

Instability in flowmeter flow Rates can generally be defined as abrupt, rapid, or unexpected fluctuations in flow Rate during normal operations. Instability can result from a wide variety of causes including:

- Fluid turbulence
- Low fluid conductivity
- Chemical and solids effects
- Moisture entering the flowmeter body or electronics enclosure
- Stray electrical currents in the fluid
- Electrical noise, both radiated and conducted

In many applications, a moderate amount of instability may be tolerated as long as it does not significantly impact the accuracy of the required measurement. For example, the accuracy of the accumulated Total flow measurement (gallons, cubic feet, etc.) may be well within the specified accuracy of the flowmeter even though the indicated flow Rate displayed (GPM, cubic ft/min, etc.) is unstable due to one of the above factors. If the purpose of the flowmeter is primarily to indicate accumulated Total flow, and the difficulty of reducing flow Rate instability is high, it may not make sense to attempt to remediate the instability. However it will still be necessary in this case to verify that the flow Rate instability is not symptomatic of a more serious problem that could be degrading the accuracy of the accumulated Total.

FLUID TURBULENCE

Sources of fluid turbulence include flow disturbances, non-full pipe, and pulsating flow. Flow disturbances are caused by pipe fittings (bends, wyes, tees), pipe diameter changes, obstructions in the pipe and valves; particularly check valves and partially closed valves. To diagnose these problems, begin by verifying that the upstream/downstream straight pipe recommendations in the flowmeter installation manual are followed for bend distances from the flowmeter. Verify that all nearby valves are fully open. If these guidelines are compromised, the piping system may need to be changed to improve the stability. Full-bore magnetic flowmeters are far less susceptible to these types of problems as long as the pipe is always full at the flowmeter.

Non-full pipe may result from any significant fluid air entrapment, or a partially filled pipe, which may cause instability and also degrade accuracy. If the flow Rate indicated by the flowmeter appears to be significantly different than expected, this

possibility should be investigated. Following the installation manual piping guidelines will normally provide sufficient fluid back pressure to prevent this condition. Check for upstream internal pipe obstructions and verify that upstream valves are fully open. A condition known as “hollow water” may occur when a turbulence-producing upstream obstruction or piping component such as a partially closed valve (with insufficient downstream back pressure) results in the pipe being only partially full when the fluid reaches the flowmeter. Partially closing a downstream valve (to temporarily increase back pressure) and noting an improvement in flow rate accuracy and stability is one means of diagnosing this type of problem. The condition may not be a problem if it occurs only during the time just after the pump has started and back pressure is still low due to the piping downstream from the flowmeter not yet being full.

Another turbulence-related problem is surging or pulsing flow. Full-bore magnetic flowmeters are highly immune to most causes of fluid turbulence but battery-powered types can be susceptible to surging or pulsing flow due to their low measurement sampling rate. An example is an agricultural application where pipes from different well pumps join upstream of a flowmeter, causing a slowly oscillating change in flow rate through the flowmeter. Diagnosis includes turning off one of the pumps and noting whether the flow rate becomes more stable.

LOW FLUID CONDUCTIVITY

Magnetic flowmeter flow Rate instability may increase as the fluid conductivity approaches the specification lower limit, typically 20 $\mu\text{S}/\text{cm}$. Below this conductivity, accuracy will also begin to decrease. Low conductivity will be a problem only for very pure water or other fluids with extremely low ion concentration. If suspected, the fluid conductivity can be measured by a water quality lab.

CHEMICAL AND SOLIDS EFFECTS

Injecting or mixing chemicals upstream of a magnetic flowmeter may cause chemical stability problems. The recommended solution is to move the mixing or injection downstream from the flowmeter, while maintaining the previously mentioned straight-pipe requirements.

Solid particles mixed with the fluid sometimes results in unstable flow rate readings as the particles impact the electrodes. Characteristically, the instability becomes more prom-

inent as flow rate increases. For cases of moderate instability, total flow accuracy should not be significantly affected.

An electrochemical effect that causes temporary flow rate instability sometimes occurs in installations with newly galvanized pipe. Total flow accuracy, however should not be significantly affected. The instability will decrease over time as a zinc carbonate layer forms on the inside of the pipe.

MOISTURE INGRESS

Moisture can potentially enter the flowmeter body or electronics enclosure during normal operations in environments with significant hi/low temperature differentials, or in highly humid environments (think Florida during a summer day/night cycle). This is especially the case if the flowmeter needs to be opened for service, or during routine battery replacement. Condensation on the inside of the flowmeter display window, or instability that seems to be associated with the appearance of condensation, are telltale indicators. Once the source of moisture ingress is found and eliminated, replace the gel desiccant packs (if present) with new ones, and reassemble the flowmeter. If the source of moisture ingress is not eliminated, causing moisture to accumulate over time, the flowmeter will eventually fail.

STRAY ELECTRICAL CURRENTS IN FLUID

Accuracy and stability of magnetic flowmeters are typically insensitive to moderate amounts of stray electrical currents in the fluid. However, problems can arise when excessive stray currents from nearby electrical equipment such as pumps, controls and transformers find a conductive path into and through the fluid. This may result from incorrect wiring, grounding system problems or failing insulation in electrical equipment. To determine whether stray currents are the cause of the problem, try disconnecting or turning off nearby electrical equipment. If one piece of equipment appears to be causing the instability make sure that it is properly grounded. A good grounding system functions to return ground currents as directly as possible to their source rather than take alternate paths such as through the fluid. To improve the grounding system, make sure that equipment wiring meets the requirements of regulatory agencies (such as the National Electrical Code in the USA.) First, assure that there is a low resistance ground between the source of the stray current, the metal piping between it and the flowmeter, and then beyond the flowmeter. All parts of the piping system may need to be electrically bonded with wire or straps. Use AWG 6 or larger wire, or 1" tin-plated copper braid to connect the various metal sections of the piping system together including the flowmeter body (unless plastic). Be sure to remove paint and corrosion to bare metal as necessary to achieve low electrical resistance connections. Also minimize corrosion at connections using compati-

ble metals and anti-oxidant grease as necessary. Make sure the electrical equipment also has a low resistance connection to earth ground, either locally, or at the electrical distribution panel. Do not depend on metal conduit as the earth ground return path; use a separate ground wire for each piece of electrical equipment properly sized as required by electrical codes. These wires are required for safety, but they also can reduce instability due to grounding problems. The resistance from the electrical equipment ground to earth ground must be less than 25 ohms. The resistance between any two points on the metal piping or electrically operated equipment in contact with the fluid must be less than one ohm. Separated multiple earth grounds usually aggravate the stray current problem, so try to bond all metal parts of the system to a single earth ground point if possible. This earth ground should normally be at the main electrical distribution panel.

Also check AC power wiring for loose or reversed ground and neutral connections. Occasionally stray ground currents are caused by faulty electrical insulation or shorted wiring in nearby electrical equipment. First, check motors providing power to equipment in contact with the fluid. Motor repair shops can check motor insulation condition for leakage between phases and ground. On large pump motors, it may be necessary to install grounding brushes on the pump drive shaft if they are not already in place. (This also extends bearing life since stray ground currents leaving the shaft can cause bearing balls to pit and fail.)

In plastic piping systems, grounding rings or grounded metal pipe sections may be necessary to divert the stray currents from the fluid passing through the flowmeter.

ELECTRICAL NOISE, RADIATED

Electrical noise radiated by nearby antennas or electrical equipment, can penetrate a magnetic flowmeter enclosure and cause flow Rate instability, and even false measurements, if the radiation is severe. Most governments require that the accuracy of flowmeters and other measuring devices be unaffected by these types of radiation up to limits specified in government standards. These limits are usually 3 to 10 volts/meter over a frequency range of 80 to 1000 MHz (except for the USA, which has no requirement for immunity to radiated noise at the present time.) Plastic-bodied flowmeters are typically more susceptible to this type of radiated noise. If this type of instability or measurement error is suspected, the source is best determined by turning off nearby potential electrical and radio frequency noise sources.

Welders, RF heating equipment, handheld VHF/UHF radio communications devices, arcing electrical brushes and contacts, electric motor-driven equipment and even power tools with worn brushes can produce radiation that exceeds govern-

ment testing limits. Once the offending source of radiation is found, the problem can be eliminated by a number of methods. The first approach is to see if the radiation coming from the offending source can be reduced. Often the radiated noise is due to maintenance issues such as worn brushes or arcing relay contacts, which also may be causing problems with other nearby sensitive equipment. Another solution is to increase the distance between the radiated noise source and the flowmeter. Sometimes improved grounding methods will be required as described in the next section.

This is especially true for externally-powered flowmeters, or whenever a cable is attached to carry flow measurement signals (pulse or 4-20mA current loop.) The cable acts as an antenna, picking up the radiated noise, and conducting it inside the flowmeter enclosure where it can disrupt the sensitive electronic circuits. In this case cable shielding may sometimes help but it must be grounded effectively at both ends, and sometimes along the way, depending on the severity of the radiation. (Note that this violates the common instrumentation rule-of-thumb that the shield be grounded only at one end. Both methods have validity, however, depending on the source of the noise.)

ELECTRICAL NOISE, CONDUCTED

Whenever a power or signal cable is connected to a magnetic flowmeter, the cable provides a path for electrical noise to enter the flowmeter and cause instability or accuracy degradation by upsetting the sensitive electronic circuitry. (Mechanical flowmeters with electronic pickups are more immune but may still be affected by this type of noise.) The sources of the noise include those in the previous section. In addition, noise from power supplies and their AC power sources must be considered as well as the antenna effect mentioned above.

There are two main types of AC power supplies to consider: switching and linear. Switching power supplies generate about 0.1 Volt of high frequency noise on their dc output connections which is then conducted by the cable into the flowmeter. This may sound like an innocuously small voltage, but unfortunately it is thousands of times larger than the signal representing flow being measured by a magnetic flowmeter. Mysteriously, one switching power supply may cause the flowmeter to malfunction while a different model with very similar output noise specifications may work fine. Linear power supplies produce roughly 100 times less output noise, and are a good choice for replacement in this case. However they are becoming less available.

Most flowmeters have at least one or two levels of built-in filtering to guard against noise entering via cables. Again, government standards in most developed countries outside the USA impose immunity requirements on the flowmeter manufactur-

er for conducted as well as radiated electrical noise for flowmeters sold in that country. A flowmeter that has been certified to meet these standards (such as the European EN61000 standards that allow the manufacturer to place the CE sticker on the flowmeter) may have better immunity. However, even these stringent standards are not sufficient to prevent flowmeter instability or error when proper installation wiring practices are not followed.

Usually, when flowmeter wiring practices are mentioned, the focus is on grounding and cable shielding connections. These are important, but the biggest cause of flowmeter noise problems related to wiring is the proximity of the cable to other electrical equipment cables carrying high power and/or high frequency currents. The worst case occurs when the flowmeter cable runs close to and in parallel with noisy cables over some distance (say one or more feet) such as in conduit, wiring trays or wire bundles. The longer the parallel run, the higher the current, and the higher the frequency (and to a lesser extent the higher the voltage) the more likely the coupled electrical noise will cause flowmeter instability or malfunction. One of the worst cables to run next to is the wiring from a variable frequency drive (VFD) controller to the motor it is controlling, because the cabling carries both high frequency and high current. Any cable carrying AC, noisy DC or high current to loads which switch on and off can cause problems.

Because parallel cables in close proximity results in magnetic field coupling, ordinary braid or foil cable shielding is not effective. Cable shielding suppresses electric fields well, but not the magnetic fields induced by typical parallel cable runs. Here's what is really important:

First, always use twisted pair cable for flowmeter power and signals. Power should be on one twisted pair and each signal pair (pulse, 4-20 loop, etc.) should have its own twisted pair either in the same cable or a separate cable. This is much more effective than the best shielded cable. We recommend 18 twists/foot or more, but 12 is usually sufficient. If the cables inducing the noise can also be made twisted pair, this will also help, but is not usually practical due to wire size.

Second, separate the flowmeter cables from noisy cables as much as possible. Cables crossing perpendicular to each other even in close proximity should not cause problems, and even one foot of separation between parallel cables will often eliminate most cable noise coupling problems.

Lastly, if the flowmeter cables must be run close to, and in parallel with, noisy cables, there is one solution that can be effective for flowmeter cabling: schedule 40 or heavier steel conduit. It will be even more effective with at least 6-12 inch separation from noisy cables.

As with instability due to stray fluid currents described above,

radiated and conducted noise instability problems are frequently improved by better grounding. The method of grounding depends on many factors such as whether the flowmeter has a ground lug or it uses its cable shield or negative power conductor as its grounding conductor. If there is a ground lug, it should be connected to upstream and downstream metal piping (or grounding rings in the case of plastic pipe) and to earth ground as described above in the paragraphs on stray fluid current problems. Normally there should be no ground connection to the output of the dc power supply (typically to the negative wire) supplying the flowmeter. However, if there is no ground lug on the flowmeter, it sometimes helps to connect power supply negative and/or the flowmeter cable shield to the piping system and/or earth ground. The "and/ors" above indicate that there are many possible grounding combinations to try if the flowmeter is unstable. Start with the grounding scheme described in the flowmeter installation instructions and check for improvement while trying the others. If you see no improvement the problem is not likely related to grounding issues. Finally, the cable shields should usually be connected at just one end of the cable, normally to the grounded metal enclosure of the component it connects to, such as an indicator, PLC or other flow signal input device. However, if the shield is internally grounded at the flowmeter end, the shield should be connected to the piping system components having metal contact with the fluid or to a local earth or frame ground, whichever is most

noise free. (You can use an ohmmeter to check whether there is continuity from the flowmeter metal enclosure to the shield.)

From the above discussion, it is evident that there is no one-size-fits-all grounding method. It is dependent on the type of flowmeter, noise sources, noise coupling path, pipe material and the type of equipment connected to the flowmeter. In some cases, increasing the number and types of grounds may reduce or eliminate instability, where in other cases, reducing the number of different or interconnected grounds may resolve instability in magnetic flowmeters. In all cases, be sure to follow safety and electrical code requirements, and follow best wiring practices.



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