

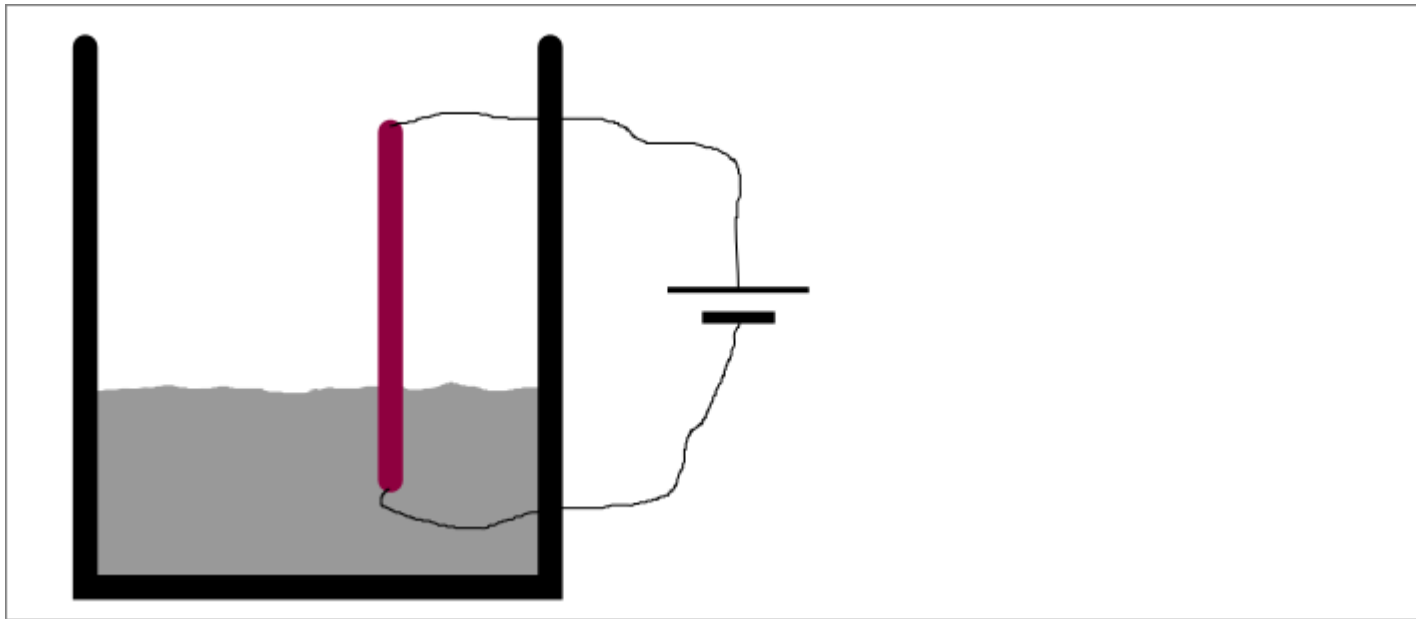
# Level measurement on liquids

## Basics (principle and simulation)

By Dieter Stotz  
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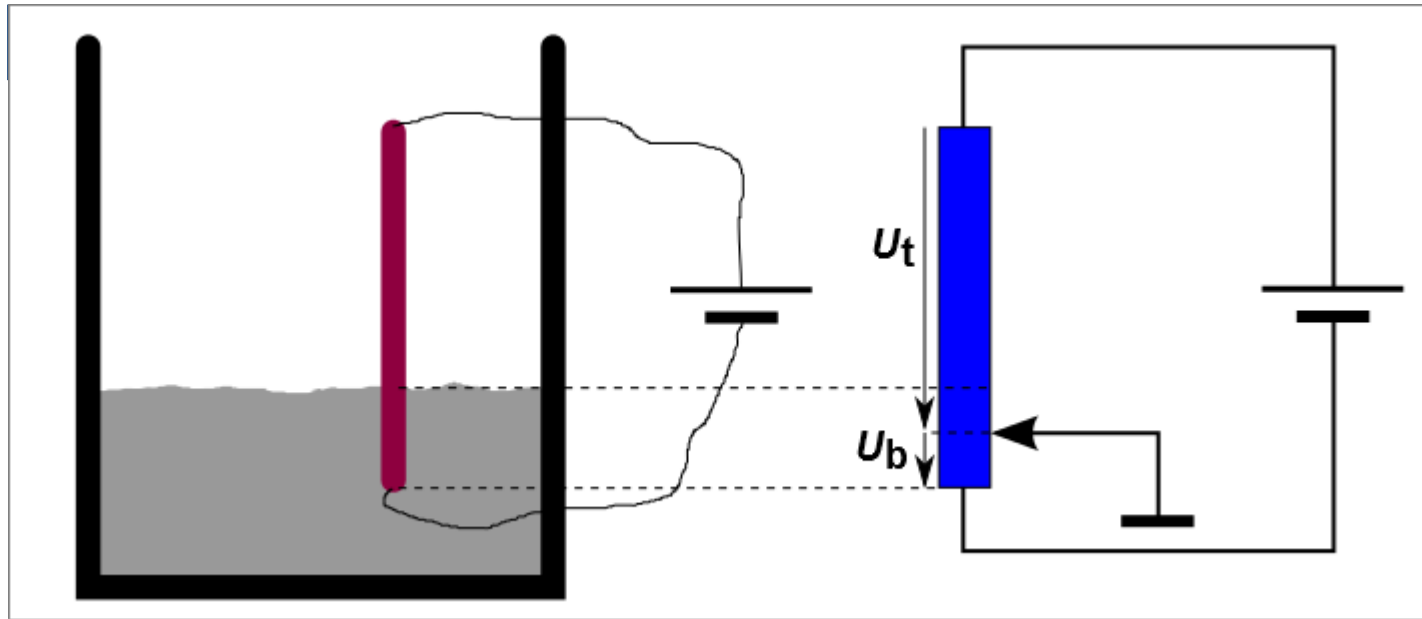
A simulation program is an adequate tool to analyze the situation in a system with conductive liquids, which can be level measured by a simple potentiometric method. Especially Quickfield of Tera Analysis fulfills all requirements to generate meaningful results and just needs very simple inputs. How simple, we will show you now.



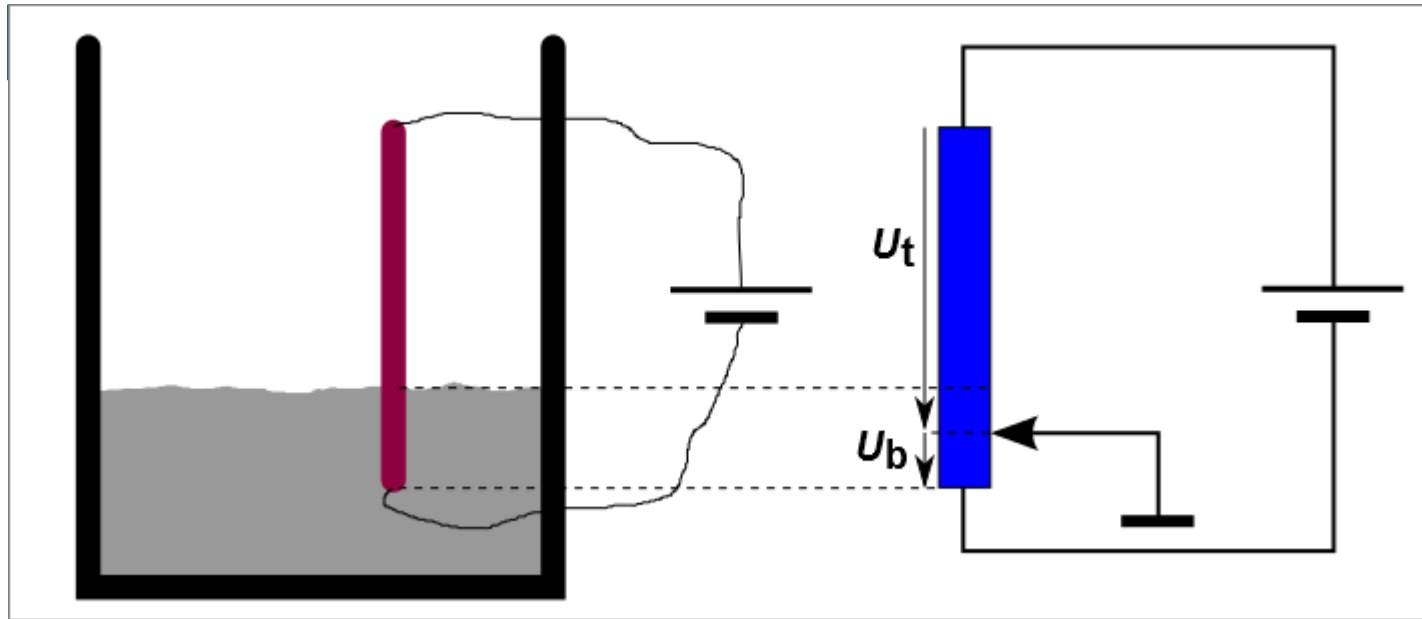
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### **Principle of a continuous potentiometric level measurement**

The basic idea of the potentiometric method is to use a metal rod, which is installed into a vessel and is energized by an electric current, so there is a voltage difference between the rod's bottom and its top. Naturally, the current leading wires have to be isolated, and the rod itself has to be isolated from the vessel too.

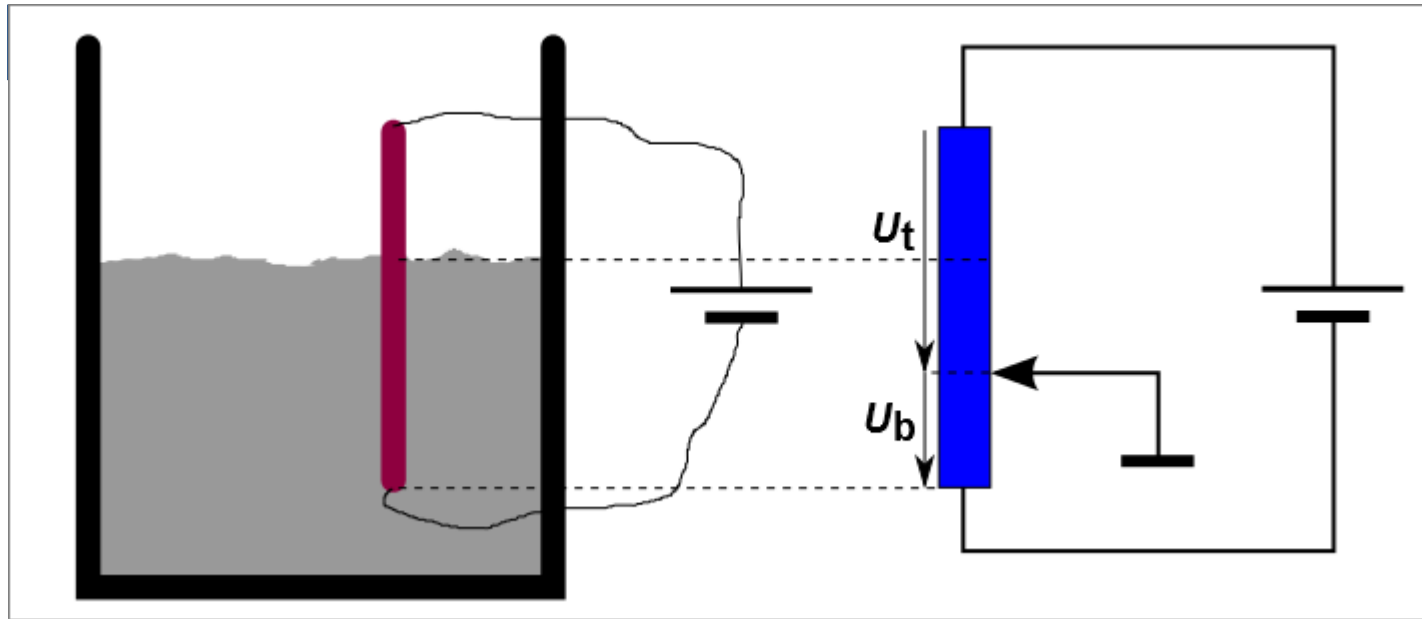


A liquid is a medium with a certain conductivity, which can be seen as the potentiometer's wiper – more exactly the middle of the covered height of the rod is the point of that wiper. Equivalent to this position we will get the two voltages  $U_b$  and  $U_t$ , namely as the voltage at the bottom and the voltage at the top of the rod, both in relative to the wiper's potential.



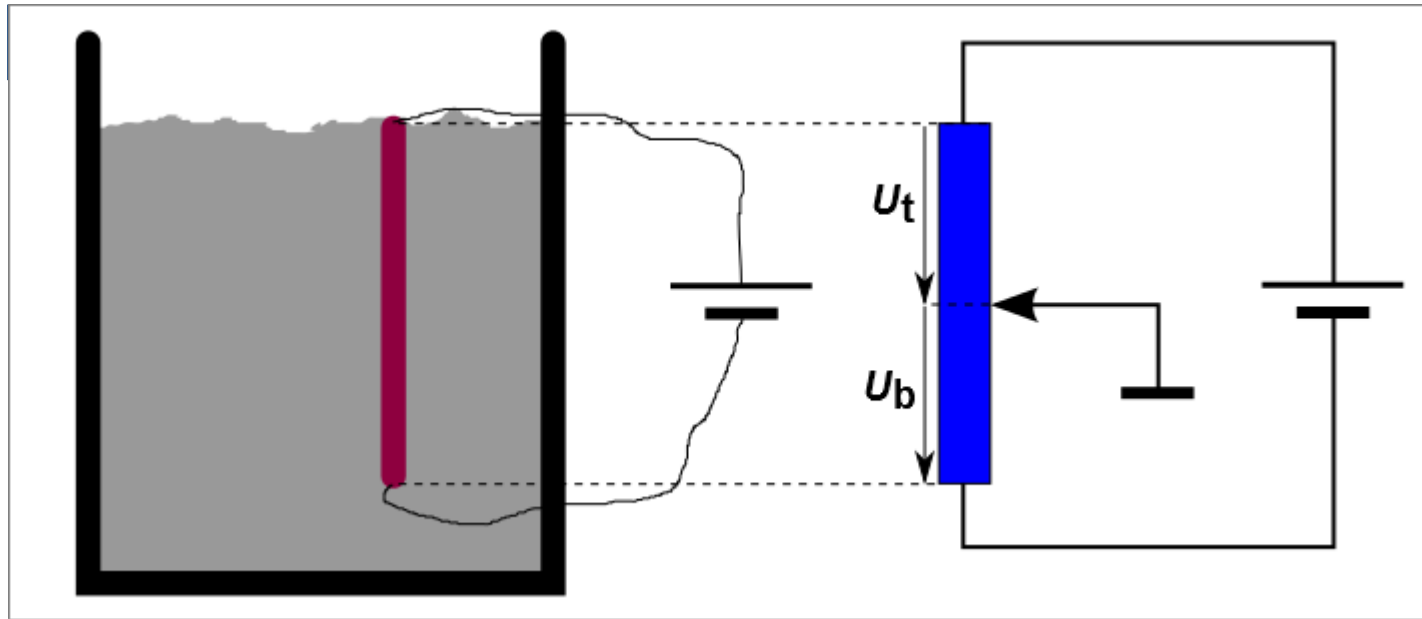
This wiper – the representative of the liquid – is connected to ground, because the vessel is usually grounded, so both voltages are always in respect to ground.

In fact, the relative level is given by the very simple expression:  $2 \frac{U_b}{U_b + U_t}$



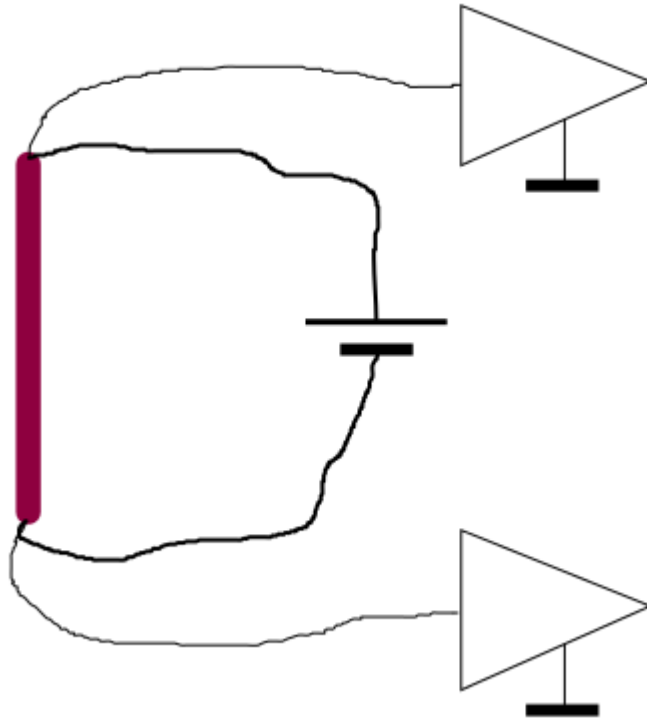
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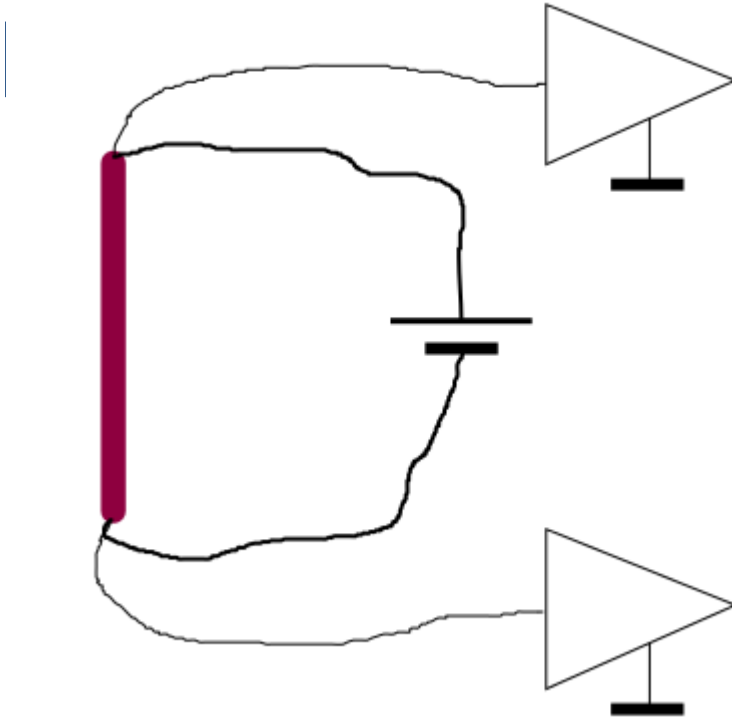
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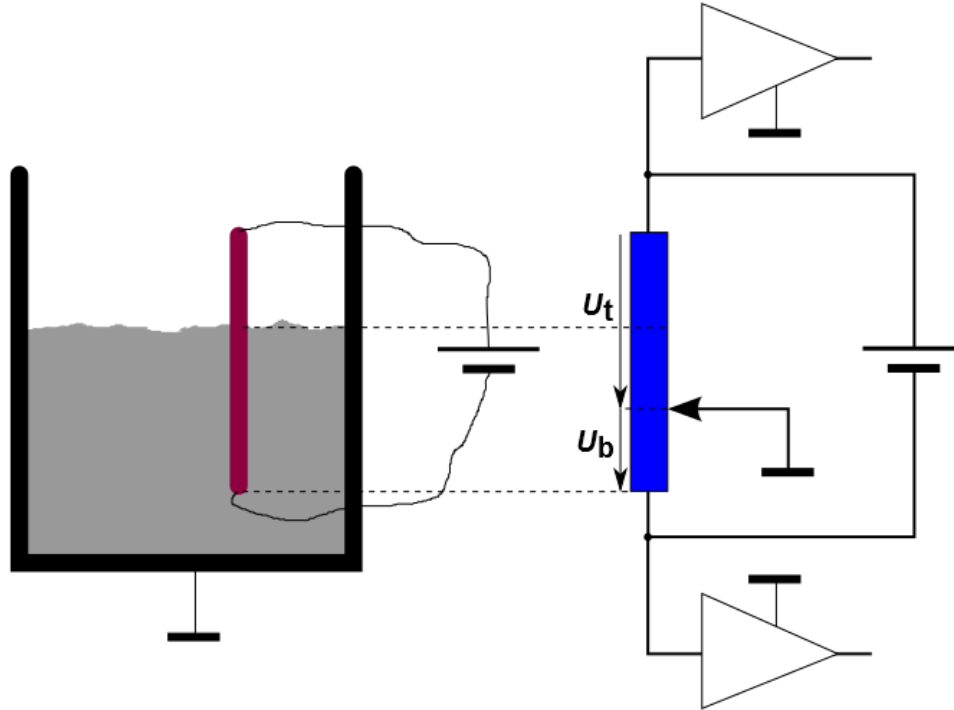
The factor 2 is because the virtual wiper always is in the middle of the covered height. To get the two voltages it is necessary to have a four-wire measurement, thus both ends of the rod have to be connected by measurement lines, in addition to the power lines. Of course, these connections also have to be isolated from the medium.



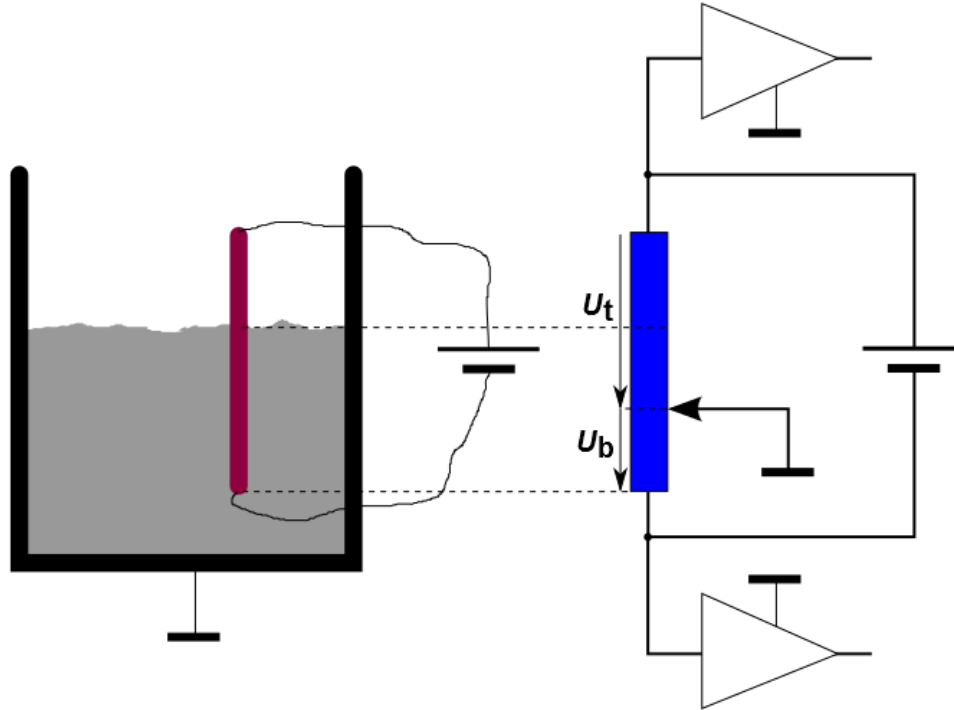


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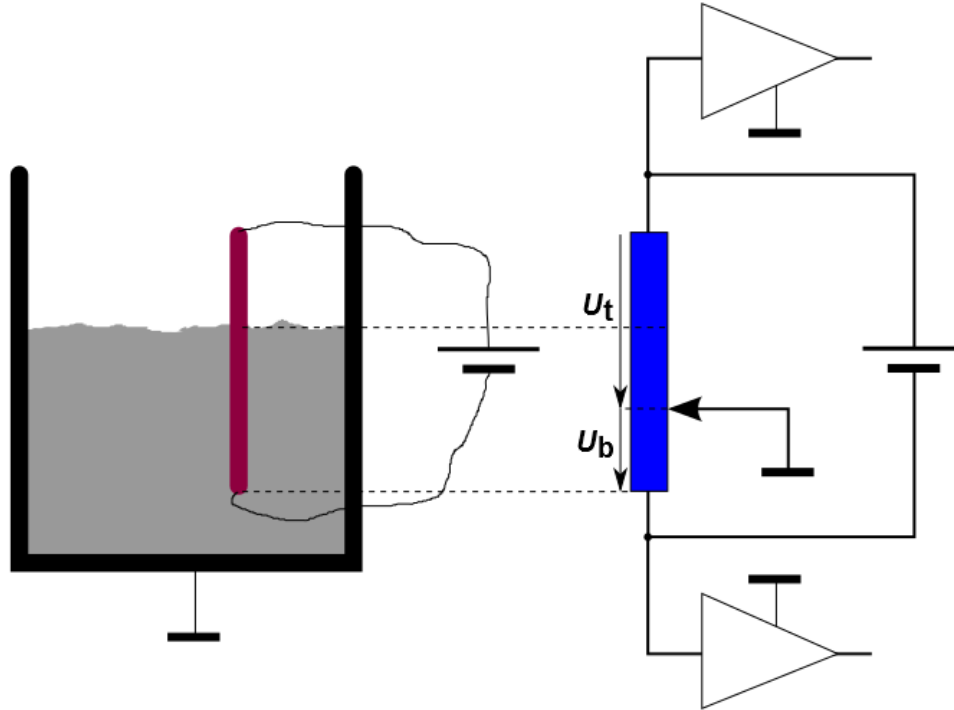
In fact, to achieve the contact to the rod, there are some technological things possible, for example to lead the wires to the bottom side through the rod itself by making it hollow and to close the bottom side.



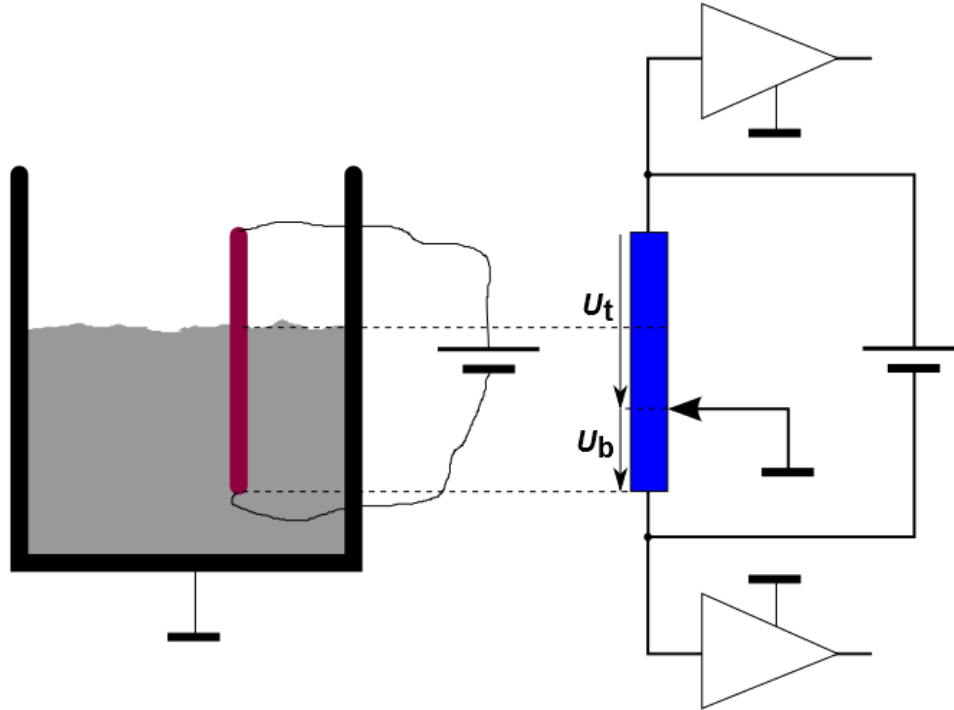
Because of the low resistance of a metallic rod, the voltage across this is not very high, i. e. it will be just few hundred millivolts as a maximum. But on the other side, the current is high. The above mentioned voltages are low and have to be gained by sensitive amplifiers.



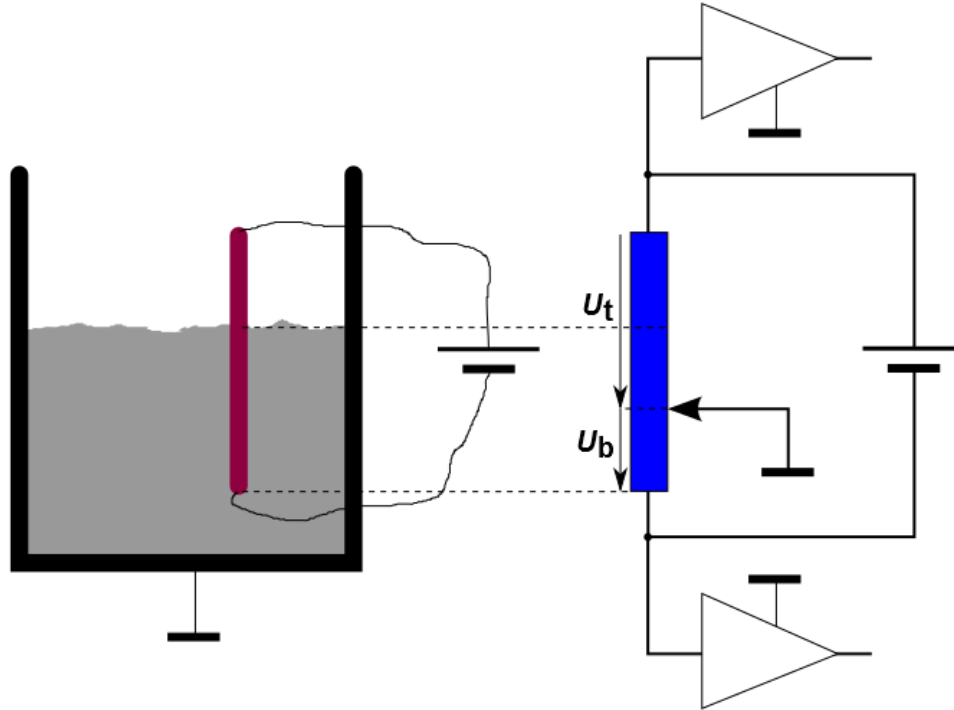
To avoid any galvanic decomposition and other undesirable effects, no DC energizing is being applied, but AC voltage, which can be generated by a transformer. Secondly, AC amplifying is easier too.



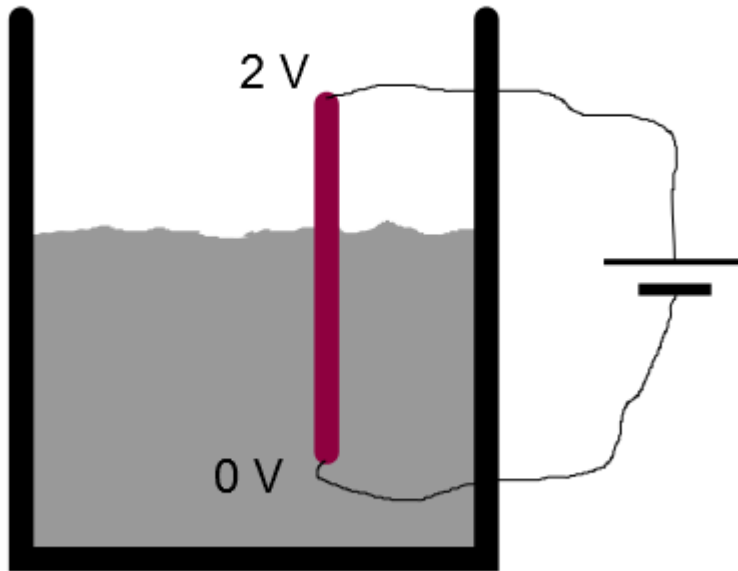
It is very important, that the generator circuitry is potentially free from ground, and the amplifiers also must have the highest impedance possible, because the potentiometer's wiper – the liquid – can have very high impedance, and the measuring system must not load that source. The floating battery in the figures fulfills that request of potential freedom.



The described principle features the property of a ratiometric measurement too, because the ratio of the voltages is independent of the generator magnitude. But for better results, it is good to have sufficient signal strength.



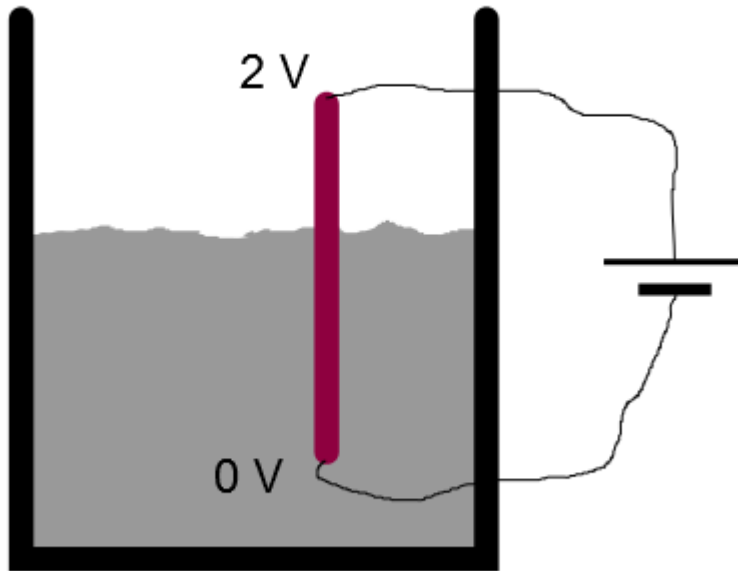
The model in the figures is idealized, that means in fact, the medium area to the vessel's bottom and the vessel shape also will have an influence of the accuracy of the method. Further on we have some effects with the medium's conductivity and the inhomogeneity of the conductivity, caused by temperature gradients. To estimate these influences, we will use the simulation.



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### Constructing the model

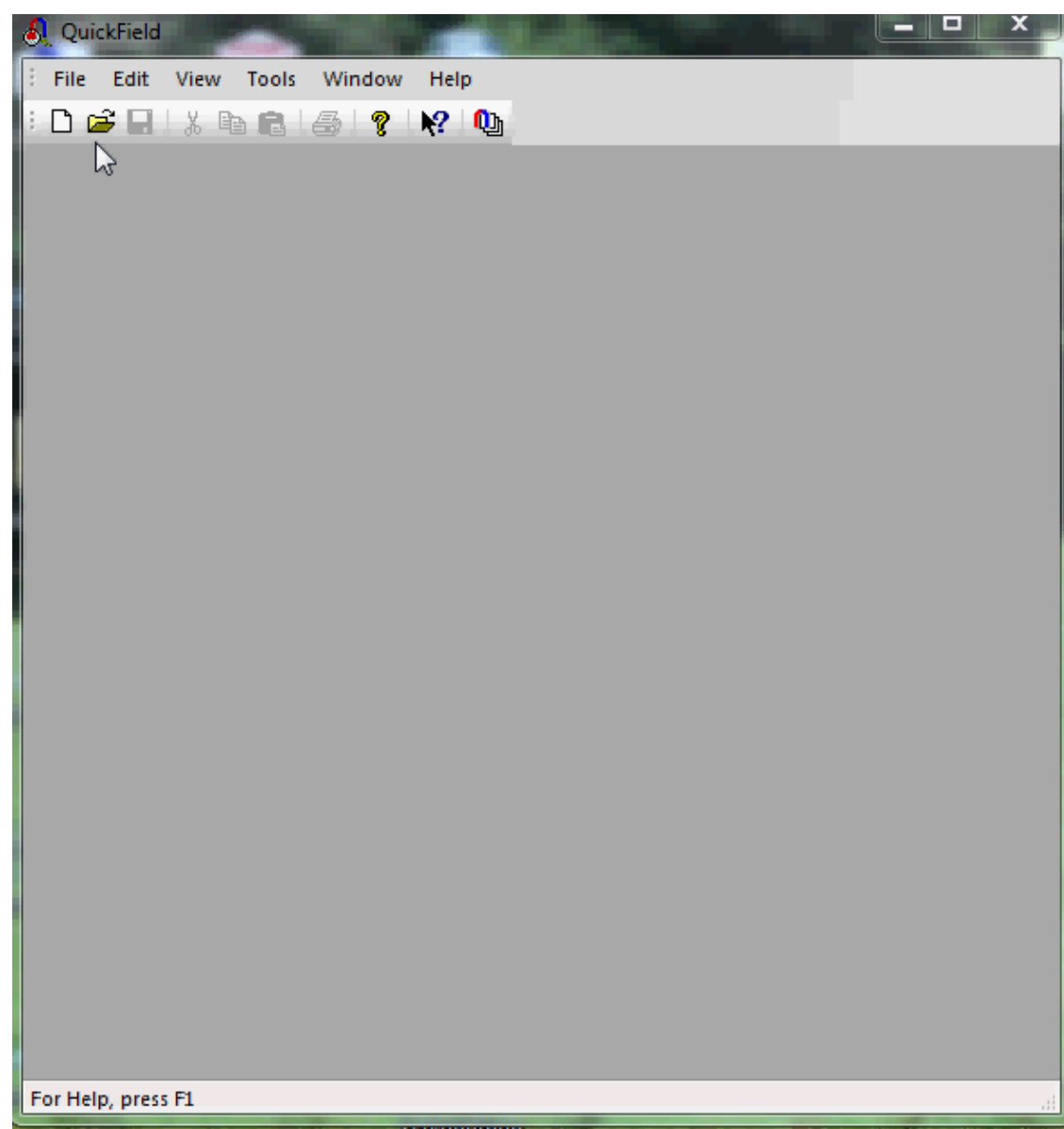
First of all it is an idea, to simplify the model in a manner, which differs from the reality. It deals with the potentials, which are in our focus. Let us explain it with the figure. In fact, we go closer to a normal potentiometer operation, in which the bottom connection is put to 0 Volts and the wiper gives the result voltage.



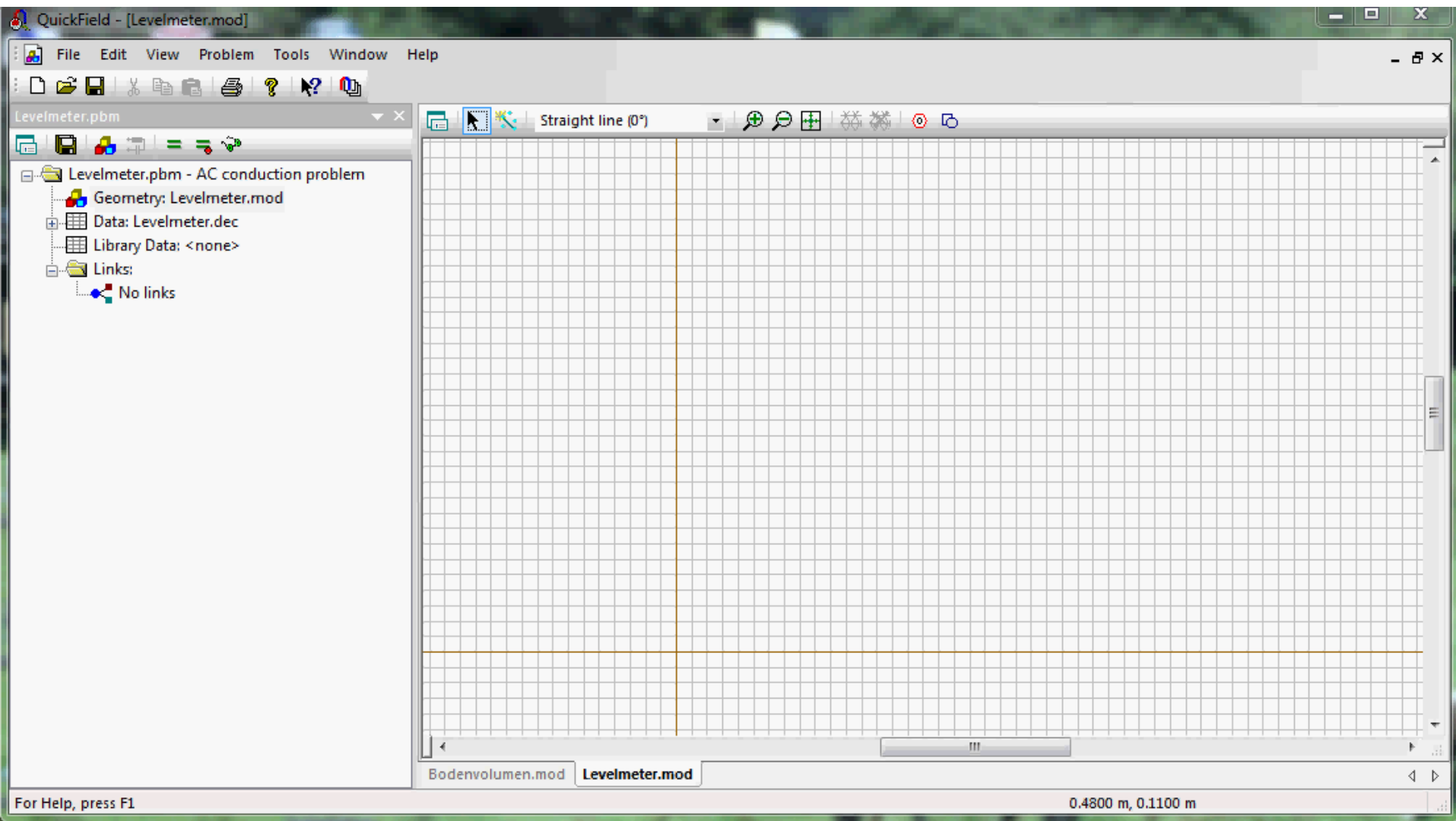
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This is the vessel, and it is not connected to anywhere, it is floating. The top connection is put to a certain voltage. This is suitable at 2 Volts, then the highest filling level produces 1 Volts as the potential of the vessel. This way, we don't need to recalculate the dealing with normalized values. This is our preliminary consideration to simplify the simulation model.



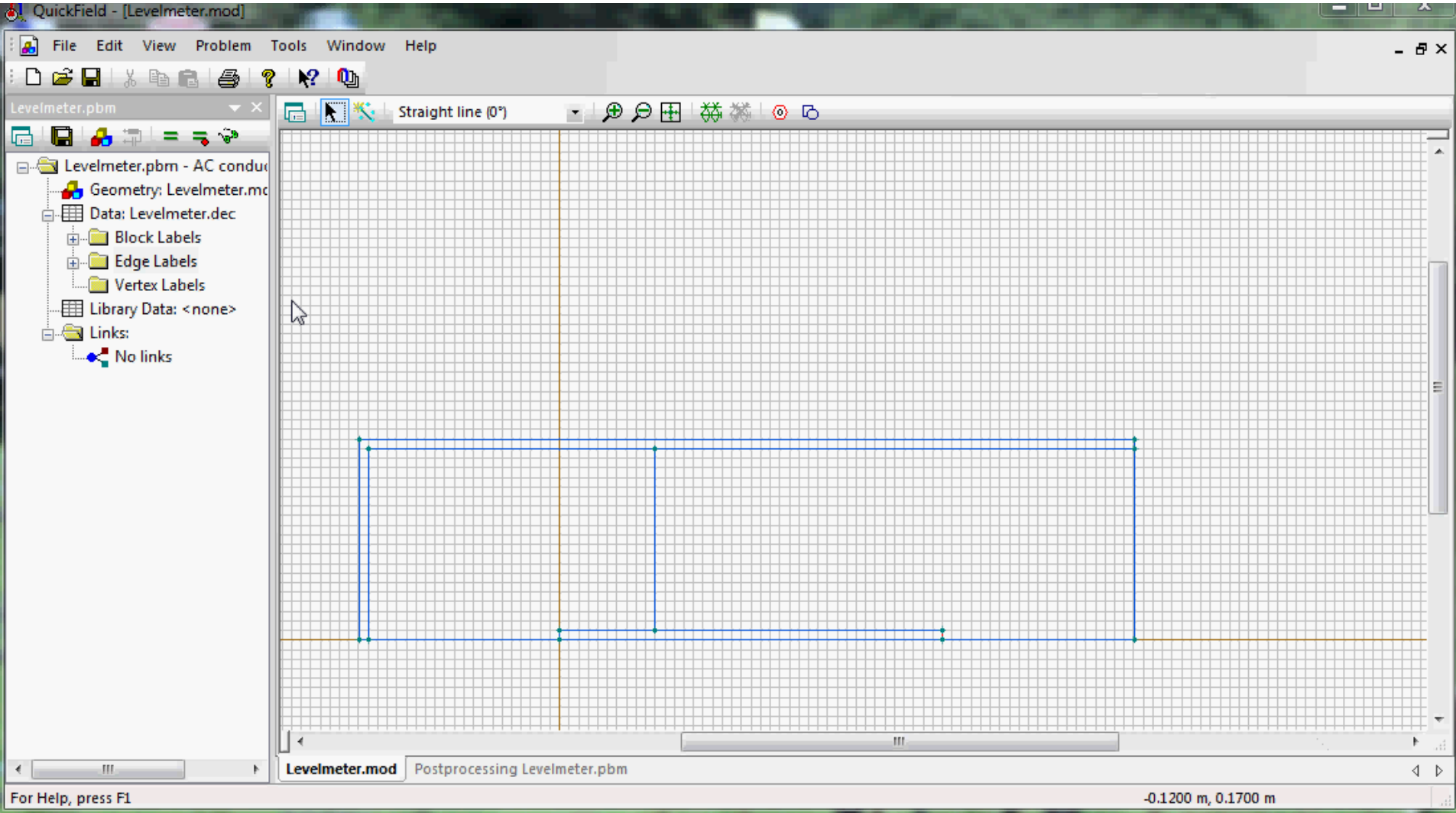


to reduce the problem to two dimensions. We have two options: *Plane-parallel* and *Axisymmetric*. The first option assumes that the model reaches into the Z-axis, which is the perpendicular direction of the drawing layer. The second option, the axisymmetric class, assumes rotation symmetry to the axis, which goes to the right side. In this case this is the Z-axis, while the upright axis is the R-axis. For our problem, we can imagine that a vessel is a rotation-symmetric construct. And one dimension is the vessel's axis, where the filling height is also located. Another advantage of using axis-symmetry is, that to draw just one half side is enough to define the whole geometry. We select *Meter* as the unit – this is just an option, to which we have to adapt our vessel dimensions.

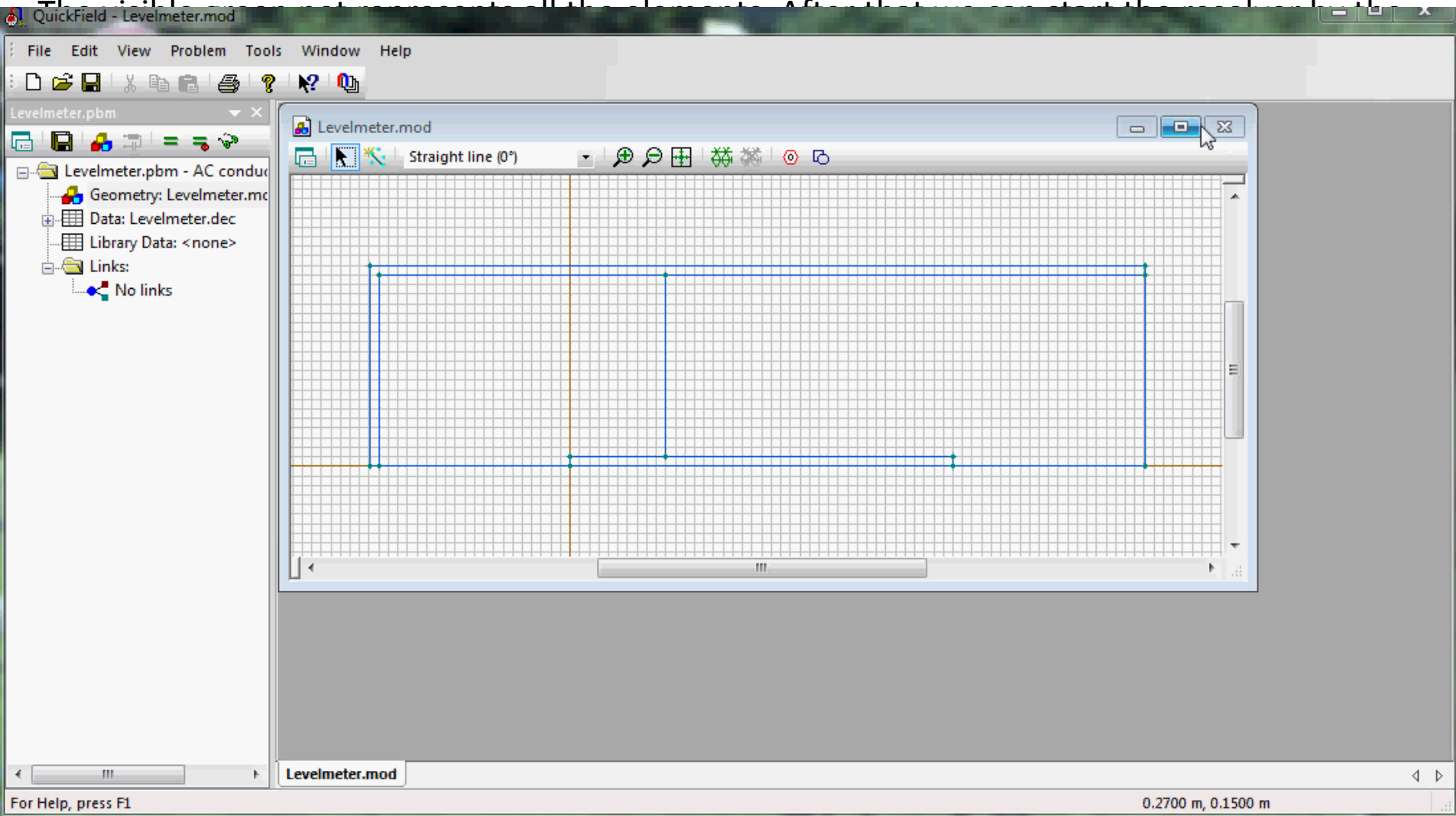


The last drawing step is to form the outline of the vessel on its outside, that means, the vessel's wall.

After all that drawing work, we should have 4 different blocks: Medium, Air, Rod, and Vessel. After assigning these names, the block properties have to be defined. We still need two edge labels – the rod's bottom and its top, because we want to assign their voltages later on.

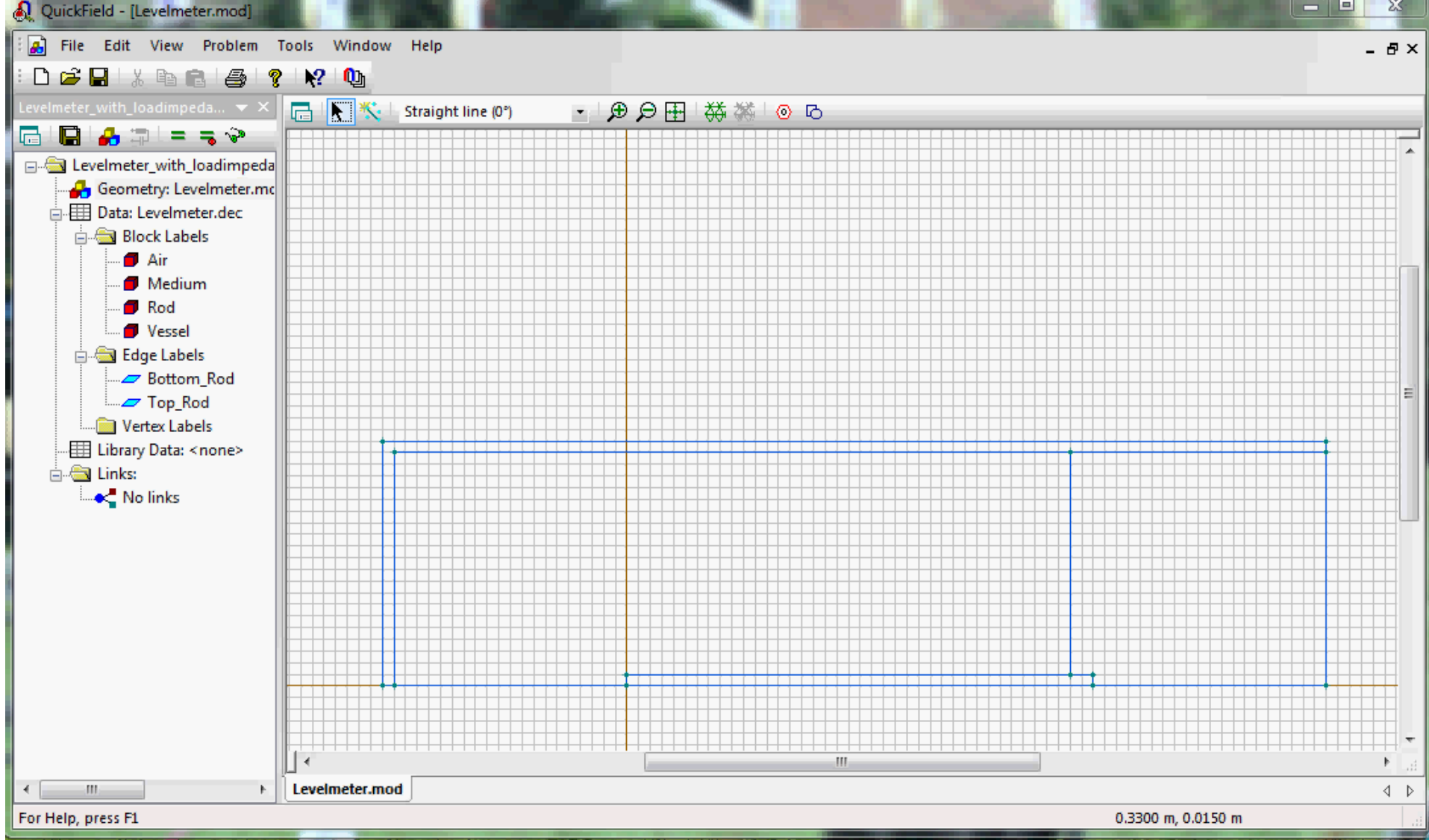


rod's left side to zero point of the drawing, which is also the null level. As soon as the medium level exceeds this point, the voltage on the vessel goes into positive values, starting from zero, when the level touches the rod's edge. The bottom of the vessel is on the left side in the minus area of Z-axis.

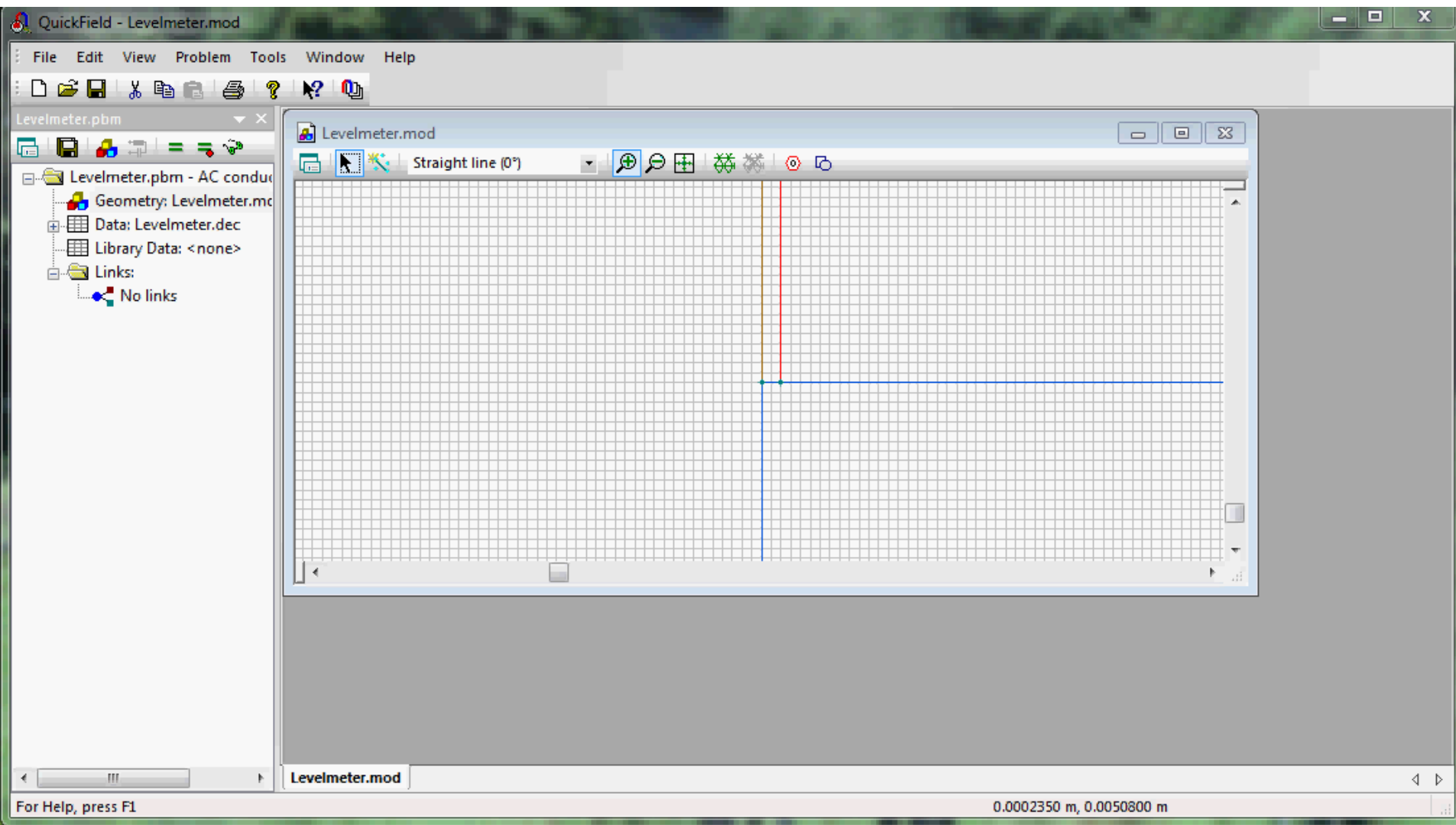


rod.

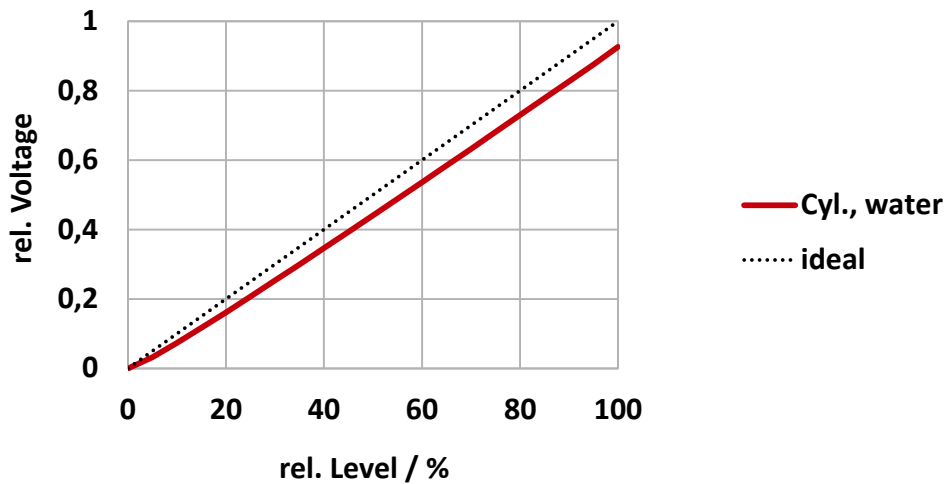
We expected to get 1 Volt, because the whole rod is covered, and the medium should take the average value between 0 and 2 Volts. But in reality, just 0.92 Volts are reached. We can also say, only 92 % are reached, when the rod is wholly covered. Why is that? This will be discussed below.



If the contour is parallel to the rod and only in the medium, the course is smooth and continuous. Close to the rod's middle, the current density of the medium is at minimum, because there is a wider distribution – closer to the rod's ends we have a field concentration.



– as before – for certain filling levels. It is possible to mark this line and to move this selection by choosing Move selection, then enter a value into the field Delta-z. After each move select the mesh command and then get the potential value, like we did before. This way we will have a series of measuring. Later on you can generate diagrams by Excel or so.



## Generating and interpretation of characteristic curves

The generated values from above can be entered into an Excel sheet. We would get a diagram like shown above.

It can be recognized, that the correlation between filling level and voltage is not linear exactly. Especially at the lower part of the curve we have some nonlinearity. This is certainly caused by the unwanted influence of the volume below the rod's bottom. You must not forget that there is conductive medium too, which pulls the emphasis of the conductivity towards the vessel's bottom and thus the voltage towards zero. How strong is this influence? It is hard to calculate, but it is easily analyzed by a simulation like this. You could vary the distance of the vessel's bottom to the rod's bottom. Better still vary this distance as a normalized value in respect to the diameter of the vessel, and you will get a general relationship in your diagram.

Next part will be:

## **Level measurement on liquids – Extensions (special cases in the field) with the following themes:**

**Conical vessel shapes**

**Temperature gradient and inhomogeneous conductivity**

**Measurement systems with finite internal impedances**

**Poor conductivity and AC measurement**

**Very high conductivity, similar to metal**



**Speakers:**

Karin Smiley, Dieter Stotz

**Sound:**

Dieter Stotz

**Dieter Stotz**

Born 1954, works since many years as a hardware engineer and developer in Germany. He also wrote several books and many articles.

His most important publications are:

**Computergestützte Audio- und Videotechnik**, Springer 2011, ISBN 978-3-642-23252-7

**Elektromagnetische Verträglichkeit in der Praxis**, Springer 2012, ISBN 978-3-642-34344-5