PROTECTING THE MONEY STREAM

The Real World of Sewer Billing Meters

EASTECH

THE REAL WORLD OF SEWER FLOW MEASUREMENT

Measuring billable flow under constantly changing conditions has always been challenging, and many times, expensive. Challenging, due to a difficult environment (hydraulics, infiltration, debris, etc.), and expensive, when flowmeters read incorrectly.

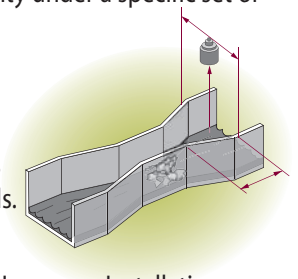
Flow measurement in the wastewater field is always carried out under harsh sewer conditions. Sewers are polluted with sludge, solids, fibers, grease and oil. Structural conditions often mean difficult hydraulic conditions. Flow measurement ranges will vary from low levels at night and during dry periods, to high levels during the day, to surcharge levels during extreme periods of rain. What does this all mean for municipalities and the many industries that have their wastewater treated by independent facilities that charge for these services? It means that anyone involved with the process of either paying for sewerage treatment or charging for that treatment should be totally familiar with the myriad of conditions that can quickly add up to thousands of dollars in questionable billings or lost income. Unless a Billing Meter is chosen that can monitor flow under all conditions, charges will quickly accumulate for rain events, reverse flows, stagnation, blockages, difficult hydraulic condition and inaccurate readings due to extremely low or high flows. A few percentage points of error can quickly add up to thousands of dollars in questionable billings or lost income

THE FACTS OF SEWER LIFE

A casual investigation by any interested party of collection system flow studies conducted by municipalities, government agencies and private engineering groups will confirm that in 95% of the cases, the average flow in a sanitary sewer is only 30% - 40% of the pipe diameter. In combined sewers, average dry day flows hover around 5% - 10% of pipe diameter. This is a very important statistic, especially in light of the fact that most open channel flow measurement technologies only perform reliably under specific conditions. Low depths of flow are very difficult for meters to accurately measure and high flows and velocities promote debris accumulation on bottom-mounted sensor housings, frequently resulting in inaccurate data and the requirement for repetitive maintenance.

OPERATING CONDITIONS

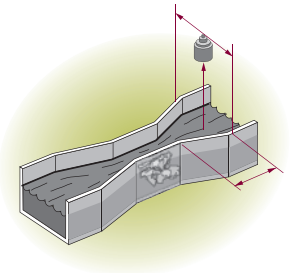
Due to constantly changing flow conditions within the sewer environment, the measurement choices available with present technology fall short of today's flow monitoring requirements by only offering accuracy and reliability under a specific set of operating conditions..



LOW FLOW CONDITIONS:
(Nighttime, Dry Days)

A Flume/Level Sensor combination is ideal for measuring flows at low levels. The drawback to this design is:

- Installation Dependent Accuracy: Improper Installation can increase flow measurement error by as much as ±15%.
- Cost Intensive Installation: Flumes, depending upon size and environment, are time consuming and expensive to install.
- Maintenance Prone Construction: Certain types of flumes are susceptible to various types of debris becoming lodged within their respective throats
- A Doppler/Pressure Cell combination is unable to accurately measure flows below 3 inches and velocities below .5ft/sec.

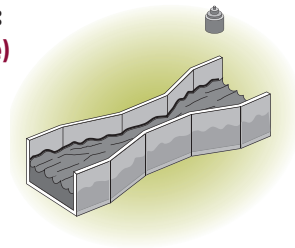


HIGH FLOW CONDITIONS:
(Daytime, Rain Events)

A Flume/Level Sensor combination is ideal for measuring flows at mid-level but again, has the following additional drawbacks:

- Limited Range Measurement: In the event of debris or blockage, Flumes will lose their ability to measure flow at upstream depths exceeding 75% of the Pipe I.D.
- Reverse Flow Conditions: Flumes are incapable of detecting reverse flow.
- Stagnant Flow Conditions: Periods of stagnation and zero flow are recognized as flow.
- A Doppler/Pressure Cell combination is velocity dependent, whereby high velocities will create a region of low pressure directly above the sensor probe, causing level measurement errors. Additionally, sensor probes located at the invert of the pipe are highly susceptible to fouling.

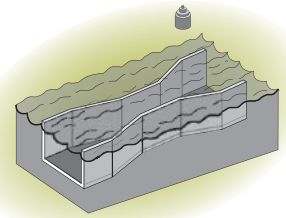
NON-UNIFORM FLOW CONDITIONS:
(Turbulence, Upstream Disturbance)



Flumes, in order to maintain accuracy, require non-turbulent flow conditions.

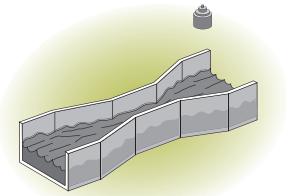
- Conditional Flow Monitoring: Flumes require a uniform velocity distribution and a tranquil water surface at the flume entrance for accurate measurement.
- Doppler Sensors require site-specific calibration. If conditions were to suddenly change, the accuracy of the ensuing flow data would be in question.
- USBR Water Measurement Manual: "Doppler flowmeter accuracy is sensitive to velocity profile variations and to distribution of acoustic reflectors in the measurement section."

SURCHARGE FLOW CONDITIONS:
(Heavy Rain Events)



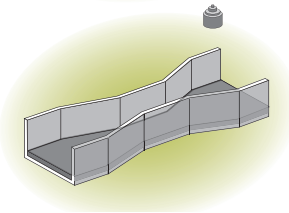
- Flumes, during heavy, wet weather conditions, cease to function.
- Backwatering, due to surcharge or submerged conditions, can violate flume design assumptions by as much as 400%.

REVERSE FLOW CONDITIONS:
(Maintenance Issues, Surcharge)



- Flume/Level Sensor combinations are incapable of detecting conditions of reverse flow.

STAGNANT FLOW CONDITIONS:
(Maintenance Issues)

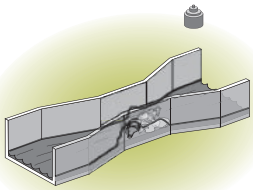


- Flume/Level Sensor combinations recognize periods of stagnation and zero flow as normal flow,

MAINTENANCE ISSUES

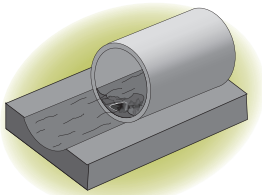
Unfortunately, many of the devices presently utilized for measurement of flow within sewers are poorly suited for the "challenging" environment of collection system networks. This environment can include high humidity, exposure to oils and greases, organic waste, industrial waste, periodic submergence and deposition of solids on the bottom invert of the pipe.

FLUME/LEVEL SENSOR COMBINATIONS:



- Flumes must be checked periodically to ensure debris, especially rags, has not accumulated or become lodged within their respective throats.

DOPPLER/PRESSURE CELL COMBINATIONS:



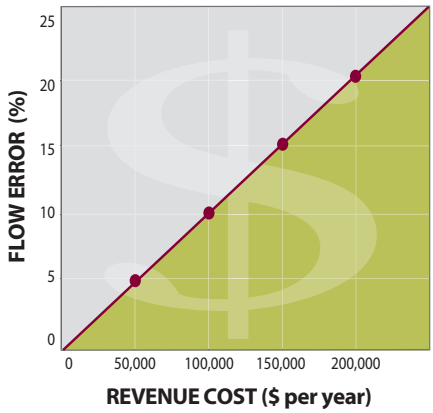
- Sensor probes, installed at the bottom invert of the pipe, are highly susceptible to accumulation of debris, grease, silt and various other media prone to accelerating sensor failure.

COST ISSUES

When industry and municipalities have their wastewater treated by outside treatment facilities, an ongoing cost for these services is always present. Now, flow measurement accuracy becomes directly proportional to dollars spent or revenue lost.

AT THE NATIONAL AVERAGE BILLING RATE OF APPROXIMATELY $3/1000 GALLONS, A 10% AVERAGE FLOW MEASUREMENT ERROR IN A 1MGD PLANT TRANSLATES TO 100,000 GALLONS/DAY OR 700,000 GALLONS /WEEK OF OVER OR UNDERBILLED REVENUE ($2,100/WEEK OR $109,200/YEAR). A HIGH PERFORMANCE BILLING METER HAS THE POTENTIAL OF PAYING FOR ITSELF WITHIN THE FIRST MONTH OF OPERATION WHILE SAVING OR ADDING OVER $100,000/ANNUM TO THE MONEY STREAM.

ACCURACY VS. COST



SO WHAT IS THE ANSWER

THE ANSWER IS A HIGH PERFORMANCE HYBRID TECHNOLOGY BILLING METER. A COMBINATION OF TWO PROVEN TECHNOLOGIES PROVIDING MAXIMUM EFFICIENCY FOR MONITORING THE FLOW OF WASTEWATER UNDER ALL CONDITIONS

By combining two technologies, maximum efficiency is achieved for monitoring wastewater flows under all conditions. The high performance hybrid design is totally based upon field confirmation test data obtained from the U.S. Bureau of Reclamation, the Environmental Protection Agency and the U.S. Department of Agriculture. In addition, prior to field shipment, every High Performance Billing Meter is individually tested, calibrated and certified at Eastech's in-house NIST traceable Flow Metrology Lab.

ACHIEVING HIGH PERFORMANCE DESIGN FOR THE REAL WORLD

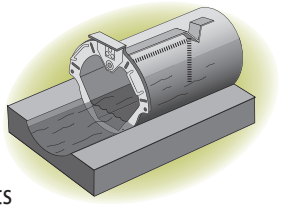
Pages 2 and 3 of this Paper outline in detail the challenges that exist when attempting to accurately and reliably monitor flow within the sewer environment. Yet, by combining and applying the results compiled from extensive government agency field investigations, it was possible to successfully produce a hybrid technology flowmeter capable of overcoming each one of these barriers. We at Eastech realize that the potential errors caused by this difficult environment will never be totally eliminated, but they can be restricted to an acceptable limit through clever design and proper installation.

HIGH PERFORMANCE BILLING METERS

Accurate and Reliable Sewer Flow Monitoring Under All Conditions

The Accuron Crossfire, designed to municipal agency test standards, is the first open channel portable flowmeter to utilize Hybrid Technology. The Technology was born through the combination of U.S. Bureau of Reclamation flume/level standards for low flow measurement applications and the more accurate EPA proven transit-time chordal velocity method for higher flow applications. This new Hybrid Technology Cartridge Meter allows for highly accurate and reliable flow measurement during a wide range of conditions that include: extremely low flows, high flow events, surcharges, stagnation, backwatering and non-uniform hydraulic profiles.

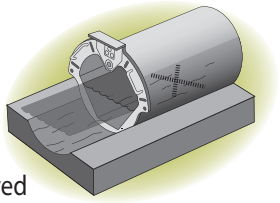
OPERATING CONDITIONS



LOW FLOW CONDITIONS:

Accuracy: +/-1 - 5%

During periods of low flow (Zero to 1/3 pipe I.D.), measurements are achieved through a highly efficient combination of a trapezoidal flume and an ultrasonic level sensor. (SEE PAGES 8 - 11 FOR MUNICIPAL AGENCY TEST DATA)



HIGH FLOW CONDITIONS:

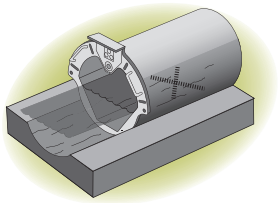
Accuracy: +/-1 - 2%

During periods of average flows (30 - 40%) and high flows (40% to full pipe), measurements are achieved through proven area-velocity methods that combine an ultrasonic level sensor with crossed path high performance transit-time velocity sensors. (SEE PAGES 10 - 15 FOR MUNICIPAL AGENCY TEST DATA).

OPERATING CONDITIONS CONT.

NON-UNIFORM FLOW CONDITIONS:

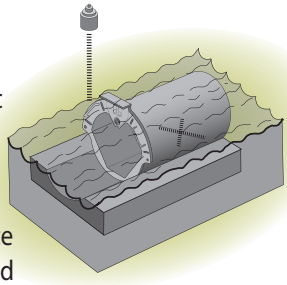
Accuracy: +/-1 - 5%
(depending upon severity)



As previously stated, "uniform flow in sewers is seldom attained except in very long reaches". Combine that fact with the fact that " in 95% of the cases, the average flow in a sanitary sewer is only 30 - 40% of the pipe diameter" and you have a situation requiring multiple velocity sensors in order to achieve any amount of reasonable accuracy during the majority of the billing period. The Accuron CrossFire , depending upon sewer level conditions and the severity and type of non-uniformity, offers a crossed path High Performance Billing Meter for turbulent, disturbed and asymmetrical flow profiles.
(SEE PAGES 14 & 15 FOR MUNICIPAL AGENCY TEST DATA)

SURCHARGE FLOW CONDITIONS:

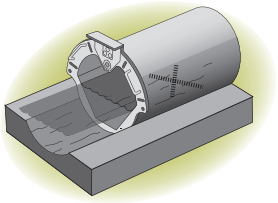
Accuracy: +/-1 - 2%



An optional "above the flow" ultrasonic level sensor is provided for continuous measurement of accurate surcharge height data. During the surcharge period, the high performance velocity sensors maintain uninterrupted monitoring of forward and reverse flows. (SEE PAGES 10 & 11 FOR MUNICIPAL AGENCY TEST DATA)

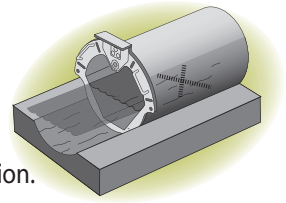
REVERSE FLOW CONDITIONS:

Accuracy: +/-1 - 2%



Reverse flows, during abnormal or surcharged conditions, are accurately measured by bi-directional velocity sensors and single or dual (optional surcharge monitor) level sensors.

STAGNANT FLOW CONDITIONS:



1/3 Pipe to Full Surcharge
In the event of a blockage or stop page of flow, the transit-time velocity sensors will report a "zero flow" condition.

INSTALLATION

The CrossFire guarantees installed accuracy and cost efficiency by providing the end user with a pre-engineered field ready system designed for "out of the box" installation. A single cartridge, pre-sized for its specific application, arrives at the job site as a fully integrated unit, requiring only 30 minutes for installation. Every component is factory precision aligned, NIST traceable Flowlab calibrated and pre-programmed in strict accordance to customer supplied operating specifications.

DATA COLLECTION

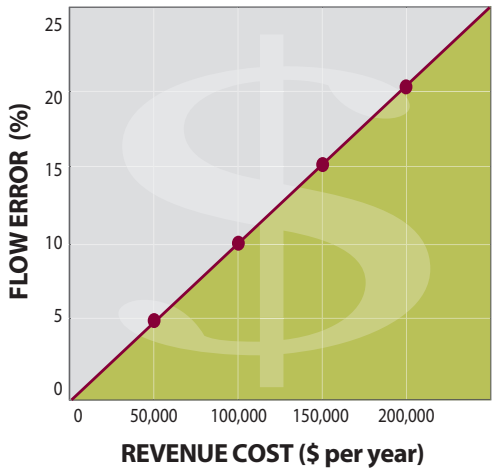
The CrossFire Billing Meter is designed with an onboard datalogger capable of capturing flow data on eight distinct channels. A factory supplied flow monitoring graphing package is additionally provided at no charge.

If the need arises for hard copy confirmation of flow data, A 24 hour to 30 day Chart Recorder, fully integrated within the meter enclosure, is optionally available.

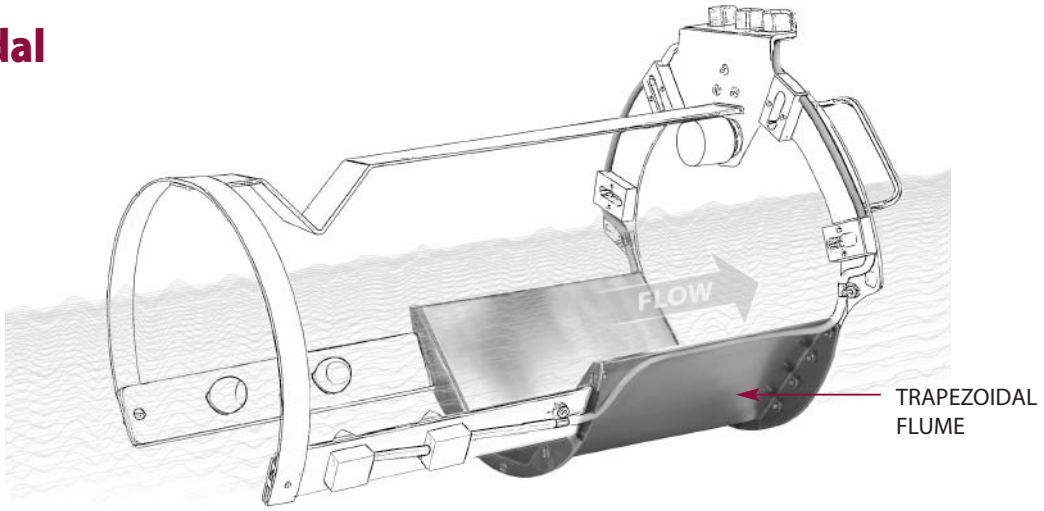
MAINTENANCE

TRAPEZOIDAL FLUME: A flat straight-through bottom trapezoidal flume permits the cartridge assembly to pass debris quite readily, while additionally eliminating the problem of sediment build-up upstream of the flume. (SEE PAGES 8 & 9 FOR MUNICIPAL AGENCY TEST DATA)
Level and Velocity Sensors: An "above the flowstream" level sensor and non-fouling velocity sensors remain free from the ongoing maintenance problems of sediment, fouled sensors and accumulated debris. (SEE PAGES 10 - 13 FOR MUNICIPAL AGENCY TEST DATA)

ACCURACY VS. COST



Trapezoidal Flume



U.S. ENVIRONMENTAL PROTECTION AGENCY DOCUMENT EPA-600/2-75-027

SEWER FLOW MEASUREMENT:
A STATE-OF-THE-ART ASSESSMENT

PAGE 86: TRAPEZOIDAL FLUMES – In attempts to obtain wider ranges of discharge than those that can be obtained with Parshall or San Dimas flumes, several investigators have considered supercritical trapezoidal flumes. The outward sloping of the flume walls provides increased sensitivity to lower discharge rates for a given size and hence, increased range.

PAGE 91: TRAPEZOIDAL FLUME EVALUATION

EVALUATION PARAMETER	EVALUATION
RANGE	GOOD
FLOW EFFECTS ON ACCURACY	SLIGHT
SUBMERGENCE/BACKWATER EFFECT	LOW
EFFECT OF SOLIDS MOVEMENT	SLIGHT
FLOW OBSTRUCTION	SLIGHT
HEAD LOSS	LOW
INSTALLATION RESTRICTIONS	SLIGHT
SIMPLICITY & RELIABILITY	GOOD
UNATTENDED OPERATION	YES
MAINTENANCE REQUIREMENTS	LOW
RUGGEDNESS	GOOD
EASE OF CALIBRATION	GOOD
MAINTENANCE OF CALIBRATION	GOOD

U.S. ENVIRONMENTAL PROTECTION AGENCY DOCUMENT EPA/600/R-01/043

PERFORMING QUALITY FLOW MEASUREMENTS
AT MINE SITES

PAGE 57: WATER MEASUREMENT DEVICE SELECTION CRITERIA

TRAPEZOIDAL FLUME – The Trapezoidal flume can measure super-critical flows. The Trapezoidal cross-section permits a wider measurement range than other flumes, and the flat bottom passes sediment and other debris.

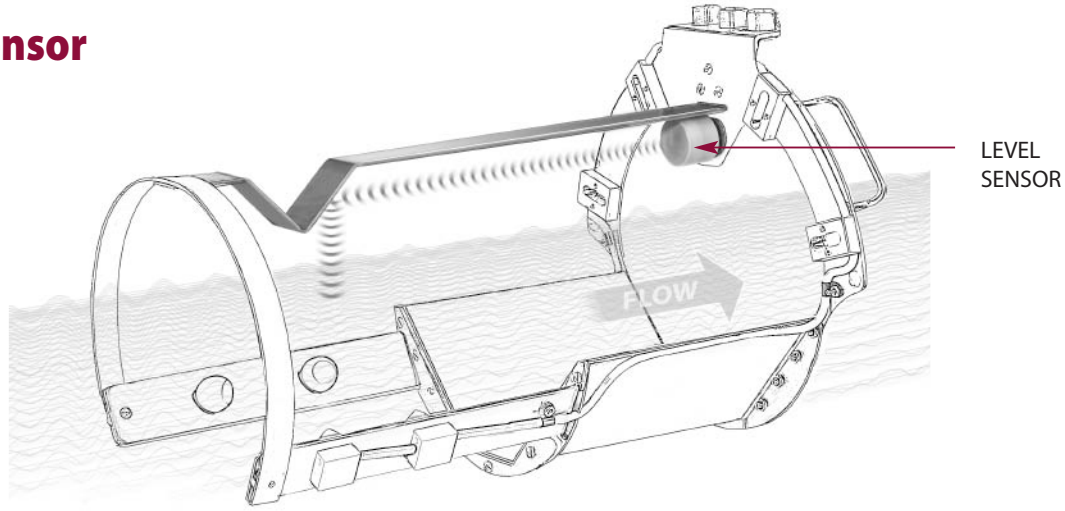
U.S. BUREAU OF RECLAMATION and U.S. DEPARTMENT OF AGRICULTURE

WINFLUME SOFTWARE FOR FLOW MEASUREMENT
VERSION 1.05.0027

(DESIGN SOFTWARE UTILIZED FOR CARTRIDGE METER FLUME CONSTRUCTION)

WinFlume is a Windows-based computer program used to design and calibrate flume and weir flow measurement structures. The software was developed through the cooperative efforts of the U.S. Bureau of Reclamation, the Agricultural Research Service (USDA), and the International Institute for Land Reclamation and Improvement. The WinFlume software allows for the design of trapezoidal flumes that meet unique operational site requirements while eliminating the need for laboratory calibrations.

Level Sensor

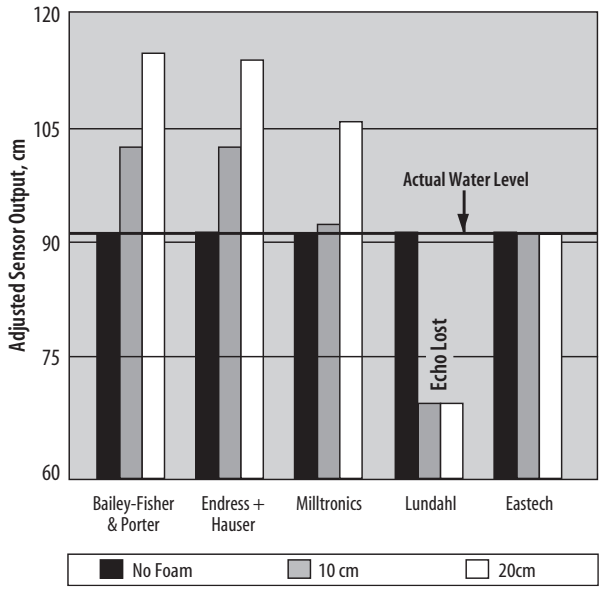


U.S. BUREAU OF RECLAMATION SPONSORED STUDY ITRC R99-002

5 YEAR WATER LEVEL SENSOR AND DATALOGGER STUDY

PAGE 56/57: FOAM – Sound waves reflect off and are absorbed by any surface, so foam can easily alter an ultrasonic level reading. Foam tends to absorb the ultrasonic pulses and reflect them in many directions, which can result in a lost signal. Figure 35 shows ultrasonic sensor response to two depths of dish soap foam on a level water surface. The ability of an ultrasonic sensor to penetrate foam grows with decreasing beam angle and increasing strength of the sound pulses.

FIGURE 35. FOAM EFFECTS ON ULTRASONIC WATER LEVEL SENSORS

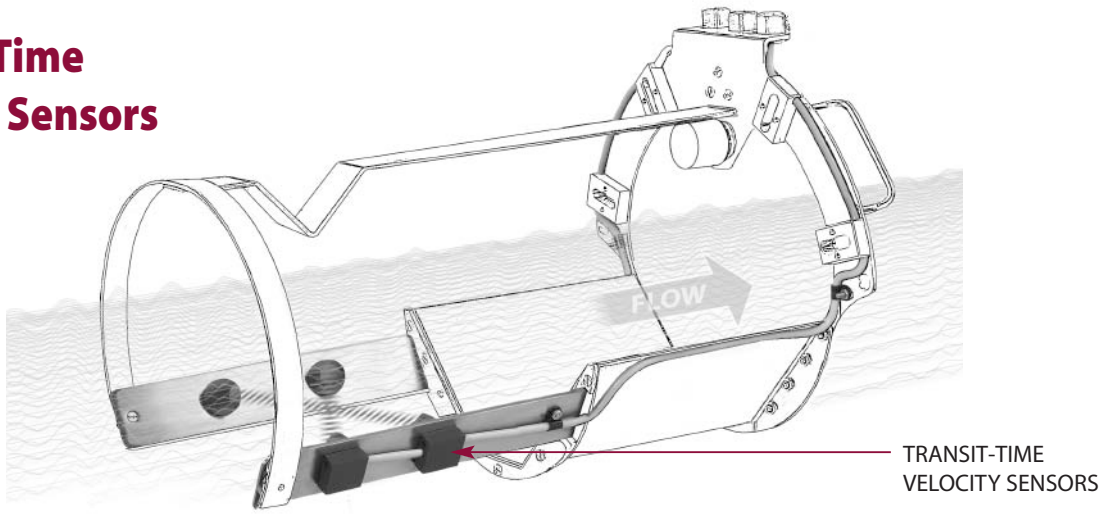


PAGE 61/62: TEST RESULTS – Of all the ultrasonic sensors tested, Eastech was the only one to successfully penetrate through dish soap foam. This is most likely due to this sensor's relatively small beam angle and powerful signal. As did most of the ultrasonics, the Eastech 2500 displayed almost perfect linearity, hysteresis close to zero, and excellent long-term reliability.

ACCURACY TEST RESULTS

Cumulative Days	20	40	60	80	100	120	Overall
Average daily error during that 20-day period, ± % full scale	0.010	0.008	0.012	0.016	0.007	0.004	0.010

Transit-Time Velocity Sensors



U.S.ENVIRONMENTAL PROTECTION AGENCY DOCUMENT EPA-600/2-76-243

WASTEWATER FLOW MEASUREMENT IN SEWERS USING ULTRASOUND

[IN AN 18 MONTH TEST, IT WAS VERIFIED THAT THE TRANSIT-TIME VELOCITY SENSORS WERE NEVER SUSCEPTIBLE TO FOULING BY PASSING DEBRIS AND GREASE, AND THE METERS ONCE OPERATIONAL, REMAINED IN SERVICE WITHOUT FURTHER ATTENTION FOR THE DURATION OF THE TEST.]

PAGE 1: CONCLUSIONS

1. Ultrasonic velocity measurement equipment in conjunction with ultrasonic level measurement can be utilized for the measurement of sewage volume flow.

2. The equipment is sufficiently low in cost to achieve general use, can be conveniently installed in new or existing sewers, requires minimum maintenance, and is suited for long term operation in the sewer environment.

3. Installation does no require special constructions.

4. Between 25% of channel depth and surcharged conditions the correlation between the average chordal velocity and the average area velocity is sufficiently predictable to enable the average chordal velocity, level and area functions to be easily integrated electronically providing flow information accurate to within approximately 2%.

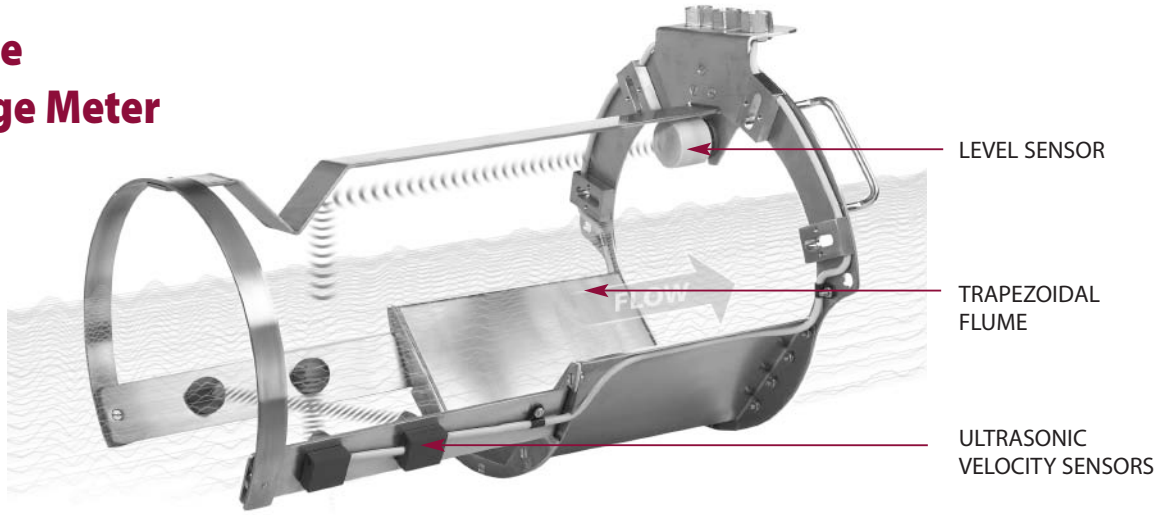
5. The system has an 80:1 turndown capability which well exceeded the flow ranges experienced.

PAGE 62: PROBE FOULING BY DEBRIS AND GREASE – One of the major design features of considerable conjecture before the installations were made was the possible susceptibility to fouling of the velocity probes by passing debris and grease. A major result of the program was the demonstration that this did not in fact occur, and the meters, once operational, remained in service without further attention at least for the duration of the demonstration (18 Months) and probably indefinitely.

PAGE 64: EQUIPMENT COSTS – The ultrasonic system continues to measure accurately when the sewer is surcharged, when weirs and flumes become inoperative.

PAGE 67: VELOCITY PROFILE ANALYSIS – Concurrently with the demonstration of the metering equipment, an investigation of velocity profiles was undertaken. By their judicious placement, a single set of velocity probes allows sufficiently accurate (1-2%) measurement of the average area velocity for a wide range of levels provided that turbulent flow conditions exist. THIS IS A RESULT OF THE RELATIVE CONSTANCY OF THE K-FACTOR OVER A WIDE RANGE OF DEPTHS. THIS K-FACTOR HAS A SLIGHT VARIATION, FROM 0.96 TO 0.98, AS THE CHANNEL LEVEL CHANGES FROM 30% TO COMPLETELY FULL.

Crossfire Cartridge Meter



U.S. BUREAU OF RECLAMATION WATER MEASUREMENT MANUAL

"In general, for every one degree of uncertainty in path angle, about 1% uncertainty occurs in velocity measurement. Use of crossed acoustic paths will compensate for variations in flow stream direction."

"For multipath systems, accuracies of 2% or better can be achieved over a wide range of flow rates and channel conditions."

"In general, deviations in velocity profiles are best accounted for by increasing the number of acoustic paths. Exact cancellations of secondary flow errors can be accomplished by using a cross path configuration."

EPA REPORT: EPA/600/JA-02/226-2002

"Improved accuracy of measurements could be possible by installing multiple sensors."

EPA REPORT: EPA/600/R-06-120-2006

"Accuracy of flow measurements vary greatly depending on flow conditions at the measurement point and the particular technology used. In general, single point flowmeters are not as accurate over the entire range of flows. Depending on the assumed flow profile, errors can exceed 25% of the true flow rate under poor conditions. THE MULTIPATH INSTRUMENTS MAY HAVE ERRORS AS LOW AS 1 TO 3% OF THE TRUE FLOW RATE."

ASTM D-5389: SECTION 13.1.3, REF. 2

" Cross-flow error due to off axis flow velocity components may be the largest source of errors for a single path velocity measurement. IF TWO CROSSED PATHS ARE USED AND THE OUTPUTS AVERAGED, FOR PRACTICAL PURPOSES, THIS ERROR IS ZERO."

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