August 15-16, 2017
Boulder, Colorado

Caterpillar Surveillance Panel COAT Conference Minutes

Conference Attendees:
Jim Gutzwiller (Chairman) Elisa Santos, Gang Hu – Infineum
Jim Carroll (Secretary), Jim McCord, Randy Harmon- SwRI
Hind Abi-Akar – Caterpillar
Alex Ebner, Kevin O'Malley – Lubrizol
Jim Moritz, Tim Griffin, Dave Horstman, Michael Govoni– Intertek
Sean Moyer - TMC
Mark Cooper – Chevron-Oronite
Bob Campbell, Christian Porter - Afton
Justin Posey – John Deere
Alex Ebner - Lubrizol

Andy Burnett, Rich Hall, Tim Patten, Ray Loudenburg – Emerson Micromotion

Tim Patten Spoke on the theory of operation of the Coriolis sensor.

There are two tubes in the Coriolis meter and the two tubes vibrate using drive coils pushing against magnets. The wave forms of each tube are sensed with separate coils and magnets. The natural frequency of the tubes is targeted and as fluid flows through the tubes the two sine waves get out of phase. The out-of-phase period is proportional to mass flow. The frequency is very high, ~135hz with oil. The sensor rarely has outside interference due to precise peaks. Movement is on the order of Angstroms. There is a 2 degree phase shift at full scale, with 2 nanoseconds between peaks. There is a flow calibration factor unique to each meter.

For the CMF25 the 10 to 1 turndown from maximum flow of 1.5L/min is still well within the measurement capability of 200 to 1 turndown.

The tubes are vibrating akin to springs and the frequency of a spring is affected by temperature. This is why they measure temperature. An RTD is placed between the two tubes in the inlet manifold of the tubes. Nitrogen surrounds the tube space.

Density is inferred due to the fixed volume of the tubes and is related to the vibration period squared.

Tim Patten on transmitters and processors

The core processor (Puck 800 for the CMF25) drives the tube vibration, and measures its period and any phase shift between the two tubes. It calculates mass flow and density and sends those measurements to the transmitter. The core processor must be kept at less than 60C for durability. The transmitter sends out the data to the DAQ (Data Acquisition). The sensor housing and tubing is operational up to 200C.

The 60C limit for the sensor shown in Micromotion literature is for IS (Intrinsic Safety) considerations. The graph in the questions sent to Emerson was associated with core processor temperature limit, not the sensor.

The core processor can be relocated on all the sensors. It has to be done by Emerson, and it will change the model code. It needs to be done for approvals. The processor-to-transmitter four wire and nine wire communication systems are functionally the same. It's just that the nine wire has low-level voltage and needs to be connected well.

All the calibration and measurement is associated with the core processor. The core processor is insensitive to the environment. The different transmitter makes no difference on the results.
Big caveat, anytime the core is built into the transmitter the temperature limit is 60C.

When the core processor is remote from the sensor, Micromotion calls this a double hop connection.
Q: What is the reason to have a double hop?
It is because of the temperature affects. From a measurement point of view they are exactly the same.
The Puck 800s in all of your sensors are exactly the same.

McCord: There was a fear that software and firmware could effect the result so everyone went to Puck 800.

Patten: Regarding Old vs New sensors, new sensors have SN in this format 15000000 since 2006 and the RTD is mounted in the manifold.

The older RFT9739 transmitter has different processing. It provide a slope and offset for the RTD. You could calibrate it yourself. It also affected the flow and density measurement.
New transmitters do not affect flow or density with either the Puck 700 or 800 processors.
Why did it change? Never had it come up, but you loose traceability.
RAY: It probably is because when people tweaked it and found it screwed up their readings.

You can put a ‘meter factor’ into the transmitter if you know the density. The problem with a meter factor is it’s a multiplier and does not account for different conditions.

Campbell: How would you do it if someone posed this problem? What we are doing is not right. Maybe we are close.
Patten: I think you are very close.

Posey: Doesn’t the RTD measure tube temp?
Patten: When you have turbulent flow the best representation of the tube temperature is the fluid temperature measured by your thermocouple.

McCord: Does the transmitter make any difference?
Patten: No but I would steer us to the 5700 transmitter. There is a USB port that can download all the data from the day it was installed using HISTORIAN. Very powerful diagnostic tool. 1hz data logging. The newest transmitter SMV will offer a reason for the problem you are seeing. New software available in September. Will not change any coefficients for the calibration. 2700 transmitter software is not planned to be updated.

The core processor is where grounding is needed. It is ok if the sensor floats.

Group was taken on a tour of the Engineering Lab showing calibration stands, vibration stands, flow stands, pressurized to destruction stands.

3 pm Q&A session

Ray Loudenburg started off:

Drive gain indicates how much energy is needed to keep the tubes vibrating at the correct amplitude. 100% drive gain may still be good. Typical gain is in the single digits. Two-phase fluids need more gain. All the alarm codes are identical in the transmitters. Severe two-phase bubbles could cause more noise. Hind was concerned of the noise. Justin Posey of Deere said that he sees problems at 25% aeration.

Should we look at drive gain?
It would be a diagnostic to look at, but there are a number of things that affect it.
10W-40 vs 20W-50 make a bit of difference. Rule of thumb anything less than 100% drive gain is good.

You could set an alarm in your own DAQ to tell you when there is a high number.

Does SMV look at this?
Can’t run an SMV if at 100% drive gain.

Tim Patten took charge of Q&A and started out with the panels set of questions.

Where is the temp sensor. The old one is on the tube, since 2006 it's between the tubes on the intake manifold. Potted with thermally conducted epoxy.
If there is the a temp difference between inlet and outlet. Is the average
WE rely on our flow to get the temp correct. Tim "You are running too slow flow to get the heat up to fluid temperature."

McCord If you could measure the fluid temp, you would use it?
Patten: Yes.

Can that be done?
There are a couple of ways, and I will get into it.

Are the firmware differences affecting any results?
Not if you have an 800 core processor.
Transmitter is translating the processor signal into an output we read, including digital.
5700 transmitter is recommended due to the diagnostic capabilities.

What are the differences important in the sensor.?
I will hold off till later on that. Flanges make no difference. It makes sense to use a tubing connection if that is what you have.

The Puck is the processor and as long as all are the same then no one will get different results.

Intertek has their Puck on the sensor.
The older 9739 processor can't be remote mounted. It's not as good as all the Puck based processors. It's a matter of durability/longevity to keep the Pucks away from high temps.

How is density calculated? Showed the calculation.
Pressure term starts making a difference at 0.002 per 1000 psi.
So ignore the pressure part of the equation.
The rest of the equation is just a straight line.

When they calibrate they correlate density to frequency.
K is tube stiffness
M proportional to the mass of the fluid and tube together.
They extrapolate K1 and K2 out to make D1 = 0 and D2 = 1.

K is a temperature corrected period. The graph is a temperature corrected surface. They correct every K measured inside the square brackets.
The constant DTC is a steel property value (Modulus/Temperature) normalized to 0C.

Over normal 200C range it is very linear.
Problems start here. We measure DTC under ambient conditions with really high flow rates. Errors of RTD = 0.1C,
We go from 20-60C during calibration.
The number they picked is no longer right at low flows.
DTC=K_D

“You can’t ignore the RTD temperature in your case.”

Poser: How does this affect us?
With perfect conditions at high flow rate you get the right number, but drop the flow and the temp is different. Obviously, the tube temperature is equal to the fluid.
How much error do we get?
0.001g/cc per C.

Density is more sensitive because.

Campbell: If you are all off 4 degrees it would be the same. To me the difference between the labs is the cause of the problem.

Patten: Our specs are set at full flow. The RTD itself and the circuitry is perfect. It is a measurement error due to the low heat transfer at low flows.

If we run at high flow at all labs, should all the labs match?
Yes, if everything else is equal around the sensor.

How close can the RTD temperature be measured sensor to sensor?
Within 1%.

Hind: Why did we have low flow?
Tim: To keep from robbing oil from the engine.

The glue between the RTD and tube is the biggest error, the newer epoxy is better but it’s a compromise. Fluid temp is the best approximation.

Patten: That’s only heat transfer condition due to flow rate. If you proceduralize everything at each lab they should be similar.
Sean: If you move away from that point it would invalidate the test.

In Emerson’s calibration method they correlate frequency to density. They use the DTC constant. It meets most customer needs. They offer a temperature compensation package.

The 3ZZZ in the sensor model number is the higher density calibration which does include some temperature compensation to calibrate the DTC value better. But it is at a high flow rate. If you run at high flow, or in an isothermal oven you get the right number.

Tim G: We do that at 5 temperatures during our calibration. And, it matches D4052.

McCord All the labs no longer use the sensor to get relative density change, now we use D4052, so we need to normalize to fluid temp to get correlation to D4052.

WHAT TO DO?

Four Options:
1. Control all temperatures in an isothermal environment.
2. Use external TCs and average and write the temperature to the transmitter and processor.
3. Emerson can provide the frequency signal and labs calculate density. (thru the Modbus) Or map it to the mA or pulse signal from the transmitter.
4. Back out frequency from the equation, and then calculate forward with new temperatures.

Patten: “all options will give the same result’

How does this affect the volumetric flow rate?
Patten: The errors associated are really small. If at 90C, all errors are eliminated.

Moritz: What about a heat wrap?
Rich Hall: We offer a wrap that can be used to surround the sensor with temperature controlled fluid.

Patten What I would do is give you a whole new set of DTCs based on your calibration data.

Tim G: Can I use Modbus to send it to my meter?
Patten: Yes

Hind: Is the second option is offered for all systems.
Patten: Yes

McCord: If you have 115C fluid temp should we move the core processor using an extender?
Patten: Yes

Moritz: What is the adjusted density calibration factor?
Patten: It is a calibration adjustment. If we send him the data from our calibration, he can give each sensor a factor.

Griffin exposed the 5700 transmitter.
McCord didn't like the data drops.
There was a discussion of how this can be alleviated.

Campbell: What are we going to do?
Sean: Have another meeting soon, face to face to resolve this.
Hind: Idea is to have all have the same approach.

McCord: This puts us all starting at the same spot. Then we can explore if a pressure difference or other factors cause lab-to-lab differences. Filter in and out pressures are different. Gallery pressures are similar.
Campbell: We need to think around, and look for other causes of differences.
McCord: I was against looking across labs without correcting to 90C temp. Now I think we can find some differences. We could purchase a shell for the sensor, look at tube lengths, internal diameters. Transmitters could be changed.
Moritz: But for 3 years two labs have been at the same RTD temp.
Hind: Getting everything similar is OK but there are always differences.
McCord: The box grew organically, we can all converge on the same measurement and device.
Alex: I do not have the refined DTC calibration which may have given us a larger correction.
Campbell: Before we leave we will have defined our path forward.
Moritz: I will recommend 2 days face-to-face just on COAT.

August 16, 2017

Rich Hall opened the meeting.

Alex brought up using SMV for flow calibration.

Hall: The old plus/minus 4% was a limit on the change in tube stiffness depending on mounting effects. There will be a more information soon.The algorithm will be updated with a different temperature correction. Looking for erosion, corrosion, coating, bending, freezing, expanding of the tubes. Will use more data collection and statistically compare

the data to the factory specs. This will reduce the variation on drive gain when doing a test while in operation. It will go to a pass/fail result from an SMV. There will be suggestions as to the cause of the problem of note.
McCord: Coating may become a problem with SS and lacquer from the oil.
Ray: If you saw an error response from the SMV then you could run a density check with a reference fluid.
Hall: Emerson is trying to get accreditation of the SMV such that the COAT procedure will not need to run a flow cal.
The labs run running mass flow calibrations but not on the COAT.
The labs could run the fuel through the whole system, or part of the COAT system.

Hall: If a repeat SMV failure occurs then run a mass cal. You may need to run a mass call periodically. The SMV is just a verification of tube stiffness changes or not. It is checking the stiffness of the tubes.
Griffin: Would our density check pass imply that the flow cal is OK or not?
Hall: We have customers that do that.
Griffin: Then, calibration of density shows that the flow cal is still valid.
Ray: That is a correct statement
Alex: But what if you change the density slope and offset. How does this affect flow, is it the same ratio?
Ray: Not sure.

Mark Lee VP of Quality

Emerson is integrating all their products. Goal is to have products identical regardless of production location. Going to combine all product production into a single global Quality Management Systems (QMS). They send one production quality team from one facility to another to audit themselves. All suppliers are also checked thoroughly. They use a gate process for Product Development.
“New replacement products should be twice as good as the products they replace.”

Calibration Facilities are ISO 17025 certified, get 3rd party approval from different companies in different countries. VSL in the Netherlands will check flow specs from calibration labs around the world.

Rapid Response team funnels questions to appropriate response person. Goal is to have a process to capture, catalog, respond, and react. And, to keep customer informed.

How do you track training?
Every skill has multiple tests and training by more than one person. Some are done by outside (eg. for Xray) trainers.

Some questions Rich Hall got from the panel were answered in a presentation.
1 What about using a smaller meter at the same flow rate?
Tim's response: The ratio of the velocity to heat transfer area makes things worse.

2. Different ways to address the fluid and RTD temp differences?

1: Keep chamber up to 90C. Or put box from Micromotion around sensor.
2: Use a temperature measurement more in sync with process fluid. Put that into transmitter and have it process the density. Ray noted they have a way to input the process temp and tell their transmitter to use it for the modulus in the calculation. Write via Modbus or Hart input (this will take an analog channel)
Will it need a software change?
2700, 2500, and 5700 transmitters can do it. It can be configured using the "Hart" by 1 Take the average of our inlet and outlet, 2 use an external RTD, 3 Use our calibration data to correct the DTC, 4 take the sensor frequency and fluid temp and calculate the density with our DAQ.

The measured frequency could also be reported to TMC.

Moritz: Writing to the transmitter is another control output we have to monitor.

McCord: What is the most robust approach?
Hall: Iso-thermal control from the start takes care of everything. It's a tough question but all approaches will get you there.

McCord: The differences at the labs are mostly seen from our data collection.

Moritz: There is some amount of entrained air, do we need to mount the orientation up?
Hall: Tim said yesterday that he did not see a need to change mounting.
Ray said the same "don't change it."

Campbell: The boxes need to be the same. Define parts, orientation, iso thermal system etc.

Hall: The iso-thermal box eliminates the problem.

McCord: I suggests setting the control temp to the average of in and out.

Griffin: Are we going to set the actual size of the box?

Campbell. We should be able to dimension and size a box so that Joe Blow can reproduce it. My guess is that there are still things we do not understand.

Hind: What are the current differences?
Griffin: Puck location, transducer location etc.
Campbell: The box is there to keep delta T low.
McCord: No it was transducers. And ambient temp made changes in delta T.
Campbell: Which direction are we going? Isothermal or the others.
Moritz: We need to address the current offset from the temp.
McCord: You can't compare across labs without fixing this.
Sean With the data we generate now we can correct it. If we have to go forward we can correct everyone to 90C.
Moritz: it will shut down a lab.
Sean: I am not saying we should chart it. Just correct it.
Sean: I am not comfortable with having software modified by Emerson to use fluid temp.

Can the heated jacket be attached without moving the processor?
Hall: Not sure.

General discussion about how to make the corrections.

Alex could get a better DTC with his calibration data but that would not overcome any bias if the fluid and RTD temps do not match.