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THE USE OF THE SANDBOX-APPARATUS TO DETERMINE pF-CURVES IN THE RANGE pF 0.4 TO 2.7

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The sandbox-method was developed in 1958 at the Laboratory of the Institute for Soil Fertility at Groningen.

From the end of 1959 onwards, this method has been applied for routine determination by the Laboratory for Soil and Crop Testing at Oosterbeek. Both laboratories gave data for assemblage and use of the apparatus.

This method was adopted by the Laboratory of the Institute for Land and Water Management Research at Wageningen. The experience obtained at this laboratory led to a revision and extension of the provisional description. An English version of the revised description is given here.

COMPONENTS OF APPARATUS[x)]

Boxes

Material: stainless sheet steel, gauge 1.25 mm.

Dimensions: length x width x height = approx. 600 x 300 x 350 mm.

Construction: hole drilled in front side of box to allow passage of drain outlet, centre of hole 40 mm. above bottom. Top edge of steel box flanged inwards 15 mm. to obtain a rigid construction. A coating of lead paint or priming is applied to the interior of the box to promote good adhesion with the sand.

Lids

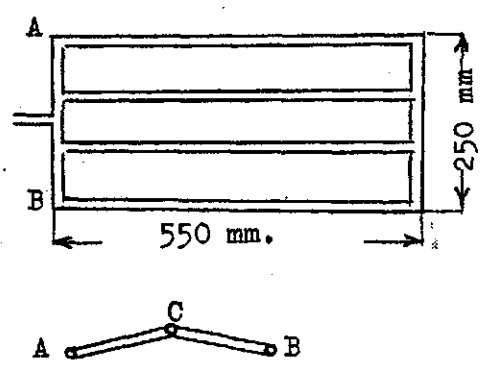
Material: Aluminium sheeting stiffened by a flange of 40 mm., thus obtaining a closing cover; it can also be used as a tray to carry samples to and from the precision balance.

Drains

Material: P.V.C. conduite-pipe 10 x 12 mm.

Dimensions: length x width = 550 x 250 mm.

Construction: bottom of drain is slotted (0.3 mm. wide, spacing 10 mm.). Tube ABC is bent as shown on the figure, C being the highest point of the drain. Nylon cloth ribbon is wrapped around the drain in such a manner that a covering is obtained consisting of three layers of nylon cloth. Washing beforehand in T-ppl is recommended as to remove all traces of dressing from the nylon tissue. The drain is fitted inside the box with the outlet through the drainhole. Water- and airtight fitting can be obtained by using a packing made of a small piece of rubber tubing of 12 x 18 mm. A packing gland is tightened using a cap-nut thereby compressing the packing. Care has to be exercised not to turn on the cap-nut too tightly



x) see drawing in flap back cover

as otherwise the P.V.C. tubing inside may be pinched. The drain has to be fixed inside the box sloping away to the back, the minimum clearance there being 10 mm. off the bottom. By doing so draw-in air will move to the outlet, being the highest point of the drain

Tubing

Transparant plastic tubing of 6 x 9 mm. and 9 x 12 mm. The latter size has to be connected to the overflow-tubes, thus facilitating the outflow of water.

Panel with stopcocks and tubes

Material: perforated angle iron (Dexion) and plywood.

Dimensions: length x width x height = approx. 65 x 30 x 35 cm.

Construction: a stand of perforated angle iron is assembled to enable the mounting of a panel on which the stopcock and tubes are fixed with Terry-clips (no.80/00). Nine vacuum two-way stopcocks (bore 2-3 mm.) are attached to the panel in this manner, forming three sets of three stopcocks each; each set serving one sandbox.

A mercury manometer, essential for the determination of the suction to which the samples in the kaolin-sandbox are subjected, is also fixed to the panel.

Sliding measuring stand with levelling bottles

Material: profile copper, steel rod, clamps, glass vessels with overflow and plastic supply bottles

Height: about 1.30 meter

Construction: the copper stand is graduated 0-100 cm. Along the graduation a clamp, supporting the levelling bottle, can be moved as it slides over a guide rod. The bottle can be adjusted at the required height by tightening a wing-screw fixing the clamp on the rod.

The levelling apparatus consists of a glass vessel, fitted with an overflow tube, on top of which is placed an inverted plastic supply bottle. A piece of plastic tubing, cut slantwise at the end, extends from it, touching the surface of the water inside the vessel. When the waterlevel recedes, water from the plastic bottle will flow into the vessel, thus correcting it. A rubber stopper connects the glass vessel with the plastic bottle. The stopper is partly slotted along the side by which means open communication is effected between the interioir of the vessel

and the atmosphere.

Once the filling of the pF 0.4 to 2.0 sandbox has been completed, the measuring stand can be secured permanently in such a way that the $2\frac{1}{2}$ cm. mark is at the same level as the surface of the sand. By doing so the zero mark will be at a level of $2\frac{1}{2}$ cm. above this surface. This level corresponds with approximate half the height of the soil samples; these having been taken in stainless steel cylinders of 50.9 mm. height and 50.0 mm. inside diameter (capacity 100 cc.).

Nylon cloth

In addition to being used as covering material for the drains, nylon cloth is also cut into a piece of 650 x 350 mm., to be placed on the surface of the sand. To prevent unravelling the rough edges are fused over a gasflame.

Water jet pump

This device is used in conjunction with the kaolin-sandbox to realize the suction. The pump is fitted with a non-return valve to maintain the suction when the tap is being turned off.

Erlenmeyer flask

The flask serves as a safety device to prevent water being sucked into the manometer in case of wrong manipulation of the water jet pump.

Water supply bottle

A 10-litre decanting bottle, placed on top of the angle iron stand, is in communication with the sandboxes to effect the water supply. The water level inside the bottle is not to be higher than 20 cm. above the surface of the sand.

Collecting bottles

Both 10 litre collecting bottles are primarily used as reservoirs for the water drained off the soil samples and sand. In addition the collecting bottle in the kaolin-sandbox circuit also serves as a depression vessel which, if placed inside a cooler with running water, will limit changes in suction due to temperature fluctuations.

If not placed inside a cooler it is advisable for reasons of safety

to have the depression vessel fitted with a jacket in case of the suction-force causing the bottle to collapse.

Sand

"Blokzijl" sand, obtained from the "North East Polder" (formerly part of the "Zuyder Zee") of the following granular composition (%):

<2μ	2-4	4-8	8-16	16-25	25-37	37-50	50-75	75-105	105-150	>150μ	U-figure
2.6	0.3	0.7	0.3	0.5	5.9	77.5	11.7	0.4	0.1	traces	352

Kaolin (china-clay)

To be applied on top of the sand surface inside the kaolin-sandbox.

PREPARING THE SANDBOX-APPARATUS FOR DETERMINING pF 0.4 TO 2.0

After having completed the assembly according to the arrangement shown on the diagram, water is poured into the sandbox until half full. Sand, having been sieved (size of mesh 1 to 1.5 mm.) in water first, is added in small quantities. It is thoroughly mixed with the water by hand in order to expel entrapped air. The sides of the box are tapped at the same time, thus effecting a close packing of the sand. Good adhesion of the sand to the sides of the box is essential.

Impurities floating on the surface are removed frequently. The process of filling and mixing is continued until the surface of the sand is 6 cm. below the flange of the box. Next surplus water is drained off via stopcocks 1 and 3 and the levelling bottle (stopcocks 2 and 7 are closed). For this purpose the levelling bottle is adjusted at the bottom of the sliding measuring stand. Once the water has drained off, the thin deposit of silt, left on the surface, can be dabbed up with a piece of filtering paper. If necessary the surface is planed level using a ruler.

The removal of air from the sand inside the box is carried out in the following manner:

The end of a rubber tube, extending from a water tap, is laid on the sand, the surface of which has to be covered with a piece of paper for protection, as otherwise the sand may be churned up because of water turbulence. While water is flowing slowly into the sandbox, a water jet pump is used to draw off the water via the drain-outlet. For this purpose stopcocks 1 and 3 are left open and the plastic draintube, normally attached to the levelling bottle, is temporary connected up to the water jet pump.

The suction must not exceed 0.3 atm., to prevent air being extracted continuously from the freshly sucked-in water. To verify this a mercury manometer should be connected by inserting a T-piece.

The sand surface is to be kept constantly inundated as otherwise air would enter the pores at this suction force and is sucked into the sand. This working-method is carried on for some hours; at the beginning many air bubbles will be observed passing through the transparant plastic drain-tube. Gradually the quantity of air will diminish and finally ceases altogether.

After having completed the removal of air, stopcock 3 is closed and the surface water is drawn off by means of a siphon. The residuum of silt can now be dabbed up. To remove air-residues the movement of the water inside the box is reversed by opening stopcocks 2 and 7, thereby allowing the watersupply bottle to fill the box completely via the drain. This should be done some time after finishing the foregoing procedure as otherwise the suction force inside the sandbox - only decreasing slowly after the process of draining-off water through the drain - will cause too strong a flow and may disturb the packing of the sand. For the same reason the level inside the watersupply bottle must not be higher than 20 cm. above the surface of the sand as to limit the hydrostatic pressure.

No air-bubbles should be present inside the tubes between bottle and sandbox. If there are, these can be removed by closing stopcock 1 and opening stopcock 3, after having connected the plastic tube to the levelling bottle again. This will result in a swift downward movement of the water carrying along with it the entrapped air.

Once the box has been filled completely with water from the supply bottle, stopcocks 2 and 7 are closed. By opening stopcock 3 the excess of water is drained off via the levelling bottle until the surface of the sand is covered with a layer of 1 mm. of water only, after which all stopcocks are closed. Finally the nylon cloth is laid carefully over the sand. Air-bubbles under the nylon cloth can be easily detected and are removed by smoothing the cloth with a sponge, working from the centre towards the edges.

PROCEDURE IN THE RANGE pF 0.4 TO 2.0

Only the pF-values, that have become standard practice in the Netherlands laboratories, will be discussed.

On arrival at the laboratory the cylinders are cleaned on the outside and weighed on a precision balance; this weight is recorded as: "initial weight".

If it is not possible to proceed to the analysis directly, the samples have to be stored inside the sample-boxes and put away in a cool and humid place.

Determination pF 0.4

1. Attach a small moistened dacron cloth to the cylinders, using a metal circlip or rubber band, thereby covering the smoothest surface of the core inside the cylinder. The cloth has to be stretched as to render it taut and without wrinkles. Good contact soil-cloth will then be effected

2. Arrange the sample inside the sandbox and press the cylinders a little on the sand-surface in order to achieve good contact between sample and sand.

3. Open stopcocks 1, 2 and 7; water from the supply bottle is now introduced into the sandbox. Once the water has risen until 1 cm. below the top edge of the cylinders, stopcocks 2 and 7 are closed.

4. Place the lid on the sandbox and leave the samples to stand for saturation for 1 to 3 days (depending on soil type and moisture content of the soil)

5. At the end of the period required for complete saturation, the levelling bottle is adjusted at the $2\frac{1}{2}$ cm. mark; opening stopcock 3 will result in a lowering of the waterlevel until the surface of the sand. To speed up the process the water can be partly siphoned off

6. The samples are left to stand for some hours now to attain equilibruim with the $2\frac{1}{2}$ cm. suction (in practice it has been found convenient to drain off the water in the evening; by doing so equilibrium can be obtained overnight.)

7. Next place the samples in the lid, dry the cylinders on the outside and weigh. Weight to be recorded as "pF 0.4".

Determination pF 1.0, 1.5 and 2.0

1. Prior to applying the suction of pF 1.0, always moisten the sand-surface with a wet sponge, cleaning and smoothing at the same time to remove air-bubbles and impressions from the cylinders in the sand. Occasionally it may be useful to remove the nylon cloth and wash it in a detergent.

2. Replace the samples in the sandbox

3. Adjust the levelling bottle at the 10 cm. mark, causing a neg tive hydraulic pressure of 10 cm. water (pF 1.0), as taken from half the height of the cylinder.

4. Leave the samples to stand for approximately 3 to 7 days, depending on soil type. Alternatively check-weighings can be carried out in the meantime to observe the decline in weight in order to establish whether equilibrium has been reached and with that the moment when to change-over to the next higher pF-value.

5. Weigh after having dried the cylinders externally and record the weights as "pF 1.0"

6. For the carrying out of the analysis pF 1.5, respectively pF 2.0, the instructions 1 to 5 also apply, with this difference that the levelling bottle is adjusted at heights corresponding with those higher pF-values, viz. at 31.6 cm. for pF 1.5 and 100 cm. for pF 2.0 and the weighs are recorded accordingly.
   For heavy soils more time may be required to attain equilibrium

When changing over from one pF-value to the next higher, always replace the samples in the sandbox first, before lowering the levelling bottle.

For determination of the higher pF-values the samples are transferred to the kaolin-sandbox.

PREPARING THE KAOLIN-SANDBOX-APPARATUS FOR DETERMINATION FROM pF 2.0 TO 2.7

The same instruction for filling-in the sandbox and the removal of air apply to the kaolin-sandbox, except for the following details:

1. The surface of the sand is kept at 8 cm. below the flange of the box instead of 6 cm.

2. For drainage of surplus water the collecting bottle is used instead of the levelling bottle. To this end stopcocks 4, 6 and 8 are opened

3. The removal of air from the sand inside the box is effected via drain-outlet, stopcocks 4 and 6, collecting bottle (stopcock 8 closed) and Erlenmeyer flask, using the water jet pump

4. The suction - realized by means of the water jet pump - is registered by an open mercury manometer. Usually the values pF 2.3 and 2.7 are determined.
   When adjusting the suction, allowance has to be made for the vertical distance between half the height of the cylinders and the drain outlet. Assuming this distance being 27 cm. (27 cm. = $\frac{270}{13.53}$ x) = = 20 mm.Hg.) and the suction to be realized pF 2.3(200 cm. water = = 148 mm.Hg.), consequently the difference in height between the two mercury columns in the manometer has to be 148 - 20 = 128 mm.Hg. To obtain a suction of pF 2.7 (501 cm. water = 370 mm.Hg.) the difference in height between the two mercury columns of the manometer should be 370 - 20 = 350 mm.Hg.

The expulsion of air-residues by means of water from the supply bottle entering the drain via stopcocks 7, 5 and 4, has to be carried out thoroughly; once the kaolin-coating has been applied this method of air removal is not recommended (the kaolin-layer may become detached from the sand) and it will become increasingly difficult to extract entrapped air.

Before proceeding to the kaolin application the water on the sand has to be drained off.

In the sand-surface a bevelled groove is cut along the sides of the box to procure good anchorage of the kaolin cover. Also incisions, evenly distributed over the surface, may assist in this respect.

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x) Density of mercury at 25°C

Kaolin, obtained as a fine flour-like powder, is mixed into a thin smooth paste with water. Consecutively 3 layers of approximately $\frac{1}{2}$ cm. thicknes each are applied, consisting of different sand-kaolin mixtures, the sand-kaolin ratios being 3 : 1, 1 : 1 and 1 : 3 successively. Finally an upper layer of $\frac{1}{2}$ cm. thicknes of pure kaolin-paste is applied.

After application of each mixture the water is sucked-off gently via drain-outlet, stopcocks 4 and 6 (5, 7 and 8 being closed) into the collecting bottle by turning-on the water jet pump.By doing so a firm layer is obtained before the next paste is poured on. Having drawn-off surplus water, the top-layer of kaolin is smoothed level and the edges are pressed firmly against the sides of the box, especially in the corners, in order to minimize the possibility of air-leakage there.

Hot water of water reclaimed from the collecting bottle (containing less air) is poured into the box and sucked through for some hours at approximately 500 mm.Hg. During this process air will constantly be removed through the plastic drain tube and although decreasing, the passage of air-bubbles will not cease completely. The suction force will continue to extract air from the water entering into the kaolin.

Following this stopcock 4 is closed and the water jet pump is turned off. Provided the surface is kept under water, the potential inside the sandbox will be eliminated as the water enters into the kaolin and sand.

Opening stopcock 4 quickly, having made certain first that the suction inside the collecting bottle is still approximately 500 mm.Hg., will result in a sudden removal of air residues. This proceeding is repeated once more, after which stopcock 4 is closed. Eventually the suction inside the collecting bottle is reduced by opening stopcock 8 until the mercury manometer indicates the required suction (pF 2.3 or pF 2.7).

The suction inside the box is also reduced by allowing surface water to be drawn into the sand. By opening stopcock 4 momentarily it can be ascertained, going by the direction of the watermovement inside the plastic draintube,whether or not the potential in the sand has reduced to below pF 2.3, respectively pF 2.7. As soon as the water is flowing away from the drain-outlet, stopcock 4 can be left open.

Once the water on the kaolin surface has drained-off, the apparatus is left to stand for 48 hours at pF 2.3, respectively pF 2.7, to check on leakages. At the end of this period the reading on the manometer

should be practically the same. Air-bubbles should be absent; if not, it indicates an air leakage, most likely along the sides of the kaolin--layer. This may be corrected by pouring hot water (or water reclaimed from the collecting bottle) on the kaolin, smoothing and pressing it, especially along the edges and in the corners and repeating the removal of air in the manner as described on page 10.

During the process of preparing the kaolin-sandbox, much water will accumulate inside the collecting bottle. To dispose of surplus water air is admitted via stopcock 8 after having closed stopcock 4. The bottle is subsequently unstoppered and emptied. Suction inside the bottle is restored first before opening stopcock 4.

In case of changing from pF 2.7 to pF 2.3 the suction inside the kaolin-sandbox has to be lowered by closing stopcock 4 and covering the surface with water. Stopcock 8 is opened until the negative pressure has reduced to pF 2.3. Occasionally stopcock 4 is tentatively opened in order to establish whether the suction has decreased until below pF 2.3, in which case stopcock 4 is left open. Next surplus water is partly siphoned off. The remaining surface water will be drawn-off at pF 2.3 via stopcock 4.

If the kaolin-sandbox is not used immediately, stopcock 4 is closed and the suction inside the box is eliminated by allowing surface water to be drawn into the sand. The kaolin-surface is kept inundated during this period.

Prior to being put into service again surplus water is drawn-off at pF 2.3, respectively pF 2.7.

During pF-determination the collecting-bottle should not contain much water as the steady-effect on the negative pressure will be impaired.

PROCEDURE IN THE RANGE FROM pF 2.0 TO 2.7

As already mentioned before, only the values pF 2.3 and pF 2.7 are usually determined.

Determination pF 2.3 and pF 2.7

1. Moisten the kaolin surface using a spray or wet sponge. Good contact between samples and kaolin is thus obtained
2. Place the samples on the kaolin surface. It is not necessary to cover the surface with a nylon cloth; only the dacron tissues attached to the cylinders seperate the soil cores from the kaolin
3. Realize the required suction (pF 2.3 or pF 2.7)
4. Leave the samples to stand for 6-14 days, depending on soil type. Meanwhile check-weighings can be carried out (e.g. every 3 or 4 days) in order to follow the decline in weight, thus establishing more accurately the moment the pF 2.3 of pF 2.7 determination can be terminated
5. Weigh after having dried the cylinders externally and record the weights as "pF 2.3" or "pF 2.7". When changing over from pF 2.3 to pF 2.7, always replace the samples first before increasing the suction.

FINAL PROCEDURE

When the pF 2.7 equilibrium has been reached the steel cylinders with dacron cloth and circlip are put away inside a laboratory-oven during 24 hours at 105°C.

Having cooled down weighing is carried out and noted as: "gross oven-dry weight" (weight steel cylinder, dacron cloth and circlip included).

The volume-percentage of water at each pF-value is obtained by deducting from the equilibrium weights at the corresponding pF-values the gross oven-dry weight.

The field moisture-content (vol.%) is obtained by deducting from the figure recorded as: "initial weight" the gross oven-dry weight(minus weight dacron cloth and circlip).

Nett oven-dry weight is obtained by deducting from the gross oven--dry weight (minus weight dacron cloth and circlip) the weight of the steel cylinder.

If rubber bands are used instead of metal circlips, these must be removed before the samples are dried in the oven. In this case the weight of the rubber band should be added to the gross oven-dry weight (i.e. weight steel cylinder and dacron cloth included), because the above-calculated values are based on the gross oven-dry weight including the weight of the circlip.

GENERAL REMARKS

1. By preference weighing is carried out on a precision balance, with an accuracy of approximately 0.05 gram.
   The results are recorded correct to 0.1 gram

2. It is advisable to cover the samples - once placed on the lid for weighing-purposes - with non-transparant plastic cups to minimize moisture losses due to evaporation. Obviously the samples must be weighed without cups

3. When the (kaolin-)sandbox is not used the surface is kept inundated and all stopcocks in connection with the box are closed

4. To disinfect the (kaolin-)sandbox a small quantity of a $HgCl_2$-solution (0.2%) can be added to the inundation-water

5. If supply-, collecting- and levelling bottles made of dark-coloured glass are not available, growth of algae can be limited by adding small pieces of red copper

6. Take care to close stopcock A and (or) B before turning off the water jet pump. This to prevent water rushing into the Erlenmeyer flask and a sudden loss of suction in case of the non-return valve not functioning properly

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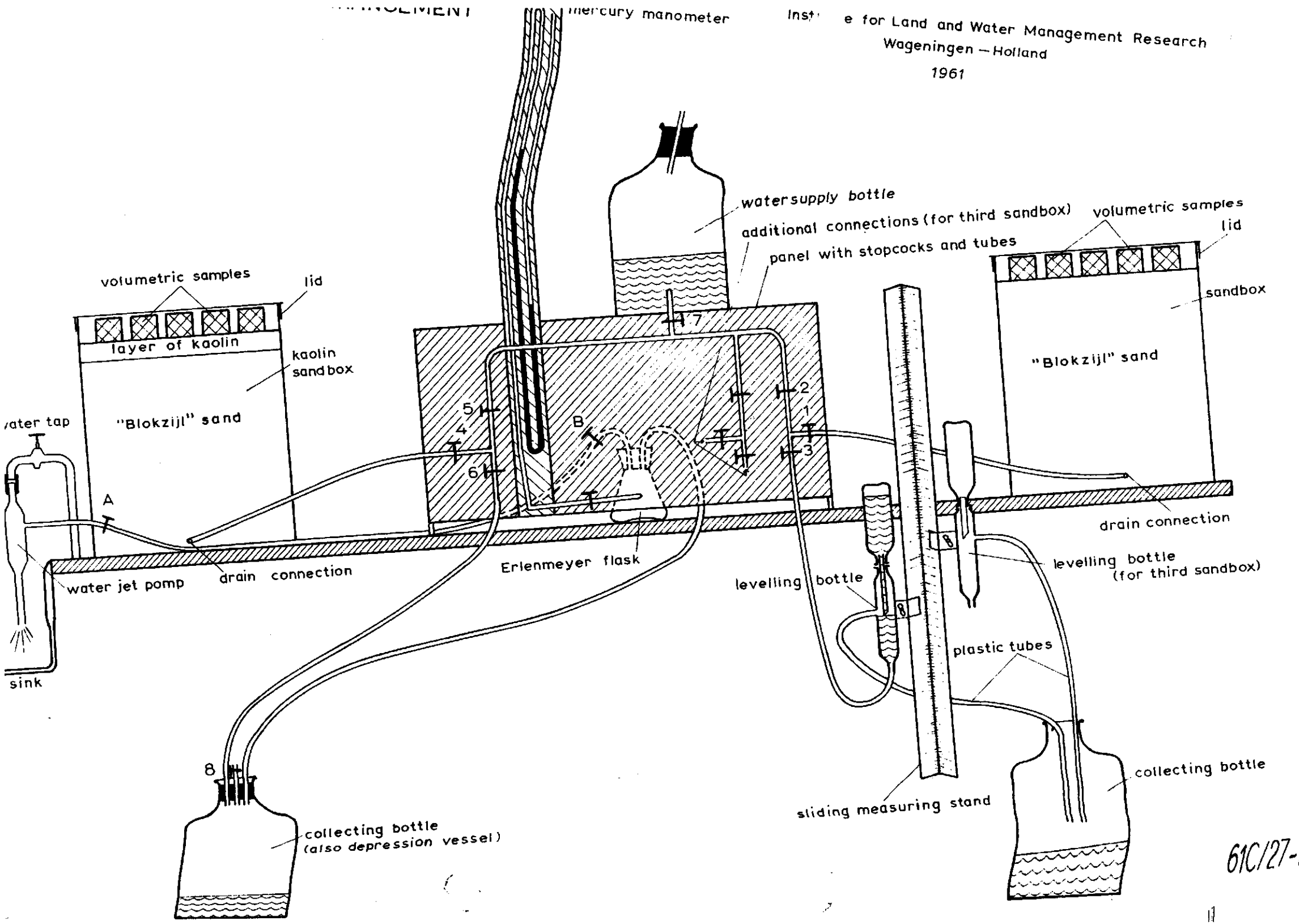

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