# FW Bell  Gaussmeter Probe Selection and Application Guide

When selecting a gaussmeter and probe several things must be considered to determine the best gaussmeter and probe models for the application.

1. The range of flux density to be measured.
2. Is a transverse or axial configuration required?
3. The type of signal to be measured;  DC or AC?
4. If AC
    a. What frequency or range of frequencies are of interest?
    b. What type of waveform, sinusoidal, square, unidirectional pulse etc.?
    c. Continuous signal or one-shot / burst / pulse etc.?
5. What accuracy (absolute or relative) and precision or resolution is required?
6. Environmental conditions; temperature, humidity, vibration, handling stresses
7. Do you require analog output signals?
8. Are digital outputs or remote control capabilities such as RS-232, IEEE-488, USB or Ethernet required?

**Probe selection**

The first thing to determine is the basic probe configuration. In many cases either a transverse or axial probe may be used if there are no physical limitations which force you to use one or the other. If for example you are just checking residual magnetism on a pipe or measuring the surface of an object either type will probably work as long as you can orient the probe stem and cable to a position which allows a proper reading.

Transverse probes are required if you need to measure the flux density in a gap between objects or surfaces such as in a cut core, between rotor and stator of a motor, or perhaps a loudspeaker magnet assembly.

An axial probe would be required if you need to measure inside of an object like a small diameter solenoid coil or sputtering chamber.

See the following photos for examples:

**Transverse probe required**

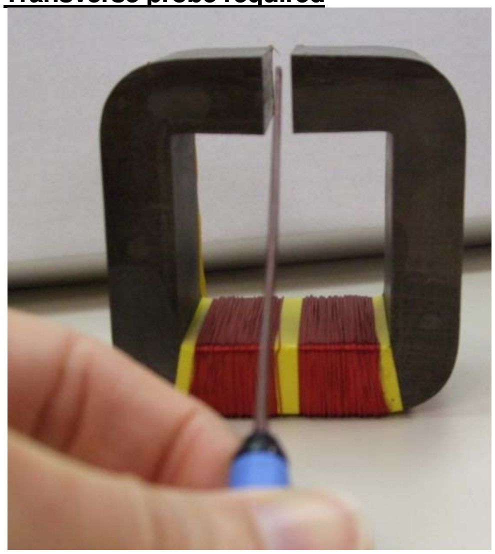

Photo 1 -Core Gap

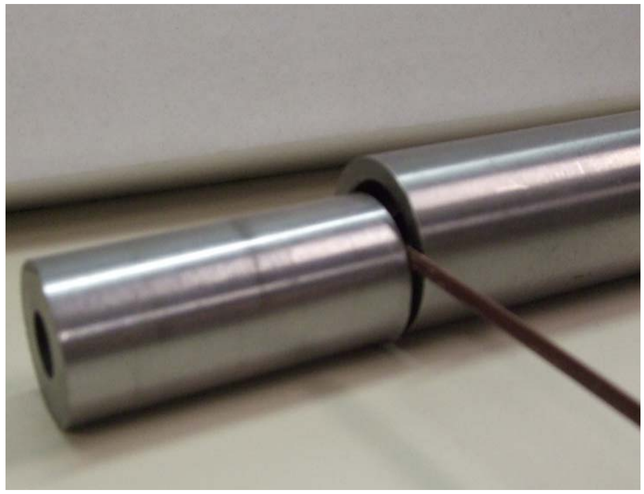

Photo 2 -Between objects

**Axial Probe Required**

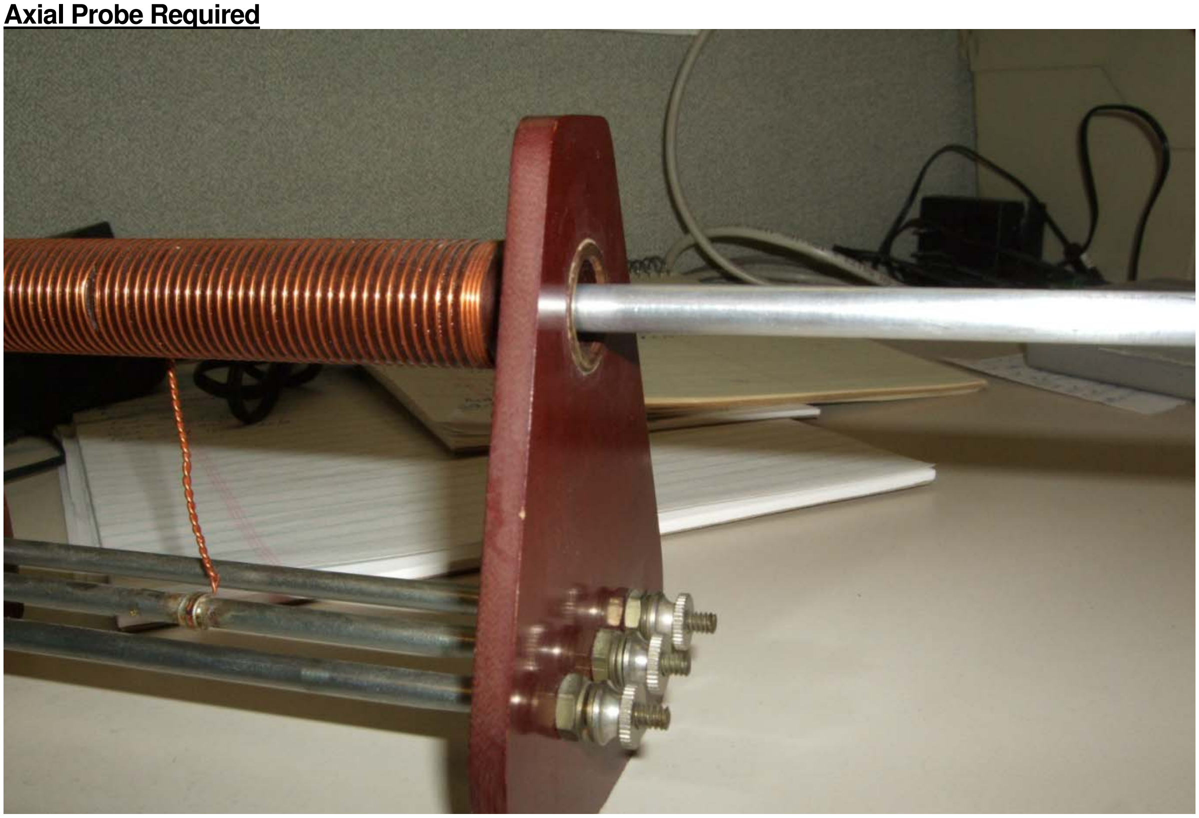

Photo 3 -Solenoid Coil

**Either Axial or Transverse** -External Surface or Free Space measurements

Photo 4

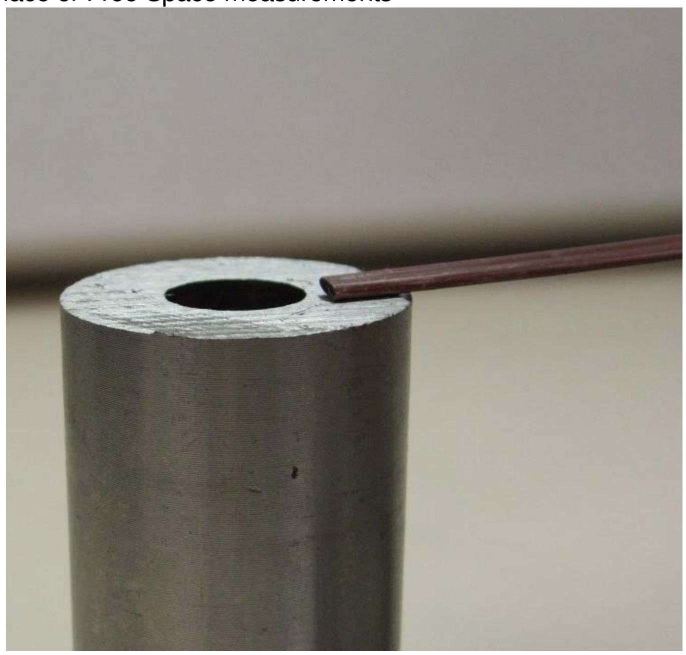

Photo 5

As can be seen from photos 4 and 5, the same measurement could be taken with either probe configuration since there are no physical limitations. In both cases the Hall plate inside the probe is parallel to the end face of the pipe. If there are no other limitations or reasons to choose a particular configuration, the axial is usually a little more robust to handling due to the larger cylindrical probe stem. This may be a concern in certain applications where there is a higher risk of handling damage.

Specifications and Accuracy

Most probes have a linearity specification which is expressed as a percentage of reading error over a range of magnetic flux; for example 1% to ±30kG, or 0.5% to ±2T. This specification is for DC fields and must be added to the accuracy specification for the gaussmeter on the range being used to determine total measurement uncertainty. Some probes such as the ZOA 3-axis types have a linearity range specified to a flux density level which is less than the full scale reading of the gaussmeter (10kG for the probe and 30kG for the gaussmeter). Most of these will still respond to higher field levels, but with increasing error above the upper specified limit.

The exceptions to this are the Low Field probes. The MOS models utilize Fluxgate technology and their internal circuitry will clip and not measure beyond the ±1.0G limit specified. The model MOX or MOW Hall probes ("MagnaProbes") with flux concentrators will respond above the 2.0G specification limit, but will become non-linear very fast between 2 and 3 gauss and may require degaussing to restore accuracy if operated beyond ±4 gauss.

Accuracy for AC fields is not as good as for DC. This is because the signal is susceptible to more parasitic effects as noted in the AC Considerations section below, and the fact that finding and constructing a primary reference standard for AC is more difficult than for DC. Since applications can vary greatly, we do not have hard specifications for AC. We attempt to compensate for the major factors to keep error within a few percent, but each environment and a probe's response to it is different. In most cases the compensation will keep the error well below the ±3dB limits often used for AC bandwidth specifications on measuring equipment.

## Geometric Tolerances as a Source of Variation

In situations where the user is positioning the probe by using the outer surface of the stem as a reference point and measuring on the surface of an object there may be differences observed between probes of the same model. This is due to manufacturing tolerances which will place the Hall device at slightly different positions within the probe. In most cases this is not of significance, but in others this needs to be considered. For example the Hall plate in a transverse probe may not be exactly centered in the stem and if the readings with one side against the surface are compared to those with the opposite side of the probe on the surface there may be a difference in magnitude. The polarity will obviously be opposite, but the magnitude could differ too. Even though this positioning error is only a few thousandths of an inch, in some applications it is necessary to be aware of this and compensate accordingly. Also the Hall plate may not be exactly parallel to the probe stem surface and relying on the outer surface of the probe stem for positioning may result in a reading which is slightly lower than the actual flux density due to this angularity error. Probes are calibrated in an air gap and rotated until the peak reading is obtained.

## Thermal Considerations

Temperature coefficients of the probe should be considered if operating at temperatures more than a few degrees from the usual ambient of ~22°C and high accuracy is required. Temperature compensated probes may be helpful in these instances and these corrections are performed automatically by the gaussmeter. In other applications which are outside the normal compensation range (such as cryogenic probe usage) manual correction will be needed. Temperature coefficient data for most probe models may be obtained from their data sheets. If it is necessary to measure an object which is hotter or colder than the specified operating temperature range for the probe, consider shielding the probe stem in some type of non-magnetic tube which has air or fluid flowing through it to keep the probe at a more moderate temperature. This can also increase accuracy even if you are within the specified operating temperature limits for the probe and do not have a temperature compensated probe.

## Thin Film Probes

There are several models of thin film probes available for the 8000 series meters. These probes have 10 to 20 times higher impedance and therefore have a little bit higher noise floor than the normal bulk types. Typical noise or short term drift for an 8000 series thin film probe is about 5mG. This is a bit of a tradeoff to get the smaller sizes available with this type of probe. Thin Film probes are also available for the 5100 and 6010 meters, but due to the lower display resolution of those meters, the additional noise is not noticeable.

AC Considerations

In general, errors from the following parasitic effects will increase proportionally as frequency increases. These apply to both continuous and discontinuous AC signals (pulses).

- Aluminum probe stems may have some error at frequencies above a few kilohertz due to eddy currents developed in the stem. Some axial probes have a small slit in the tip to reduce this error and are still relatively accurate up to 20kHz. The probes designated as "heavy duty" have model numbers beginning with an "H" do not have this slit, are thicker aluminum and may exhibit more eddy current error.
- There is always some finite loop area associated with the Hall plate itself, wiring in the stem and junctions at the Hall element and probe cable. We attempt to keep such areas as small as practicable, but they can't be totally eliminated. These loops when exposed to an AC magnetic field will generate inductive voltage signals which mix with the output of the Hall sensor. This inductive voltage increases more-or-less linearly as the frequency increases. The probe body or handle is usually the most susceptible area to external field influences and should be kept out of the field if at all possible.
- The amount of the probe stem, probe body and cable which is exposed to an AC magnetic field can affect the reading. We calibrate probes for frequency response in an attempt to increase accuracy over a wide range of frequencies, but each application is different and we can't compensate for each one. We do use consistent methods which we believe to be typical of most applications when calibrating for AC frequency response. Transverse probes are calibrated with only about 0.5" of the probe tip exposed to the AC field. Axial probes are calibrated with 2" at the tip of the stem inserted into the AC field.
- Depending on the angle of any inductive loop compared to the Hall plate the angular position within an AC field may not give exactly the expected results. For example, if the probe was positioned with the Hall device at a 60° angle to the field direction one would expect a reading about 86.6% of the value when the Hall plate is at 90° to the field. Any inductive signal could mix with the Hall signal and alter this value or produce signals which would be the vector summation of the Hall and inductive signal.

Using a gaussmeter to measure low currents

For short term experiments a gaussmeter could be used with a gapped toroid core to form an open loop current sensor. This may be helpful and easier than using an actual current sensor if the necessary power supplies or space are not available. A transverse probe can be inserted into the core gap and then a known current can be passed through a wire going through the core to calibrate the setup for a known gauss/ampere coefficient. Adding more turns of the current carrying conductor through the core can make a very sensitive current sensor. This could be useful in situations where trying to measure parasitic current drain on an otherwise high current circuit. Normally a low current ammeter or shunt used in a situation like this would be destroyed when the high current was energized. In this case although the core could become magnetized if the high current were energized and may require degaussing to be accurate at low currents again, no permanent damage would occur. If the core were not merely gapped, but a 2-piece design similar to a clamp-on type of current probe, then the core could be removed when the high current was energized thereby preventing core saturation and magnetization. Reference the figures in our current sensor catalog for open loop sensors for more details.