WHAT IS CAPACITANCE

By Arjay Engineering

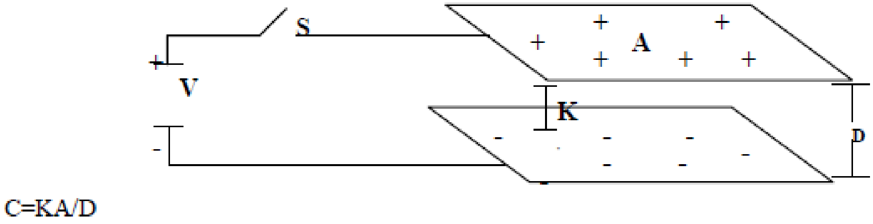
ARJAY ENGINEERING

WHAT IS CAPACITANCE?

An electrical parameter which physically is most easy to define, electrically often misconstrued.

Physically, a capacitor is two electrical conductors separated by a non-conducting (or very high resistance) medium between the conductors. Consider the two plates of area (A) in Figure 1. The plates are metallic and they are separated by a distance (D).

Figure 1.

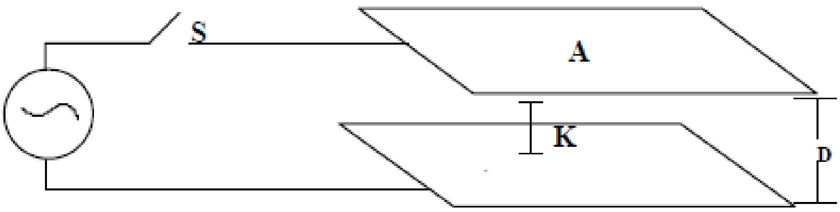


If we fill the space between the plates with a conductor (water, acid, etc.) and close the switch (S), we get a current dictated by ohms law, I=v/r (where V is voltage, and R is the resistance between the plates). If the space is a non-conductor, no current will flow but the voltage will exist across the plates. The plus side and the negative side attract, and electrical charges will exist on the plates; thus an electrical field will exist in the space between. Clearly, the larger the plates, the more charges will exist and the closer the plates (D), the stronger the electrical attraction between the plates will be.

If we now reverse the polarity of the battery, the plus plate is now negative and the negative plate plus. For the electrical charge to reverse, ¢electrons¢ must have flowed, reversing their position. Since ¢electron flow¢ is current, we have current flow when we reverse the polarity.

If we now substitute the battery with an alternating current source, the polarity will reverse every 1/2 cycle and we will, hence, get continuous current flow. Therefore, while a capacitor will not allow DC current to flow through, AC current can pass. The amount of current will depend on the supply voltage, the capacity of the plates to hold charges and the distance (D), which determines the leakage (or electrical field) in the space and the material between the plates.

Figure 2.



The formula for current flow through a capacitor with an alternating voltage applied is I=V2 FKA/D. K is defined as the dielectric of material or ability to store electrons.

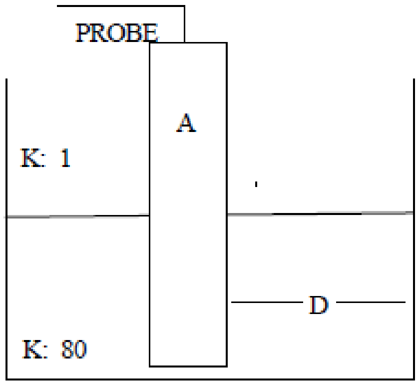
Note: - the higher the area A, the larger the current
- the smaller the D, the larger the current
- K is determined by the material having a high value (eg. water = 80) and non-conducting materials having a lower value (eg. air = 1). Current is increased with the supply frequency (f), as you are reversing the charges more frequently and current increases with supply voltage.

The plates, needless to say, do not have to be rectangular and can be any shape or size. One plate can be grounded and mostly is, in industrial circuits. While the properties of a capacitor have many useful purposes, capacitance can be an annoyance. Capacitance exists between power transmission lines and ground resulting in additional current, and hence, power loss in the lines. Great effort is invested by utilities to reduce this effect.

In capacitance instruments, capacitance is put to a useful purpose. If we keep V and F constant from a regulated circuit, then we have a situation dependent on KA/D. Keeping any two constant, we can measure the third. Here capacitance instruments can be used to measure area, or distance, or the dielectric constant.

In most applications, A and D are constant and we detect a change of K. In most circumstances, the probe is in a steel tank such as Figure 3. A is the surface area of the probe and D is the distance between the probe and the tank wall or other ground.

Figure 3.



If the tank is filled with water (K = 80), it displaces air (K = 1), and we have a dramatic change in capacitance which is utilized in the electronics to activate a relay or transmit a signal proportional to the amount of water in the tank. The electronics allow for tuning of the system so that the operator can activate a relay at any point or measure between a wide choice of spans.

Modern day instruments detect small changes and many insulating products with K factors close to 1 (eg. many petroleum products have a K of approximately 1.5) can be measured.

Most circuits use the electrical ground as one plate, or side of the capacitor, and hence the 'line' side (the probe) is 'looking' across to ground. Any change in the medium which would change net K factor will disturb the instrument (eg. a person walking by). Therefore, if the probe is not looking to a fixed ground (eg. steel vessel) but rather, in a fiberglass ungrounded tank, then a suitable ground rod must be installed. Another typical application is in dry pump protection, where a ring probe designed to mate between two flanges at the inlet of a pump detects presence or absence of liquid. The probe and ground are inside the ring probe.

The total applications for capacitance is growing continuously and is limited only by the imagination of the industry. Many proximity (variable D) applications are in use, as well as interface applications of dissimilar liquids in all shapes and sizes of vessels and pipelines. Capacitance also has the ability to measure solids (eg. wheat, flour, coal) which widely extends its application.

Capacitance is used for safety such as warning people from entering a dangerous area (the person changes the K). The probe may be railing or machine body, or many other configurations.

SPECIFYING THE INSTRUMENTATION

ARJAY offers two basic types of capacitance instrumentation, continuous measurement with 4 to 20 mA output, and On-Off Control. These are available with various power inputs and features.

1. Continuous Level Measurement

Used significantly in inventory control, batching, reservoir observation, and process control, the user is able to receive a tank level measurement at any desired time on a continuous basis. The measurement span is dictated by the length of the probe inserted in the vessel. Note: The measurement is percent level against the vertical probe and not percent volume of the tank.

The ARJAY model 9050, 9070 and 9080 series all provide continuous level measurement, the 9070 being a blind rack mount instrument providing a 4-20 mA output signal, and 9050 Series providing a wall mount unit complete with meter, alarm point(s), and a 4-20 mA output.

2. On/Off Control

Single point, On/Off capacitance controls provide an accurate, inexpensive method of providing alarm points in most materials and applications. The instrument reacts to the absence or presence of the material in relation to the probe.

The probe need only be inserted enough to meet the liquid on a high level tank alarm application. For low or medium tank alarms, the probe may be extended further into the tanks, inserted from the bottom, or inserted into the side of the tank.

If probe contact or insertion into the material proves too obtrusive, proximity plates and flush mount probes are available to provide alarms without interference into the process.

The 8820 and 9060 Series of On/Off Controls provide the customer with relay contacts for use with pump control, alarms, indicators, shut-off valves, etc. Using the basic ARJAY ON/OFF CONTROLLER, a differential option may be provided to cycle the action of the relay between two points on an ARJAY Probe.

PROCESS APPLICATION CONCERNS

The APPLICATION DATA SHEET is used to describe the process application concerns. When reviewing a project with the customer, be sure to fill in all pertinent data for future reference. Forward a copy to ARJAY ENGINEERING.

Material to be Measured (physical and chemical description)

Standard probes manufactured by ARJAY are Teflon coated. This has high chemical resistance but may not withstand certain highly corrosive chemicals. Verify with the customer or the factory on the usability of Teflon.

Erosive materials may wear down or puncture the probe insulation material. Guards may have to be supplied for these applications.

On dry materials such as powders and pellets, a stainless steel wire is wrapped along the length of the probe to drain static buildup off the Teflon.

Does the Material Composition Change?

Since the theory of Capacitance Level relies on a consistent dielectric, any composition change may cause a dielectric change. This will affect the instrument calibration and result in erroneous readings. Re-calibration is required if the material dielectric changes.

Tank Construction Material

The ARJAY probe requires a ground reference to operate effectively and without outside interference. If the tank is fiberglass or plastic, a ground reference or shield must be provided with the ARJAY probe. The ground reference may be installed on either side of the non-conductive tank wall. For a metallic tank, a reference shield would not be needed unless the probe is installed too far from the wall and the material dielectric is low. Also, if the tank wall does not act as a linear reference such as an oval tank, then a shield should be used.

Tank Pressure and Operating Temperature

Pressure and temperature both may cause erroneous readings if the variation is extreme enough to cause large dielectric changes. The ARJAY probes are rated for 1500 psi and 500 degrees F. Other materials are available for probe insulations that allow the use of our probes beyond the normal operating specifications of the probe.

Humidity Changes

Should the tank experience humidity changes, the zero calibration of the instrument may be affected. Should the change be dramatic, the less the area of the probe is exposed to the atmosphere in question, the greater the accuracy of the instrument.

Material Agitation

The probe measures level as a result of material rising flush to it. If tank agitation causes a liquid rise around the probe, this level will be read. Splashing of liquid may also be picked up by the probe, as well as any drainage over the probe from the tank inlet. To avoid these effects on the probe, a shield can be used around the probe. Time delay is also available on the ARJAY instrumentation to suppress the effects of liquid rippling and splashing, which in turn may cause false alarms and relay chattering.

Probe Data

Review the probe construction options with the customer. The Teflon coated probe with a stainless steel fitting is the ARJAY standard. This covers most applications and is readily available for manufacture at the ARJAY plant. Other materials and designs are available, should the customer have special requirements.

Email: arjay@arjayeng.com
Tel: +1 (905) 829 - 2418
Toll free: +1 (800) 387 - 9487
Website: www.arjayeng.com