Elliptical tube flowmeter

Yamatake Corporation

April 2004

Topics

1. Problems of Traditional DP Flowmeters
2. Too Much Maintenance is Required for Traditional DP Flowmeters
3. Solutions by YAMATAKE's Elliptical-tube Flowmeters
4. Principles of Operation
5. Product Lineup
6. Project References

1. Problems of Traditional DP Flowmeters

Primary Elements

a. Small Pressure tappings

b. Stagnating Area

c. Deformation of Orifice edge

DP Transmitters

d. Need Additional Temperature and Pressure Compensation

e. Narrow Flow Ranges

f. Unstable Zero Output

g. Inaccurate Flow Rate Calculations

a. Small Pressure tappings

- ***Need frequent maintenance.***
  - One of the most frequent trouble in Japan is clogging of pressure tappings.
- ***All Industrial Standards define small pressure tappings.***

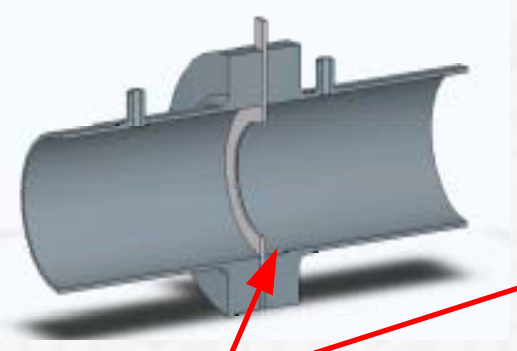
  A.G.A, ASME, DIN, JIS,・・・

The inner diameter is about 4 to 10mm at all pipe size.

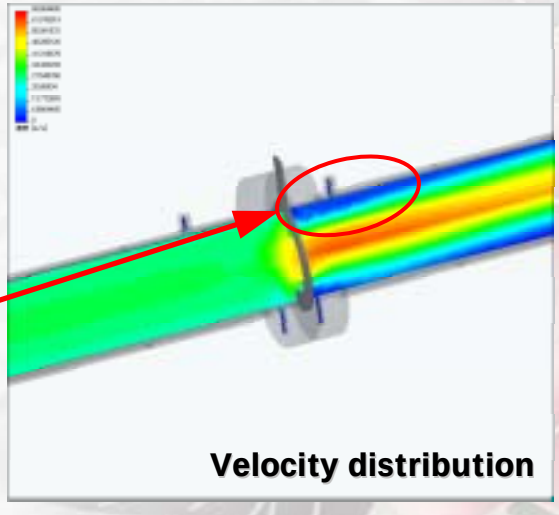
b. Stagnating Area

- ***Orifice meters cannot stably translate flow into differential pressure.***
  - **The orifice meter detects differential pressure at a stagnating area where static pressure is unstable.**

- ***Deposit cause errors in Orifice meters.***
  - **The orifice meter has a stagnating area where debris, condensation or particles from the fluid can be accumulated. The velocity profile is changed by these deposits easily. Therefore, deposits need to be cleaned periodically.**



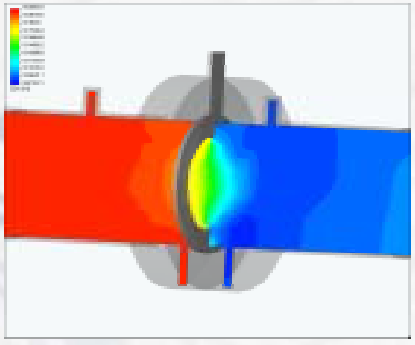
Stagnating Area



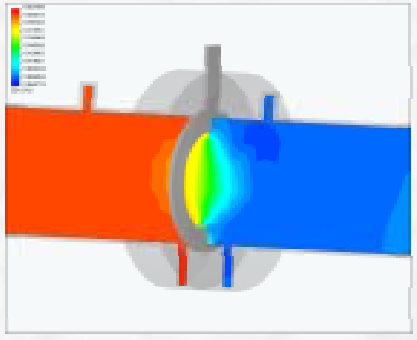
c. Deformation of Orifice edge

- ***Edges of orifices may be chipped or worn out.***
  - **Accuracy is greatly affected by edge conditions. (See table)**

Normal

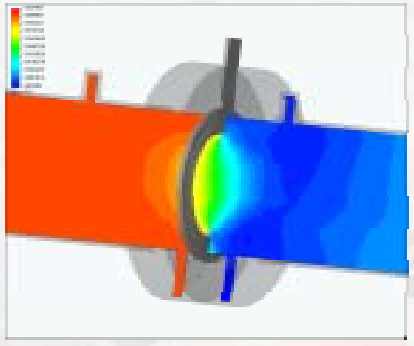


Chip



Chipped size about 3mm

Wear



Edge R=0.5mm

Analysis parameters

Square Edged Orifice
Pipe size : 150A
Gas : Methane
SP : 1MPa
Flow rate : 0.5m³/s

Table. Result of CFD analysis

Edge condition	Normal	Chipped	Worn	Unit
DP	14.85	15.28	15.23	kPa
DP error	-	2.90	2.56	%
Flow rate error	-	1.44	1.27	

d. Need Additional Temperature and Pressure Compensation

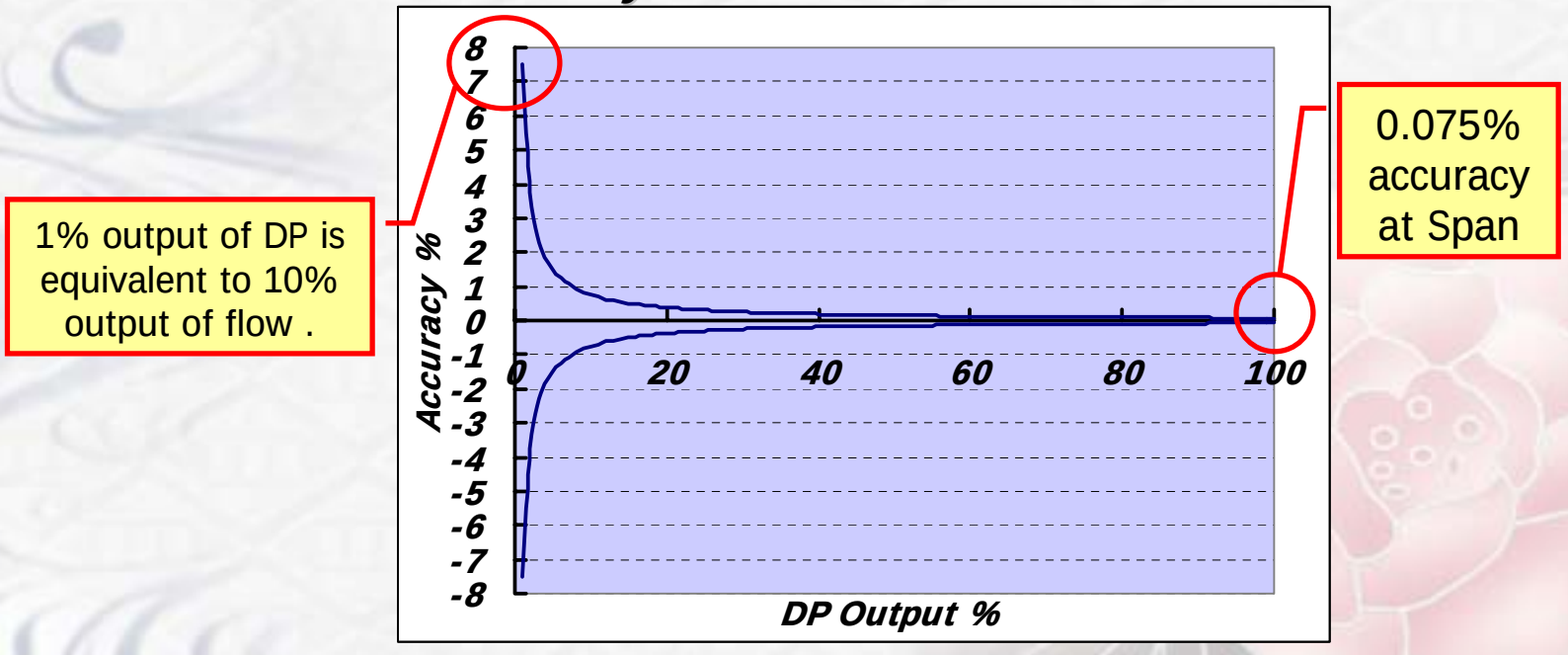
- ***DP Flowmeters have errors, when fluid density changes.***
  - In many cases, pressure and temperature change. In order to measure accurately, compensation is necessary with T and P.
  - Pressure and temperature transmitters are normally required for density compensation.

e. Narrow Flow Ranges

✓ Low Accuracy in Low DP .

- The capability of DP transmitters is insufficient to measure low flow.
- Even with DP transmitters which have accuracy of 0.075％F.S., accuracy at the point of 1/100 of F.S. is 7.5％.

FIG. Accuracy of the Traditional DP Transmitter



f. Unstable Zero Output

- ✓ ***Unstable Zero causes errors in Flow Reading at Lower Rate.***

g. Inaccurate Flow Rate Calculations

- ✓ Square-root calculation in DP Transmitters is not enough for accurate flow measurement.
- ✓ More precise flow calculation function is required outside the transmitters.

Topics

- ✓ Problems of Traditional DP Flowmeters
- ✓ **Too Much maintenance is Required for Traditional DP Flowmeters**
- ✓ Solutions by YAMATAKE's Elliptical-Tube Flowmeters
- ✓ Principles of Operation
- ✓ Product Lineup
- ✓ Project References

2. Too Much Maintenance is Required for Traditional DP Flowmeters

Many maintenance is required for DP Flowmeters in order to measure flow in sufficient accuracy.

- **Cleaning of pressure tappings**
- **Cleaning of stagnating area of orifice meters**
- **Zero re-adjustment of DP transmitters**
- **Replacement of orifice plates and transmitters**
  - **To widen measurable ranges**
  - **Deformation of orifice plate edges**

Topics

1. Problems of Traditional DP Flowmeters
2. Too Much Maintenance is Required for Traditional DP Flowmeters
3. **Solutions by YAMATAKE's Elliptical-tube Flowmeters**
4. Principles of Operation
5. Product Lineup
6. Project References

3. Solutions by YAMATAKE's Elliptical-Tube Flowmeters

Primary Element Solutions

a. Optimum-size Pressure tappings

b. No stagnating area

c. Rigid Structure

DP Transmitter Solutions

d. State-of-the-art Technology Multi-variable Sensor

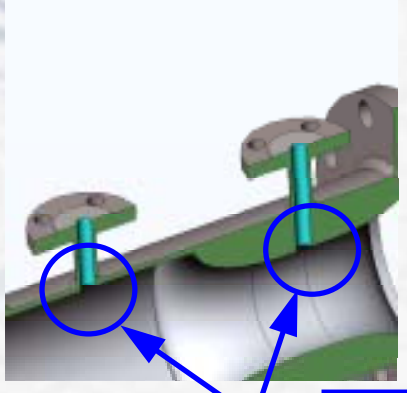
e. Wide Flow Ranges

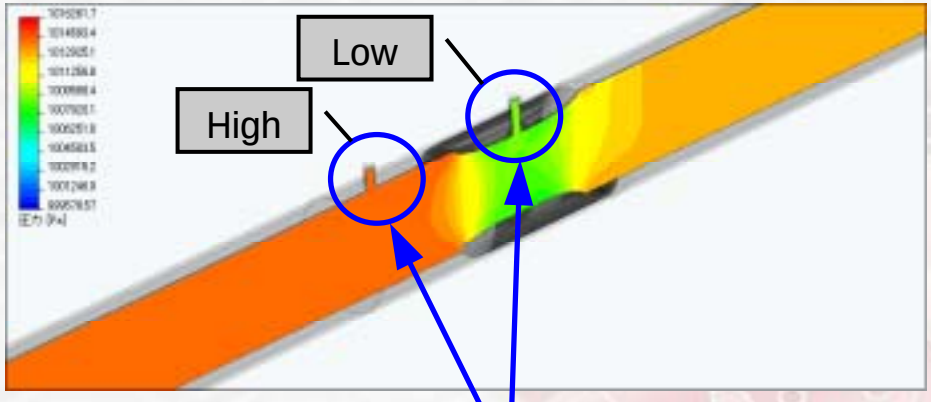
f. Zero Stability

g. Built in Flow Calculation Function

a. Optimum-size Pressure tappings

- ***To eliminate maintenance of pressure tappings, its size is designed larger than standard's size.***
- ***To detect stable differential pressure, tapping positions are optimized.***





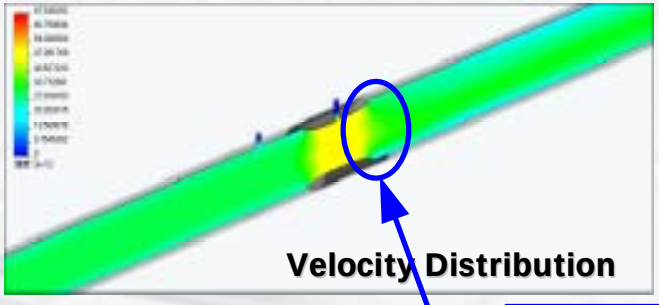
Optimum-size Pressure tappings 6" : 1.5 times larger than standard size

Pressure is stable at these positions.

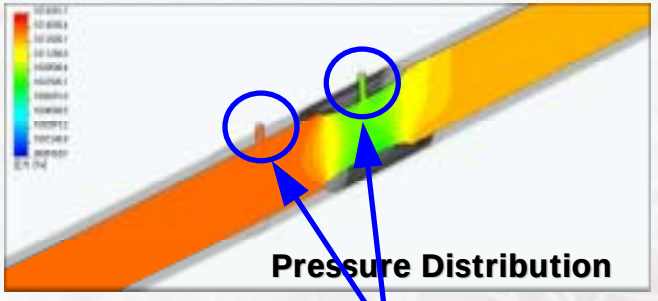
b. No Stagnating Area

- ✓ ***No maintenance necessary.***
- ✓ ***Stable differential pressure due to the elliptical profile.***

YAMATAKE's Elliptical-Tube

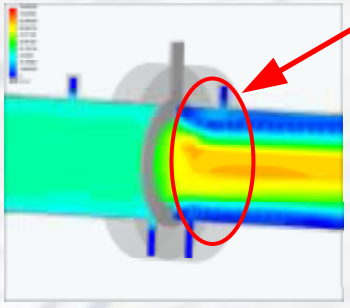


No stagnating area

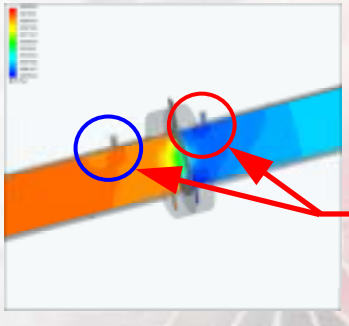


Stable Differential Pressure

Orifice



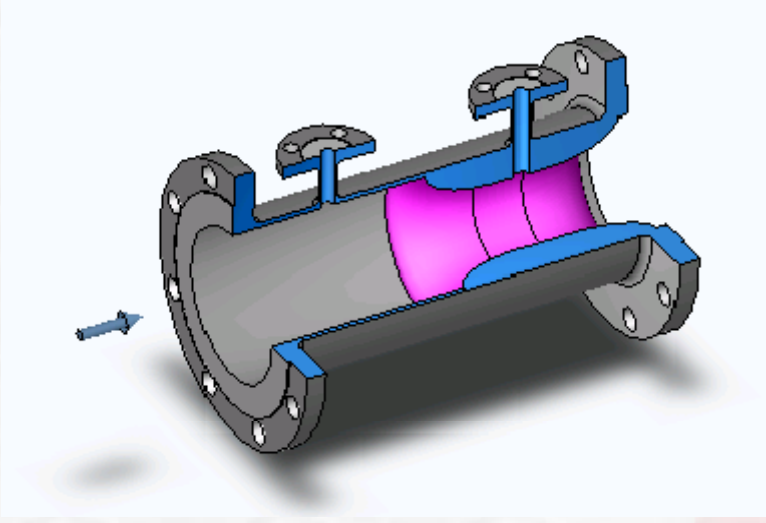
Stagnating area



Unstable Differential Pressure

c. Rigid Structure

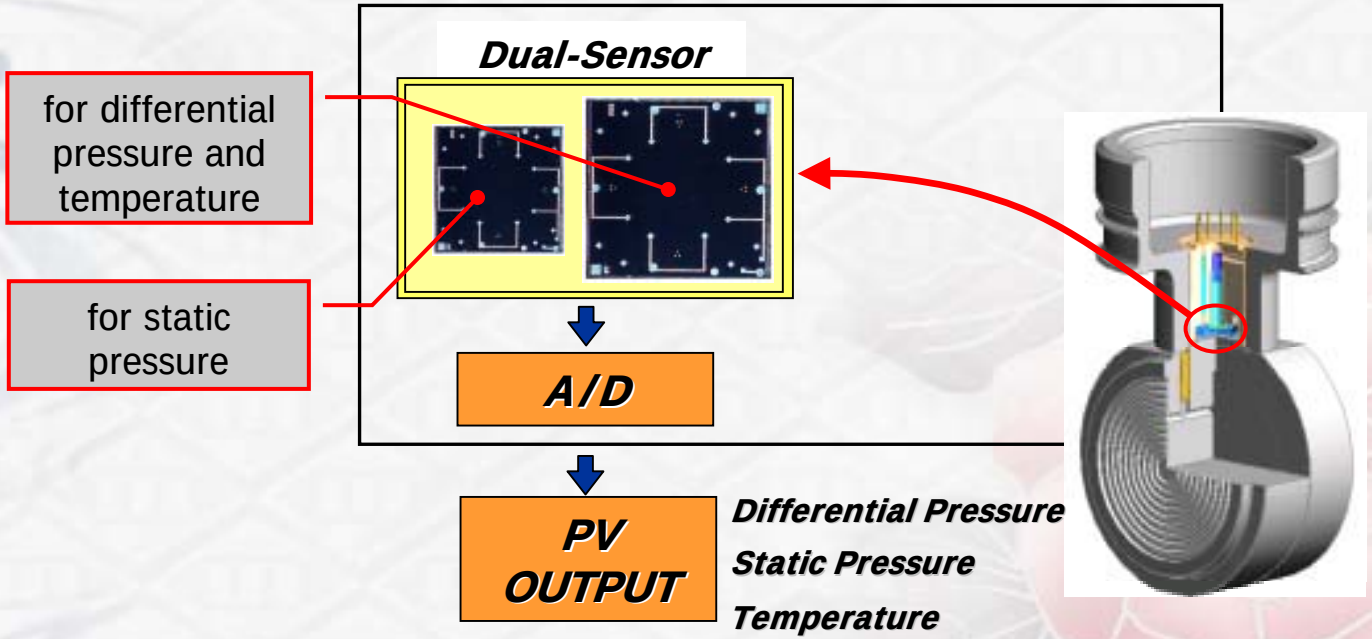
- ***The structure of Elliptical tube Flowmeters are very simple and unbreakable.***



d. State-of-the-art Technology Multi-Variable Sensor

- ✓ **Dual-Sensor detects temperature and pressure for density compensation.**

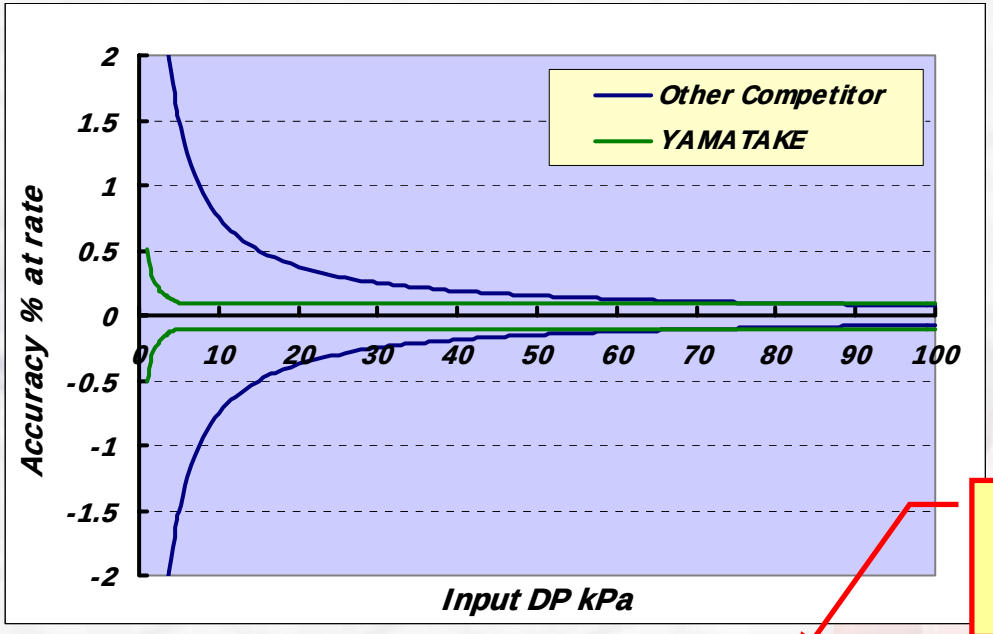
Dual-Sensor : "Two sensors on one sensor Header" enables precise accuracy in flow measurement.



e. Wide Flow Ranges

✓ Wide DP Sensor Range

Flow range is related to DP range.
Range ability of YAMATAKE's sensor is 15 times than others.



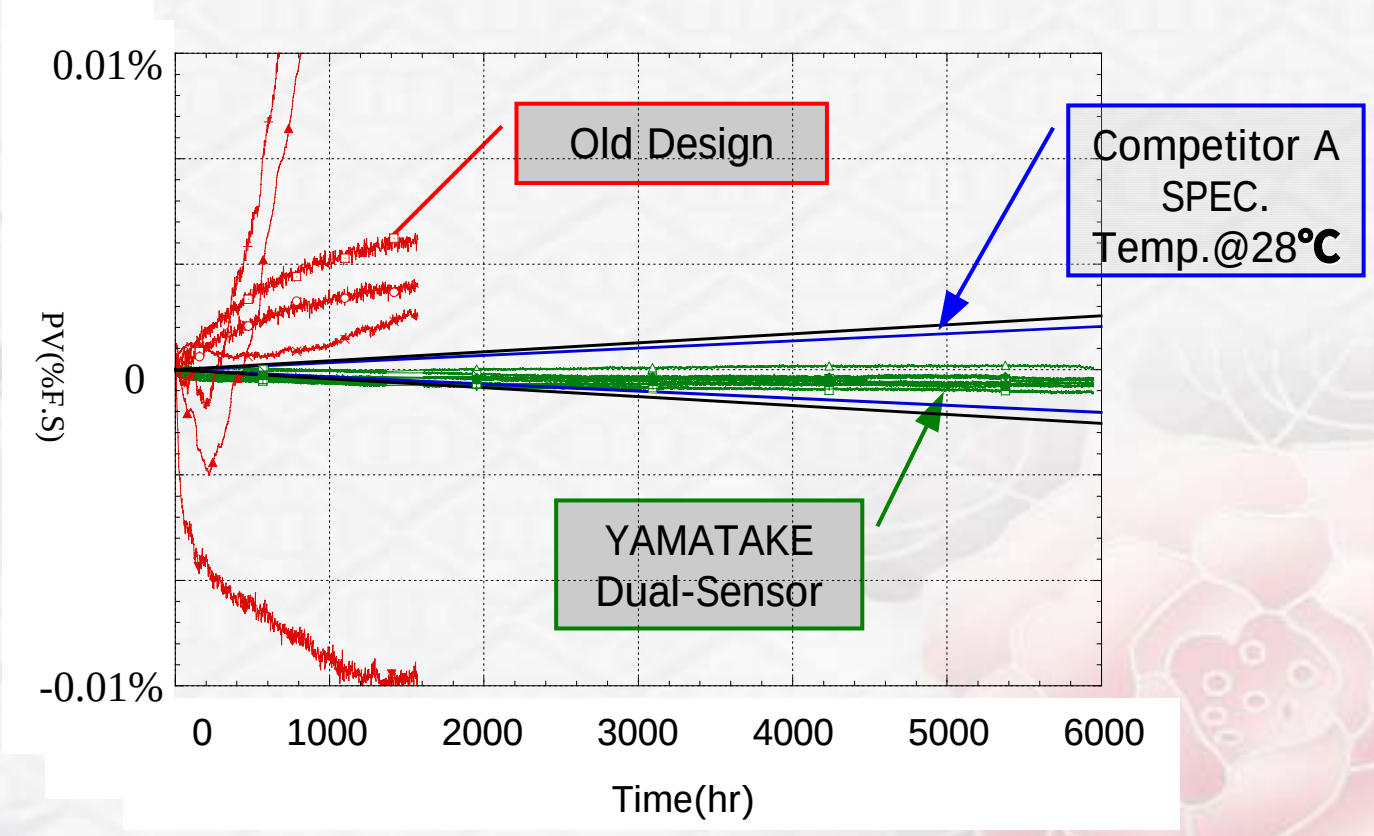
1% output of DP is equivalent to 10% output of flow .

INPUT DP	100kPa	1kPa
YAMATAKE	+/-0.1%	+/-0.5%
Other Competitor	+/-0.075%	+/-7.5%

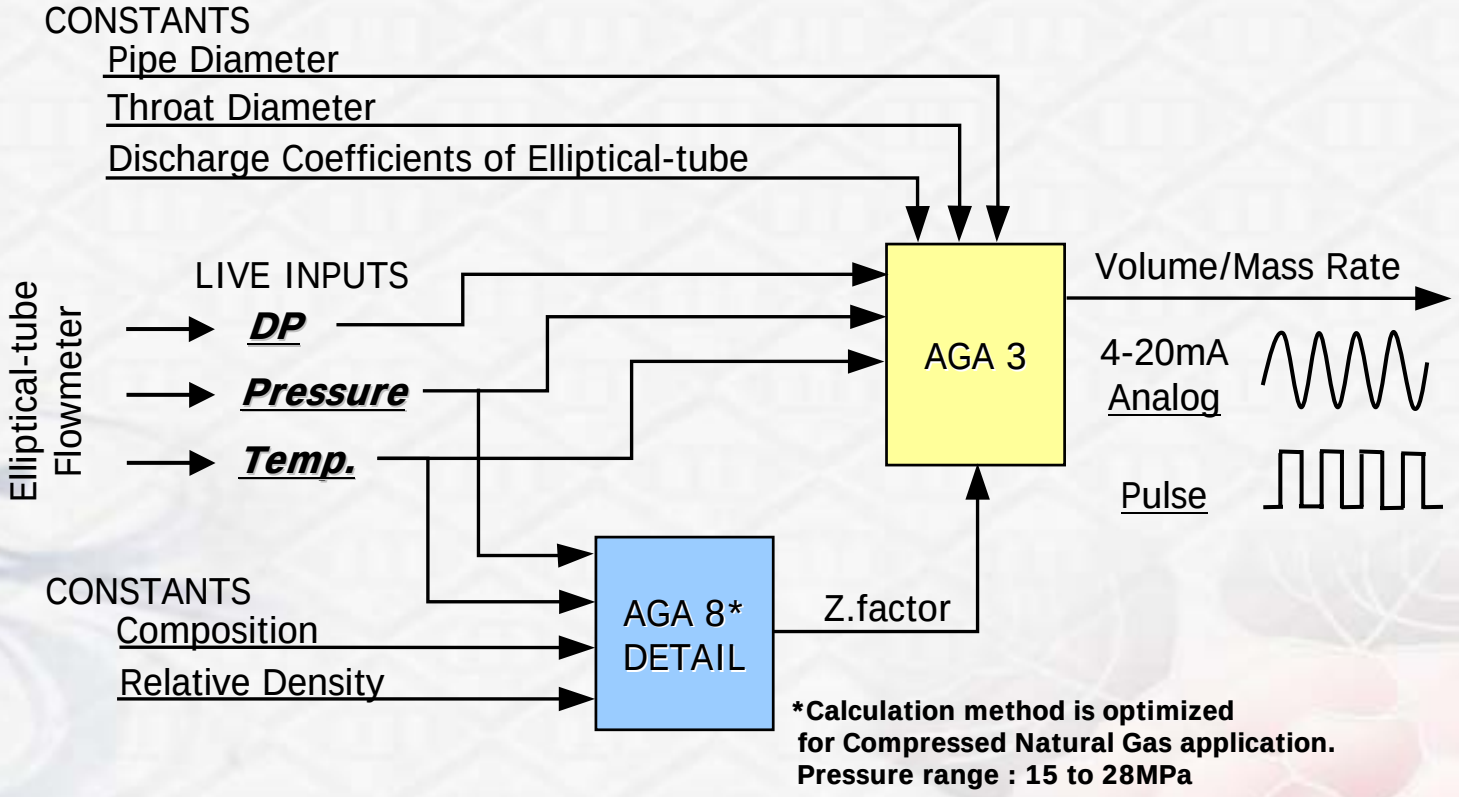
f. Stable Zero Output

✓ **Accelerated zero drift test**

Temperature :125℃



g. Built in Flow Calculation Function



✓ ***Flow rate calculation is redone, whenever live inputs changes.***

✓ ***High-speed response***

- ***Updating cycles of flow rate : 20ms.***

Topics

1. Problems of Traditional DP Flowmeters
2. Too Much Maintenance is Required for Traditional DP Flowmeters
3. Solutions by YAMATAKE's Elliptical-tube Flowmeters
4. **Principles of Operation**
5. Product Lineup
6. Project References

4. Principles of Operation

✓ Bernoulli's theorem

- Flow rate calculations are according to the Bernoulli's theorem.

$$Volume\ Flow = Ck\sqrt{\frac{\Delta p}{\rho}}$$

✓ Density fully compensated

- The dual-Sensor measured differential pressure, static pressure and temperature at the same time.

Topics

1. Problems of Traditional DP Flowmeters
2. Too Much Maintenance is Required for Traditional DP Flowmeters
3. Solutions by YAMATAKE's Elliptical-tube Flowmeters
4. Principles of Operation
5. **Product Lineup**
6. Project References

5. Product Lineup

✓ Elliptical-Tube primary element

- Standard Accuracy: +/-0.5% of actual flow
- Repeatability: +/-0.1%
- Flow Ranges: depend on the Reynolds number
- Pipe Size: 1B～6B
- End fittings: 150#,300# Flange
- Material: 304,316,316L SS

✓ CNG Flowmeter for CNG Dispenser

- Standard Accuracy: +/-1% at flow rate
- Repeatability: +/-0.1%
- Guaranteed accuracy: 10:1 of Span
- Pipe Size: 1/2B
- End fittings: 1/2NPT (Up to 42MPa)
- Wetted Parts Material: 304SS

✓ AIRcube for Compressed air in factory

- Standard Accuracy: +/-3% at flow rate
- Repeatability: +/-0.3%
- Guaranteed accuracy: 10:1 of Span
- Pipe Size: 2B～6B
- End fittings: JIS10K Flange
- Wetted Parts Material: SCS13

Topics

1. Problems of Traditional DP Flowmeters
2. Too Much Maintenance is Required for Traditional DP Flowmeters
3. Solutions by YAMATAKE's Elliptical-tube Flowmeters
4. Principles of Operation
5. Product Lineup
6. **Project References**

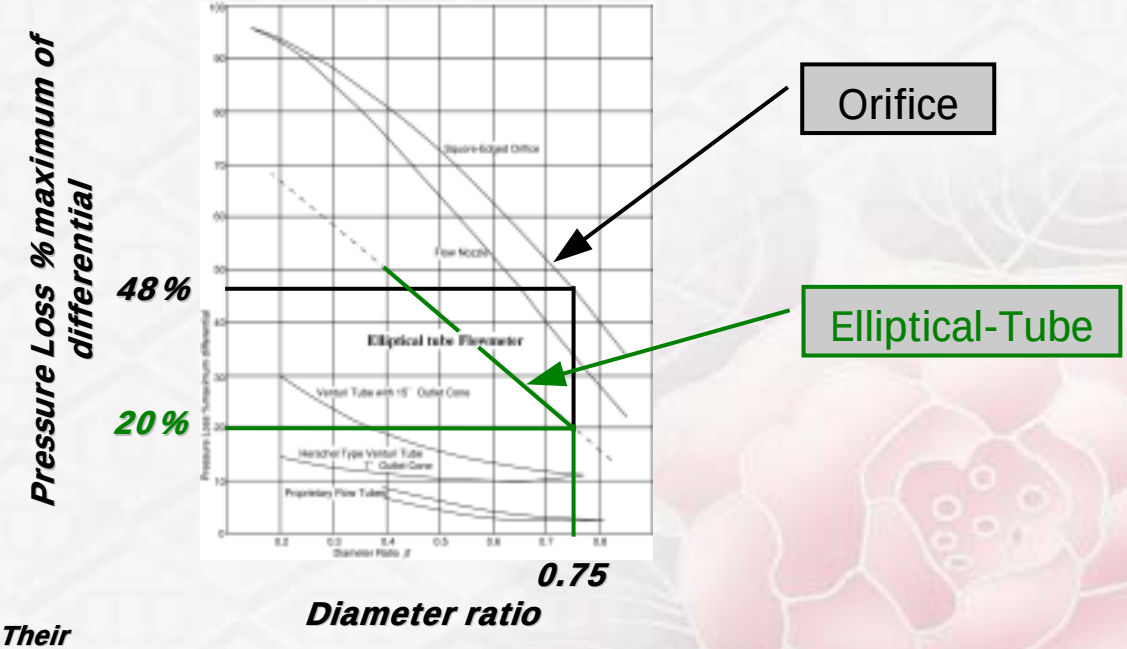
6. Project References

Customer : SUMITOMO CHEMICAL Co., Ltd.
Problem : Orifice's Pressure Tappings Clogging
Maintenance cycle was once a month.
Fluid : Polyethylene powder mixed air
Solution : Maintenance cycle is extended to once a year because of the Optimum-size pressure tappings of the Elliptical-tube Flowmeter.

Customer : KURARAY Co., Ltd.
Problem : Vortex Flowmeter could not measure low flow rate.
Fluid : Steam
Solution : Customer's demand is satisfied with wide range ability of Elliptical-tube Flowmeter.

Appendix1. Pressure Loss

- ***Orifice meters reduce the flow abruptly, so pressure loss is large.***
  - **Pressure loss leads to energy loss. A pump or a compressor consume excessive electric power.**

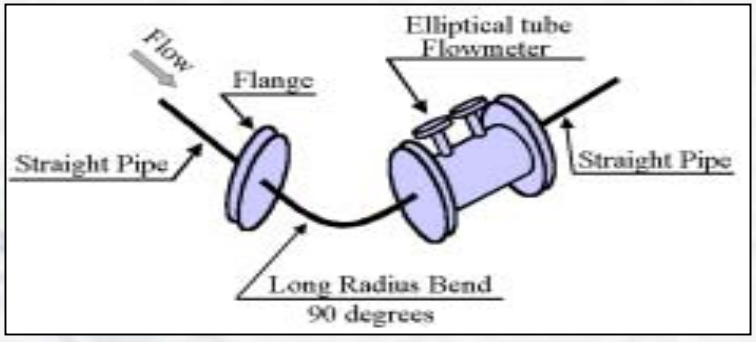


References : Fluid Meters Their theory and Application ASME 1959

Appendix2. Flexible Installation

- ✓ **Even when the upstream pipe length is zero, error increases by only +/-0.5% .**

In case of Orifice, upstream needs 10D.



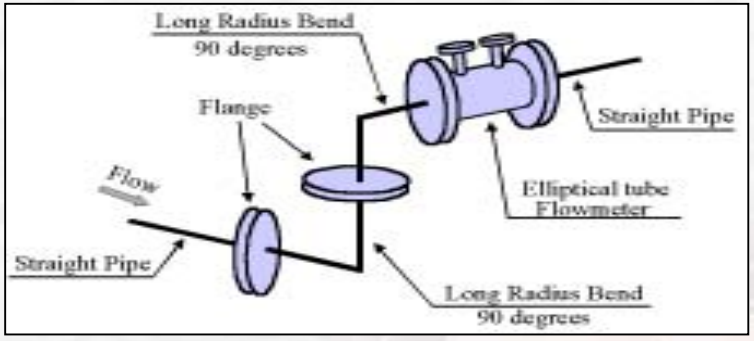


Table. Additional Errors under the influence of the upstream pipe length.

Diameter ratio	0.4	0.5	0.6	0.7
error %	-0.07	-0.17	0.12	0.78
	-0.01	-0.36	-0.18	0.62
	-0.16	-0.54	-0.51	-0.08
Ave.	-0.08	-0.36	-0.19	0.441

Appendix3. Applications

Slurry

Heavy oil

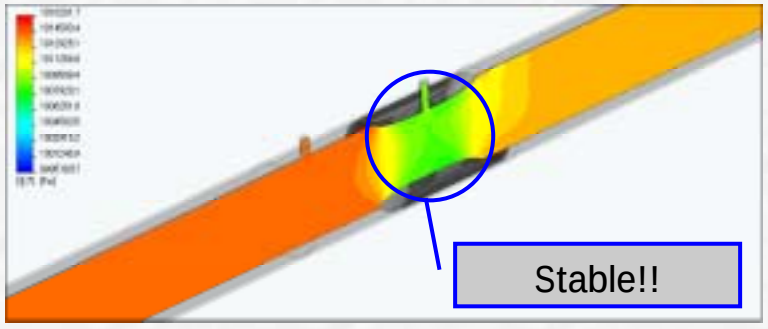
CNG

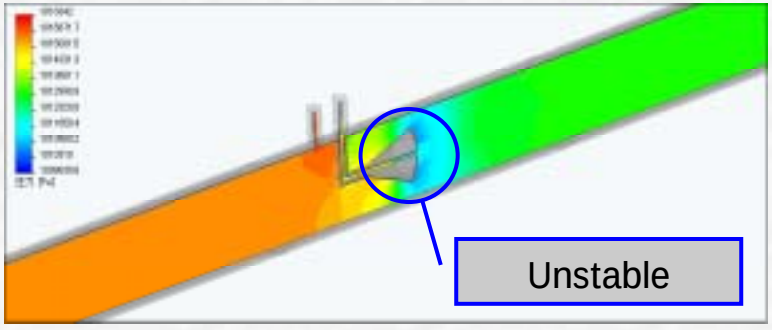
Air

Specification					Fluid Specification				Application	Shipment
Size	β	DP	P.rate	Mat.	fluid	Temp.	SP[kgf/cm2]	ReD		
2 B	0.4	928.6	ANSI150	SUS304	スチレンモノマ	96	3.2	85740	ターゲットメータが詰まるところにリプレース.	95/12
1 B	0.4	576		SUS304	酸素	10	34	77238	極低圧損(12%) 温度圧力補正(補正ROM)	95/1
2 B	0.4	1245	JPI300	SUS316	ポリプロパウダ	25	0.2	74569	固気2相流. 詰まり防止.	96/2
4 B	0.225	349	JIS10K	SUS304	蒸気	100	0	14124	極低圧損(30%)	96/1
2 B	0.4	488.9	JIS10K	SUS304	水＋樹脂	50	0	21259	低圧損.	96/3
3 B	0.6	1426	JIS10K	SUS304	高比重分液	50	0.5	127682	バッチプロセス	
2 B	0.6	4056	JIS10K	SUS304	蒸気	183.3	10	877280		96/4
3 B	0.6	1593	JIS10K	SUS304	蒸気	183.3	10	855105	流出係数と膨張係数を補正.	
3 B	0.7	1584	JIS10K	SUS304	蒸気 or	82	0.95	908549		
		2526			メタノール	127.2	1.5	819744		
6 B	0.7	1953	JIS10K	SUS316	NaOH	38	3	150941	ロータメータリプレース. (衝撃でフロートが壊れる)	96/5
3 B	0.7	1957	ANSI150	SUS304	REQ	60	7	271713		
2 B	0.4	844.8	JIS10K	SUS304	空気	20	1.2	72312	容積式リプレース	96/4
2 B	0.35	820	JIS10K	SUS304	空気	20	1.2	48208		
4 B	0.5	1098	JIS20K	SUS304	カリ溶液	70	12.5	108794	固着性流体	96/5
6 B	0.6	939.2	JIS20K	SUS304	カリ溶液	116	11	370669	(詰まり防止)	
1 B	0.4	約6000	JIS10K	SUS304	?	25	2	約500	高粘性スラリ流体	96/7
3 B	0.5	2900	jis10K	SUS304	HOT WTR	50	2	56514	容積式リプレース (ギアの噛み込みによる故障)	96/10
6 B	0.4	1700	JIS10k	SUS316	NaOH(4%)	38	4.5	118545	リピートオーダー	96/10
1 1/2B	0.7	2400	ANSI300	SUS304	ﾄﾘﾒﾁﾙｱﾐﾝ	150	25	969000	F.T	96/10
2 B	0.25	462.1	JIS10K	SUS304	C-C GAS	20	0.4	37152	禁油、禁水処理	96/8
3 B	0.4	5314	JPI150	SUS316	RLGO液	20	13.03	27914	ハイレンジアビリティ	96/9
3 B	0.4	1525	JPI150	SUS316	LCO液	20	13.04	7552		
2 B	0.6		JPI150RJ	SUS304L	HC LIQUID	400	4		HEAVY OIL	96/12
4 B	0.4	1700	JIS10K	SUS316	NAOH	38	4.5		リピートオーダ	96/12
2 B	0.4	F.T:サーマル流量計でトラブル。楕円をいろんなところに使い回して試している。								96/12
2 B	0.7	3529	Jis10k	SUS304	GO2GAS					96/12
1 B	0.5	1470	JIS10K	SUS316L	酢酸				容積式リプレース	96/12
2 B	0.5	800	JIS10K	SUS304	工業用水	15	400KPaG		競合, 渦	97/1
2 B	0.6	1230	JIS10K	SUS304	飲料水	15	550KPaG			
1 B	0.35	440	JIS10K	SUS304	N2	15	700KPaG			
1 1/2B	0.5	1000	JIS10K	SUS304	純水	15	400KPaG			
4 B	0.4	760	JIS10K	SUS304	飽和蒸気	158.93	500KPaG			
3 B	0.3	6000	JPI150	SUS304	OIL	38	7.9		ハイレンジ	97/1
3 B	0.3	6000	JPI150	SUS304	OIL	40	4			
1 B	0.45	1800	ANSI150	SUS304	ブタジエン	50	10.4		容積式リプレース	97/1
1 B	0.45	450	JIS10K	SUS316	N2	15	10KPa		競合, 渦	97/1
1 B	0.4	850	JIS10K	SUS316L	NV30%スラリ	125	4.5		他に測れるものがない	97/1
1 B	0.7	2400	JIS20K	SUS304	PRE液体	-5	10		競合, 渦	97/1
2 B	0.6	2000	JIS10K	SUS304	PREガス	10	1			
2 B	0.6	6,775	JPI300	SUS304	エチレンガス	25	35	3912119		97/2
2 B	0.4	1245	JPI300	SUS316	C3+パウダ	25	0.2	74569		97/2
3 B	0.4	1717	JIS10K	SUS304	AIR	25	6	226948		97/3
1B	0.4	2741	JIS10K	SUS304	H2	20	5	26388		97/3
3B	0.4	3273	ANSI150	SUS316	EDC	70	2	87606		97/3

Appendix4. Elliptical-tube vs. V-cone

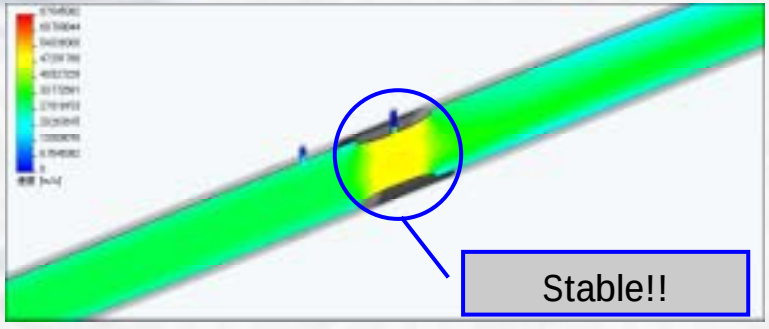
- **Point1 Low Pressure Side of DP (pressure distribution)**

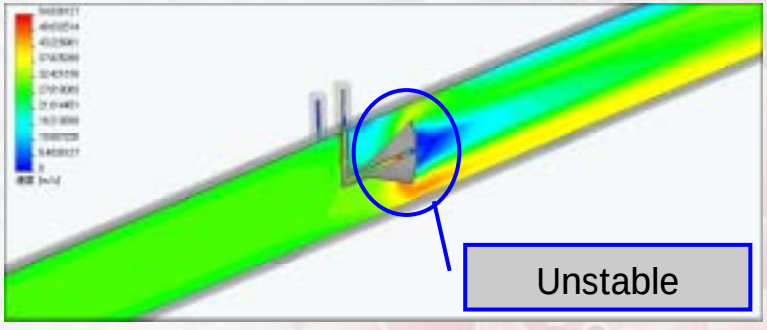




➢ Calculated flow rate is accurate, because of a stable DP.

- **Point2 Stable Flow at Throat Part (velocity distribution)**



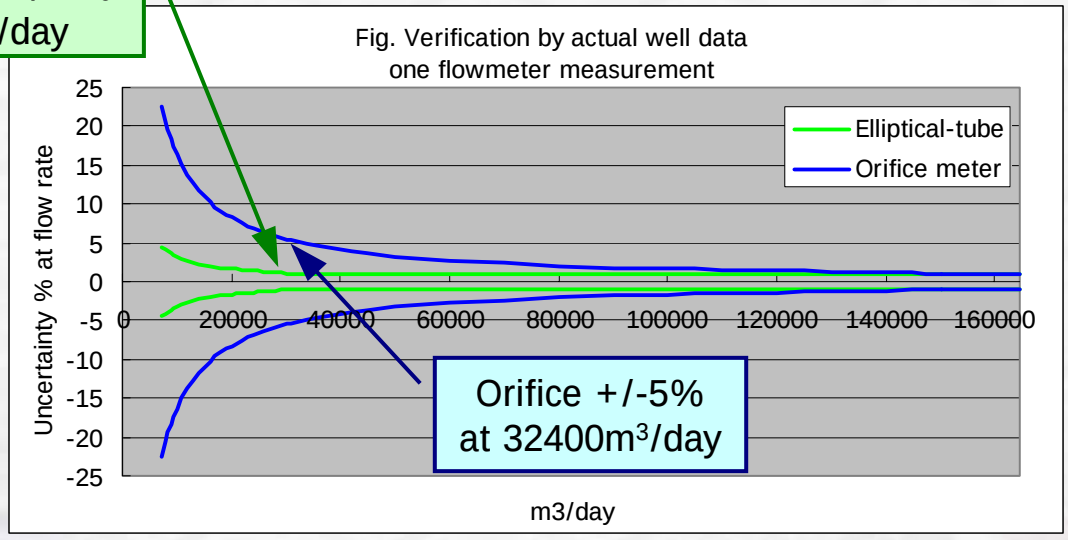


➢ V-cones make vortices.

- Noise and vibration are made by vortices.
- The instruments installed down-stream will be influenced by vortices.

Appendix5. Verification by Actual Gas Well Data

Elliptical-Tube +/-1% to 32400m³/day



Elliptical-tube Flowmeter will measure with excellent accuracy over a wide range.

Parameters

Orifice	Elliptical		
+/-1% FS	+/-1%RD		Accuracy
47.64	104.25	inH2O	DP
164500	164500	m3/day	Flow Range
-	32400	m3/day	Guaranteed
-	7300	m3/day	Measurable
3004.07	3004.07	kPa g	Static Pressure
22.98	22.98	Deg C	Temprature

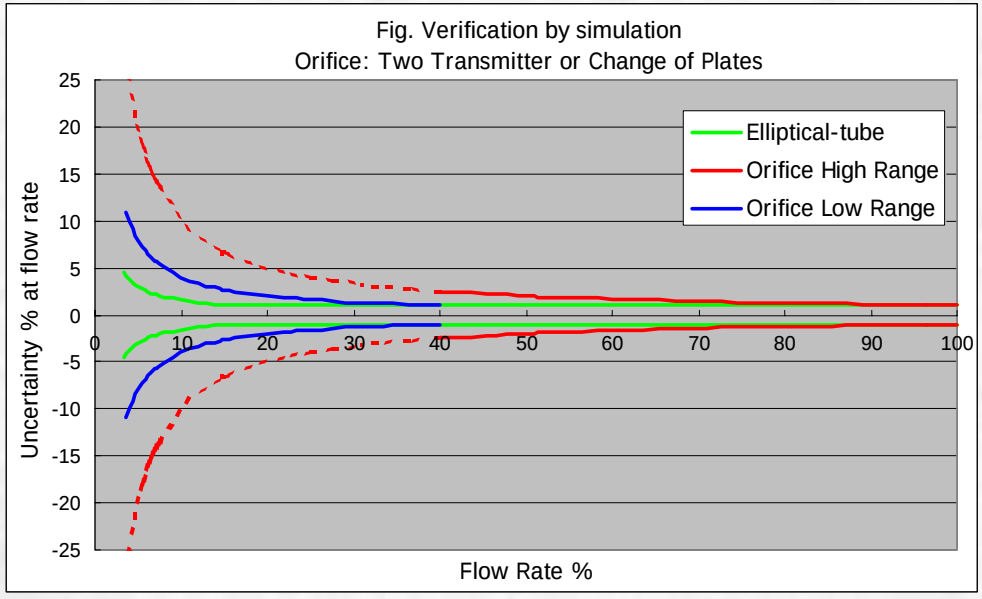
Primary Element

Orifice	Elliptical	
2.25	1.592	" Orifice Dia.
3.98	3.98	" Pipe Dia.
0.565	0.400	beta-ratio

Max. Pressure Loss

Orifice	68 % of DP
Elliptical	50 % of DP

Appendix6. Flow Range Comparison



YAMATAKE*'s Elliptical-tube Flowmeter covers more than two sets of orifice flowmeters.*

* Combination of Uncertainties : Root-Sum-Square method

Parameters

Orifice	Elliptical		Accuracy
+/-1%FS	+/-1%RD		
200	183.40	inH2O	DP
No.1 55000	55000	m3/day	Flow Range
No.2 22000	8200	m3/day	Guaranteed
	1840	m3/day	Measurable
3004.07	3004.07	kPa g	Pressure
22.98	22.98	Deg C	Temperature

Primary Element

Orifice	Elliptical	
1	0.8	" Orifice Dia.
2	2	" Pipe Dia.
0.500	0.400	beta-ratio

Max. Pressure Loss

Orifice	73 % of DP
Elliptical	50 % of DP