Applications

- **Liquid Level Control** for both hazardous and non hazardous materials.
- **Package Inspection** for product content and/or fill level.
- **Wire-Break Detection** for wire sizes down to .003".
- **Plastic Pellet Level Detection** in a hopper for injection molding processes.
- **Grain or Food Products Level Detection**; intrinsically safe models available.
- **Small Metal Parts Detection**; greater sensing range than comparable inductive sensors.

Operating Principle

The active element is formed by two metallic electrodes positioned much like an "opened" capacitor (Figure 1).
Electrodes A and B are placed in a feedback loop of a high frequency oscillator. When no target is present, the sensor's capacitance is low, therefore the oscillation amplitude is small. When a target approaches the face of the sensor, it increases the capacitance. This increase in capacitance results in an increased amplitude of oscillation.
The amplitude of oscillation is measured by an evaluating circuit that generates a signal to turn on or off the output (Figure 2).

Figure 1

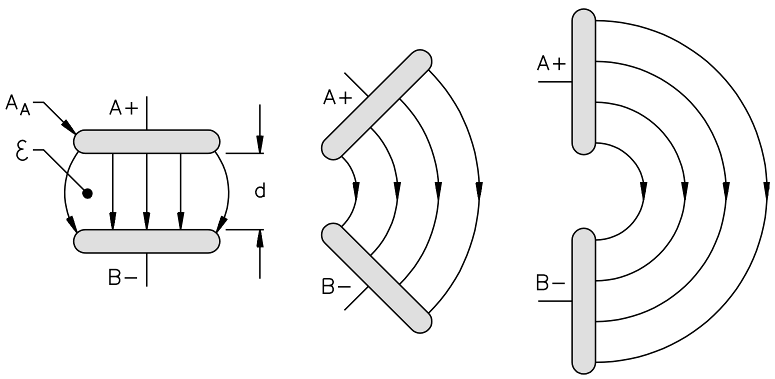
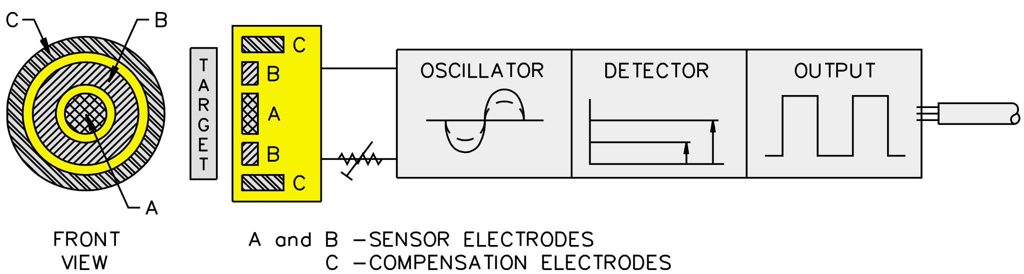


Figure 2



Capacitance is a function of the surface area of either electrodes (A or B), the distance between the electrodes (d), and the dielectric constant of the material (ε) between the electrodes (Figure 1).

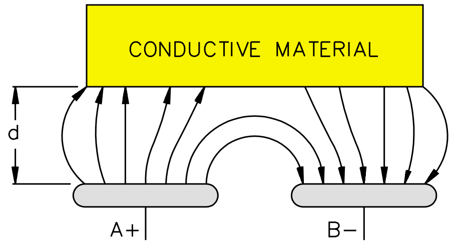
$$C = \frac{\varepsilon \times A}{d}$$

C = capacitance of sensor
A = surface area of either electrode
d = distance between two electrodes
ε = dielectric constant of material between the electrodes (found on Pages F9-F11)

When a **Conductive Target** enters the sensor's field, it forms a counterelectrode to the active face of the sensor, thus decreasing the distance between the electrodes (d), and increasing the average surface area of the electrodes.

The capacitance with a metal target present is always greater than the capacitance of the circuit in the absence of the target.

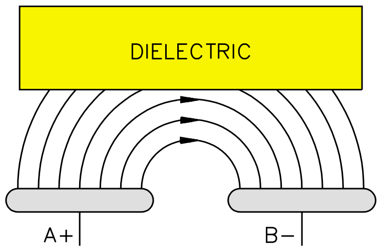
Figure 3



When a **NonConductive Target** enters the sensor's field, it acts as an electrical insulator between electrodes A and B.

The dielectric constant of the material (ε) is a measure of its insulation properties. All liquids and solids have a greater dielectric constant than air ($\varepsilon_{air} = 1$). Therefore, the capacitance with a nonmetallic target present is always greater than the capacitance of the circuit in the absence of the target.

Figure 4



Temperature and Environmental Conditions

Compensation Electrode

In practice, sensors can be affected by water droplets, humidity, dust, etc., causing false outputs. To combat this effect each **TURCK** Capacitive sensor incorporates a compensating electrode (C) which forms part of a negative feedback circuit (Figure 5).

When contaminants are on the sensor face, they affect the sensor's main field, as well as its compensation field. The negative feedback circuit detects the increase in both fields, and can filter out the effects of the contaminants.

When a large target comes into the sensor's main field, the compensation field is not affected, thus the negative feedback circuit can distinguish a difference between the two fields, and the sensor generates an output.

Figure 5

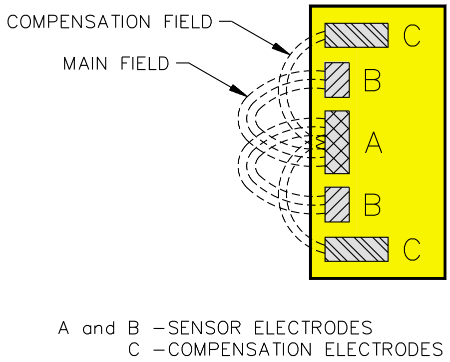
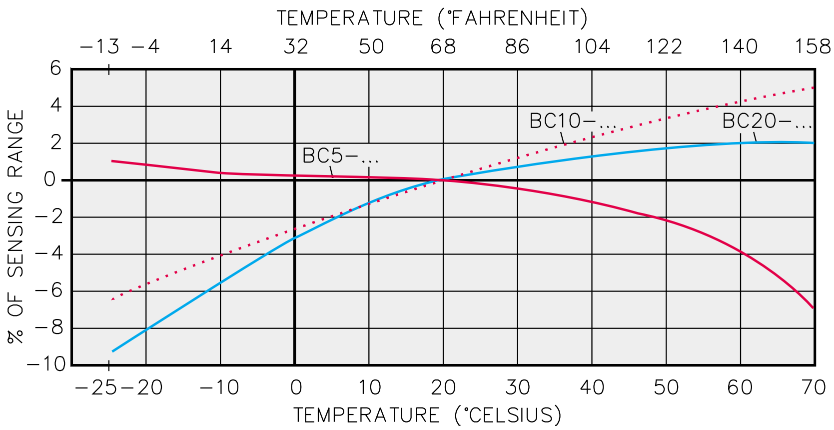


Figure 6 *Temperature Influence on Operating Distance*

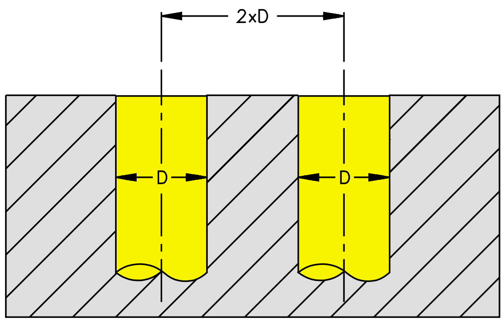


Mounting

Most capacitive sensors manufactured by **TURCK** are embeddable, which ensures that the electric field is only effective in front of the active face. They are suitable for flush mounting at the factory setting in any material (conductive & non-conductive).

When sensors are flush mounted, the effect on the operating distance is minimal and can be overcome by adjustment of the potentiometer. Minimum separation distances must be observed to avoid the possibility of interference between the two sensors' fields.

Figure 7



Operating Distance (Sensing Range) Considerations

The operating distance (S) of the different models is basically a function of the diameter of the sensing coil. Maximum operating distance is achieved with the use of a standard or larger target. Rated operating distance (Sn) for each model is given in the manual.

Standard Target

An earth-grounded square piece of carbon steel having a thickness of 1 mm (0.04 in) is used as a standard target to determine the following operating tolerances. The length and width of the square is equal to three times the rated operating distance.

Operating Distance = S

The operating distance is the distance at which the target approaching the sensing face along the reference axis causes the output signal to change.

Rated Operating Distance = Sn

The rated operating distance is a conventional quantity used to designate the operating distance. It does not take into account either manufacturing tolerances or variations due to external conditions such as voltage and temperature.

Effective Operating Distance = Sr $0.9\ Sn \leq Sr \leq 1.1Sn$

The effective operating distance is the operating distance of an individual proximity sensor at a constant rated voltage and 23°C (73°F). It allows for manufacturing tolerances.

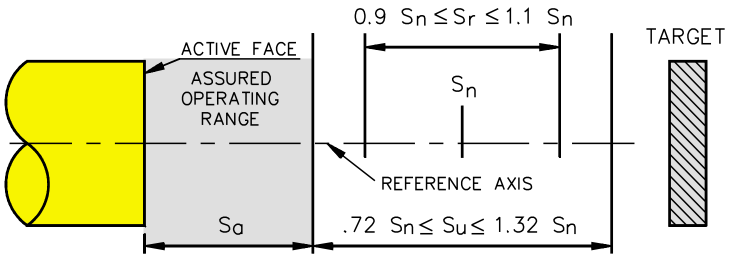
Usable Operating Distance = Su $0.72\ Sn \leq Su \leq 1.32Sn$

The usable operating distance is the operating distance of an individual proximity sensor measured over the operating temperature range at 85% to 110% of its rated voltage. It allows for external conditions and for manufacturing tolerances.

Assured Operating Range = Sa $0 \leq Sa \leq 0.72Sn$

The assured actuating range is between 0 and 72% of the rated operating distance. It is the range within which the correct operation of the proximity sensor under specified voltage and temperature ranges is assured.

Figure 8



Capacitive

Industrial Products and their Dielectric Constants

Material	Dielectric Constant
ABS resin, pellet	1.5 - 2.5
Acetone	19.5
Acetyl bromide	16.5
Acrylic resin	2.7 - 4.5
Air	1.0
Alcohol, industrial	16 - 31
Alcohol, isopropyl	18.3
Ammonia	15 - 25
Aniline	5.5 - 7.8
Aqueous solutions	50 - 80
Ash (fly)	1.7
Bakelite	3.6
Barley powder	3.0 - 4.0
Benzene	2.3
Benzyl acetate	5
Butane	1.4
Cable sealing compound	2.5
Calcium carbonate	9.1
Carbon tetrachloride	2.2
Celluloid	3.0
Cellulose	3.2 - 7.5
Cement	1.5 - 2.1
Cement powder	5 - 10
Cereal	3 - 5
Charcoal	1.2 - 1.8
Chlorine, liquid	2.0

Material	Dielectric Constant
Coke	1.1 - 2.2
Corn	5 - 10
Ebonite	2.7 - 2.9
Epoxy resin	2.5 - 6
Ethanol	24
Ethyl bromide	4.9
Ethylene glycol	38.7
Flour	2.5 - 3.0
Freon® R22 & 502, liquid	6.1
Gasoline	2.2
Glass	3.1 - 10
Glass, raw material	2.0 - 2.5
Glycerine	47
Hexane	1.9
Hydrogen cyanide	95.4
Hydrogen peroxide	84.2
Isobutylamine	4.5
Lime, shell	1.2
Marble	8.0 - 8.5
Melamine resin	4.7 - 10.2
Methane, liquid	1.7
Methanol	33.6
Mica, white	4.5 - 9.6
Milk, powdered	3.5 - 4
Nitrobenzene	36
Neoprene	6 - 9

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Industrial Products and their Dielectric Constants

Material	Dielectric Constant
Nylon	4 - 5
Oil, for transformer	2.2 - 2.4
Oil, paraffin	2.2 - 4.8
Oil, peanut	3.0
Oil, petroleum	2.1
Oil, soybean	2.9 - 3.5
Oil, turpentine	2.2
Paint	5 - 8
Paraffin	1.9 - 2.5
Paper	1.6 - 2.6
Paper, hard	4.5
Paper, oil saturated	4.0
Perspex	3.2 - 3.5
Petroleum	2.0 - 2.2
Phenol	9.9 - 15
Phenol resin	4.9
Polyacetal (Delrin®)	3.6
Polyamide (nylon)	2.5
Polycarbonate	2.9
Polyester resin	2.8 - 8.1
Polyethylene	2.3
Polypropylene	2.0 - 2.3
Polystyrene	3.0
Polyvinyl Chloride resin	2.8 - 3.1
Porcelain	4.4 - 7
Press board	2 - 5

Material	Dielectric Constant
Quartz glass	3.7
Rubber	2.5 - 35
Salt	6.0
Sand	3 - 5
Shellac	2.0 - 3.8
Silicon dioxide	4.5
Silicone rubber	3.2 - 9.8
Silicone varnish	2.8 - 3.3
Styrene resin	2.3 - 3.4
Sugar	3.0
Sugar, granulated	1.5 - 2.2
Sulfur	3.4
Sulfuric acid	84
Teflon®, PCTFE	2.3 - 2.8
Teflon®, PTFE	2.0
Toluene	2.3
Trichloroethylene	3.4
Urea resin	6.2 - 9.5
Urethane	3.2
Vaseline	2.2 - 2.9
Water	48 - 88
Wax	2.4 - 6.5
Wood, dry	2 - 7
Wood, pressed board	2.0 - 2.6
Wood, wet	10 - 30
Xylene	2.4

Sensitivity Adjustment

Capacitive sensors can be adjusted two ways in order to sense a target consistently.

1. **Physical adjustment** - moving the sensor towards or away from the target is the preferred method of adjusting sensitivity when the sensor is not in direct contact with the target. This allows materials to be moved into or out of range while leaving the sensor at the factory setting or after re-calibration to the nominal operating distance Sn.
2. **Adjustment of the potentiometer** - turning the potentiometer in a clockwise direction increases the sensitivity of the sensor. The potentiometer is factory-set for an operating distance of 0.7 to 0.8 Sn to a grounded standard target (Figure 9). It should be adjusted in increments of no greater than a quarter-turn (Figure 10). Increasing the sensitivity results in a greater operating distance to both conductive and non-conductive targets.

Figure 9 *Standard Target*

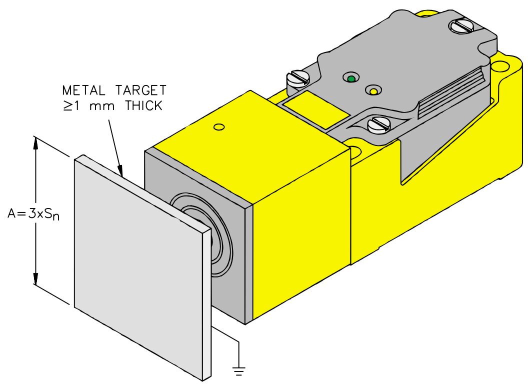
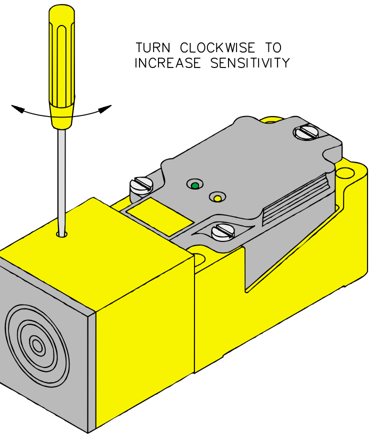
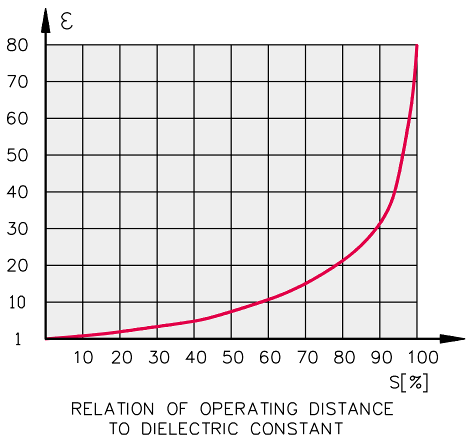


Figure 10 *Potentiometer Adjustment*



When sensing non-conductive targets, the larger the dielectric constant of a material, the greater the achievable operating distance (Figure 11). Adjusting the potentiometer affects the total curve; for example, if the potentiometer is adjusted for less sensitivity, it will have less operating distance to all materials.

Figure 11



In general terms, the larger the dielectric constant of a material, the greater the achievable operating distance.

When detecting organic materials the sensing distance will depend largely on the water content ($\varepsilon_{water} = 88$).

It should be noted that a large increase in sensitivity will cause the sensor to become nonembeddable, and may result in an unstable switching point that can be influenced by environmental changes such as temperature, humidity, dust, etc.
At adjustments of S > Sn, the differential travel (hysteresis) can also increase.

Example Application 1 - Adjustment

Problem:
Can a BC20-K40SR-FZ3X2 be used to sense the presence of ammonia from behind a .125" glass panel?

Solution:
A) In this example, the potentiometer should be adjusted so that the sensing range to a grounded standard target is 20 mm (Sn), and not left at the factory setting of 0.7 x Sn, or 14 mm.

Dielectric (ε_r) of ammonia: 20
Dielectric (ε_r) of glass: 10

From Figure 11, ε_r = 20 corresponds to 80% Sn; ε_r = 10 corresponds to 60% Sn.

Since Sn = 20 mm for a BC20: S for ammonia = 16 mm
S for glass = 12 mm

The difference is 4 mm. The glass thickness = .125", or 3.1 mm. This application will work with a 0.9 mm margin. This means that the sensor should be positioned between 12 and 12.9 mm away from the glass, so that the glass is out of range, but the ammonia is not.

B) If the sensor were left at the factory setting: S for ammonia = 11.2 mm
S for glass = 8.4 mm

The difference is 2.8 mm, which is less than the thickness of the glass. This means that the sensor will detect only the glass at sensing distances ≤ 8.4 mm, and neither material at distances >8.4 mm. The glass would have to be less than 2.8 mm thick in order for the ammonia to be detected.

Example Application 2 - Mounting

Problem:
A metal tank containing a water-based solution has a 1" outside diameter sight glass. What sensor and bracket could be used for monitoring the liquid level?

Solution:
Mounting bracket TSG-18 can be used on non-conductive tubing ranging in diameter from 0.63 - 1.12 inches, and is used with 18 mm sensors such as the BC 5-S18-AP4X (Figure 12).

The bracket can be found in Section J.

Figure 12