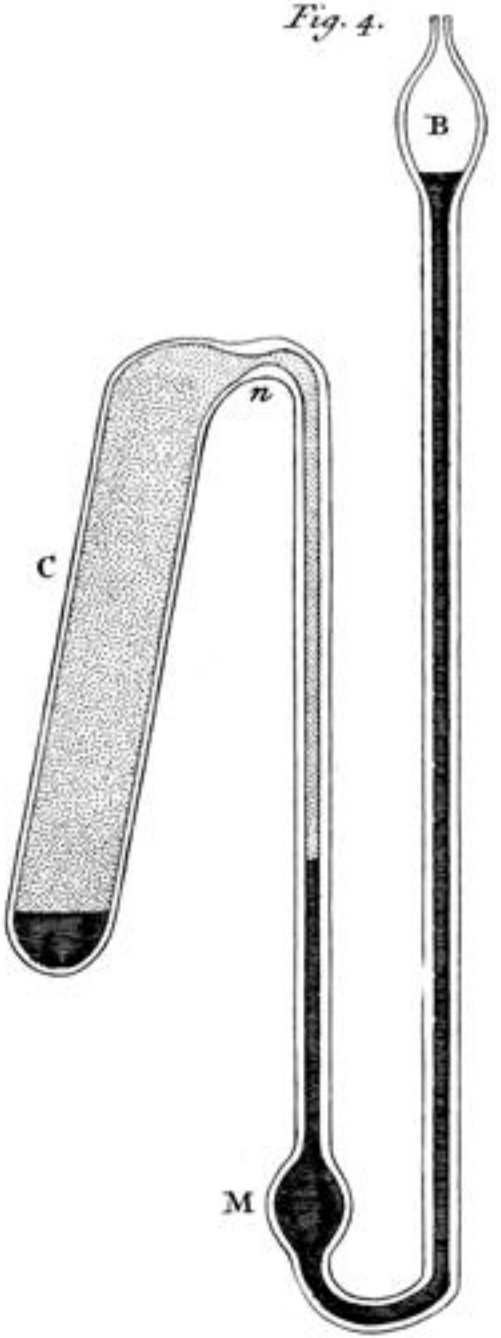



Fig. 4.

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