KUWAIT 3RD FLOW MEASUREMENT TECHNOLOGY CONFERENCE

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Calibration Methods for Minimizing Uncertainties in Ultrasonic Meters

Mohit Narain, GNV Sridhar & Vineet Singhal

Kuwait Oil Company

Speaker's Profile

G.N.V.Sridhar is an instrument engineer working in Operations Technical Support Team (Gas) of KOC. He has 27 years of vast experience in the field of instrumentation, control systems, metering etc. His experience covers all of instrumentation & process control. Presently his role in OTS(Gas) is to ensure the compliance of EPC projects to specifications & company / international standards.

Holds a bachelor's degree in Instrumentation from Shivaji Univ., India and has presented at various international conferences.

Presentation Outline

Introduction

- Inherent uncertainty emerges during all lab calib'ns
- This 'raw error' needs to be 'adjusted'
- The re-adjusted flow-meter is re-verified

Calibration Factor Adjustment Methods

Flow-Meter adjustment methods, post calibration:

- Flow Weighted Mean Error (FWME)
- Polynomial Curve Fitting
- Multipoint or Piecewise Linearization

FWME Determination

q_{ref}	q_{act}	$wf_i=q_{act}/q_{max}$**	$E_i=100*(q_{Act}-q_{ref})/q_{Act}$	$Pi=(q_{act}/q_{max})*E_i$	$E_{icf}=((E_i+100)*F)-100$	$Pi_{corr}=(q_{act}/q_{max})*E_{icf}$
M^3/hr	M^3/hr	Flow fraction	Error %	Flow Weighted Error	Corrected Error %	Corrected Flow Weighted Error%
155.000	153.000	0.025	-1.290	-0.03236383	-1.243	-0.031
311.000	308.380	0.051	-0.842	-0.04258898	-0.795	-0.040
605.000	603.360	0.099	-0.271	-0.02681237	-0.224	-0.022
1575.000	1575.035	0.258	0.002	0.00057378	0.050	0.013
3076.000	3077.100	0.504	0.036	0.01803924	0.083	0.042
4540.100	4539.540	0.744	-0.012	-0.00917920	0.035	0.026
6100.170	6098.015	1.000	-0.035	-0.03531539	0.012	0.012
Sum		2.681		-0.12765		0.000

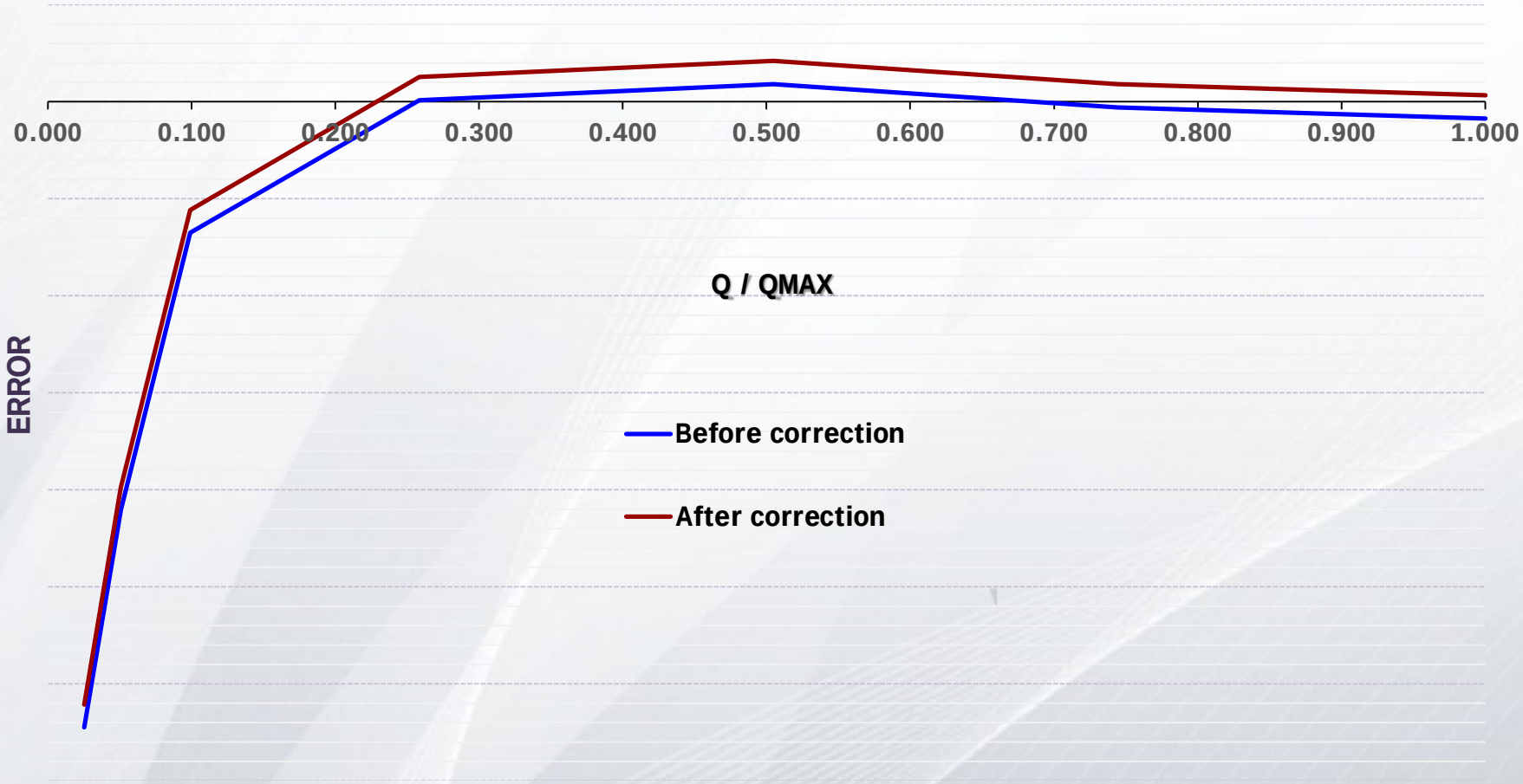
FWME = Σpi/Σwfi= -0.047610656 **qmax=6100

*Calibration Factor "F"=1.000476333 *F= 100/(100+FWME)

Impact of FWME on Readings

Flow %	Ref Flow M^3/hr	Before Correction		After Correction	
		Flow Reading M^3/hr	Error %	Flow Reading M^3/hr	Error %
0.025	155.000	153.000	-1.290323	153.073	-1.243326
0.051	311.000	308.380	-0.842444	308.527	-0.795234
0.099	605.000	603.360	-0.271074	603.647	-0.223593
0.258	1575.000	1575.035	0.002222	1575.785	0.049834
0.505	3076.000	3077.100	0.035761	3078.565	0.083388
0.745	4540.100	4539.540	-0.012335	4541.701	0.035270
1.000	6100.170	6098.015	-0.035327	6100.918	0.012267

Impact of FWME on Readings



Flow Weighted Mean Error

- Applies a constant bias to the flow readings
- Easy to implement
- Effective
  - If meter output is linear in operational range
  - To correct systematic errors
- Not so effective for correction of random errors
- Can be used if higher measurement error at lower ranges is acceptable.

Polynomial Curve Fitting (PCF)

- Tries to fit the meter output into a curve

- The following is a generic n^{th} order equation:

$$P=a_0+(a_1*X^n)+(a_2*X^{n-1})+(a_3*X^{n-2})+(a_4*X^{n-3})+(a_5*X^{n-4})....$$

$$n=6(max)$$

PCF (Linear Curve Fit)

PCF (2nd Order PC Fit)

PCF (4th Order PC Fit)

PCF (6th Order PC Fit)

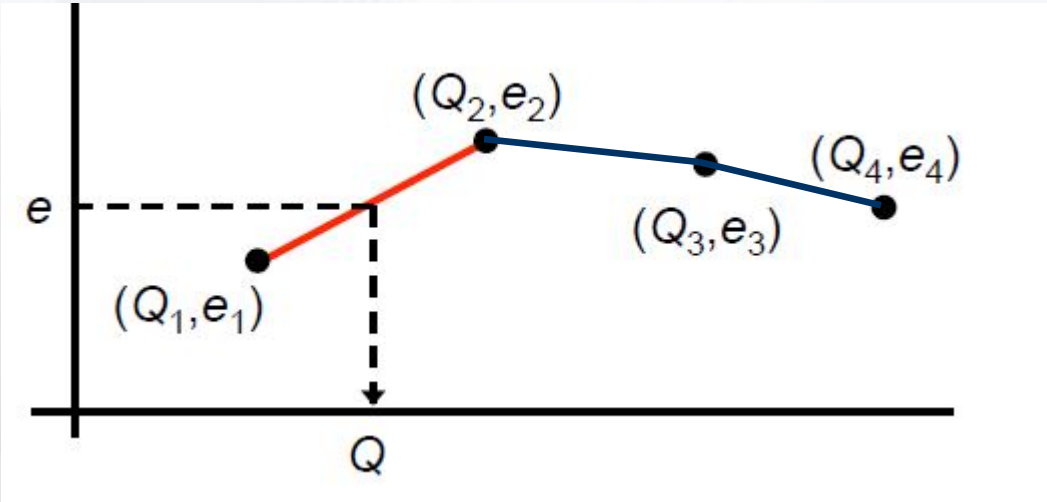
Polynomial Curve Fitting (PCF)

- Does not consider any single point / range
- Instantaneous corrected readings may have more inaccuracies compared to uncorrected values
- When flow is continuously varying error may get minimized; but cannot be quantified
- Higher order may produce undesirable oscillation of values as evident in the $2^{nd}/4^{th}/6^{th}$ order trend line
- There is no single meter factor for tracking the meter performance over a period of time

Multipoint Linearization (ML)

When Q in $[Q_i, Q_{i+1}]$

$$e = e_i + \frac{e_{i+1} - e_i}{Q_{i+1} - Q_i}(Q - Q_i)$$



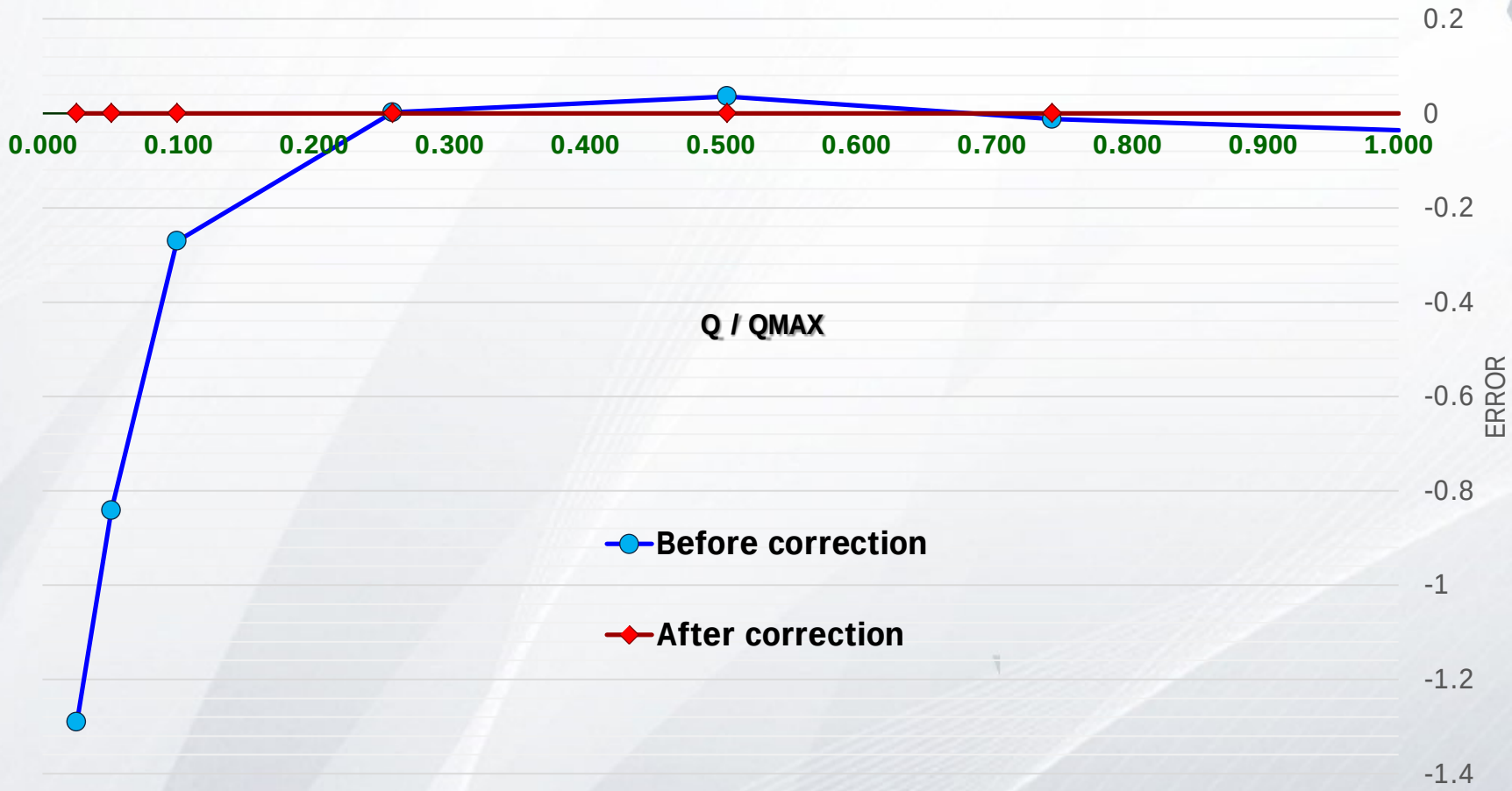
Multipoint Linearization (ML)

- Piecewise linear or multipoint adjustment
- Linear interpolation bet'n successive calib'n points
- No bias applied to the readings
- No single meter factor or calibration factor
- Slope of error curve between 2 successive calib'n points determines the correction factor
- Unique correction factor at every flowrate

Multipoint Lineariz'n (Before & After)

Flow %	Ref Flow M^3/hr	Before Correction		After Correction	
		Flow Reading M^3/hr	Error %	Flow Reading M^3/hr	Error %
0.025	155.000	153.000	-1.290323	155.000	0
0.051	311.000	308.380	-0.842444	311.000	0
0.099	605.000	603.360	-0.271074	605.000	0
0.258	1,575.000	1575.035	0.002222	1575.000	0
0.504	3,076.000	3077.100	0.035761	3076.000	0
0.744	4,540.100	4539.540	-0.012335	4540.100	0
1.000	6,100.170	6098.015	-0.035327	6100.170	0

Multipoint Lineariz'n (Before & After)



Conclusion

Multipoint Linearization or piecewise linearization is a clear winner as:

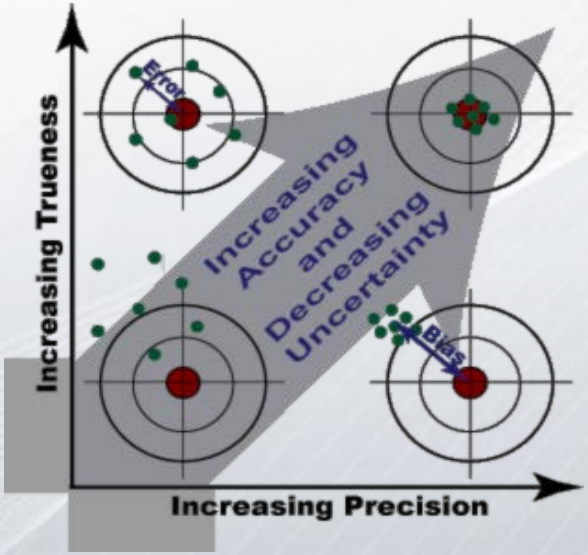
- **Error minimized through out the range of the meter**
- **A small meter-error can result in huge $ in long run**
- **No additional cost for implementation**

User's Point of View

- High repeatability alone is not everything
- Include the calibration adjustment-method in meter specifications.
- Ensure the first wet calib'n report gives all the data along with adjustment-method applied & parameters
- Protect calibration data for tracking meter-drift
- Calibration be carried out at normal optg. range in addition to flow-rates prescribed by standards.

Have We Reached

- Paradigm method
- Flow-meter fidelity post-calibration?
- Which jargons to follow:
  - Accuracy
  - Repeatability
  - Uncertainty



☺ WE ARE DONE !!! ☺