WRc DEVELOPMENTS IN DOPPLER FLOW MONITORING FOR LARGE DIAMETER SEWERS

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Introduction

The currently available flow monitoring packages used to gather data for flow survey applications are derived from the work at WRc. Originally only depth information was recorded using dipping probes, bubblers and pressure transducers. To infer flow from this measurement other data on gradient, roughness and cross sectional area was used and sites were selected where free flow was likely.

However, it became apparent from the processing of the level data collected that some means of confirming free flow was needed. This is where the requirement for velocity measurement originated.

The alternatives which could be easily used in temporary installations were limited to electromagnetic devices and ultrasonic devices using the doppler effect. The e.m. was quickly abandoned due to problems with the fouling of the electrodes and an existing clamp on doppler device was modified to work in the form of the now familiar 'mouse' which also incorporates the pressure transducer for flow depth and surcharge measurements.

Once velocity data was being collected by the flow monitor ways of using this information to apply velocity/area methods were established. Under good hydraulic conditions, and with some types of liquor, reasonable results were achieved, i.e. the level based calculations, the model and the velocity area methods agreed well enough. This has led to the very crude velocity measurement being used for velocity area calculations under all conditions.

Scattergraph techniques have been developed to assess the quality of the flow measurements thus derived. In general the technique works well enough for small sewers with fairly dirty liquor. The reasons for poor accuracy of some of the flow measurements made with the existing monitors have been postulated many times and include: varying velocity measurement point as the liquor changes, limitations of the simple signal processing electronics, poor stability in level measurement and errors in cross sectional area assumptions. This presentation will deal with the work of WRc on improving these flow measurement in large sewers and in less ideal liquors.

New Development Work

A user requirement was written as a target against which to assess the potential and achieved performance of new techniques. The important parameters as far as new velocity sensors were concerned were velocity $\pm$ 6m/sec, with direction indication and pipe size 250mm to 2.5m. The liquor would vary from aerated storm water through to domestic sewage to clean groundwater flows. An accuracy of $\pm$ 3% was suggested.

To attempt to meet this accuracy requirement some form of velocity profiling or

averaging is required. Velocity averaging by time of flight acoustic techniques were initially eliminated because of the installation difficulties and the uncertain performance in aerated liquors. Hence the requirement seemed to be for a development of the doppler system to include some spatial resolution.

Range Gating

The most convenient way to gain spacial resolution is by means of range gating, i.e. sending a burst of ultrasonic energy and only using the echos from around a set time delay. This technique is well established for river and tidal flow mapping, blood flow monitoring, and is used for wind measurements in the lower boundary layers of the atmosphere. Hence WRc placed a research contract with a university to apply these techniques to sewage flow. The results were unconvincing due to two problems. Firstly the signal processing technique used to produce the effect of range gating did not have a very wide dynamic range and hence large signals from flow near the mouse masked the weaker signals from further out in the liquor and more fundamentally there is a restriction on the maximum doppler frequency which can be measured at any given range from the mouse. This limits the maximum measurable velocity to 0.6m/sec at 0.5 metre from the transducer. Profiles were successfully plotted in this region of velocity and range using an inlet channel at STW. The problem is overcome for river and tidal flow since lower carrier frequencies are used at longer ranges. The literature on sonar and radar signal processing covers this problem well for a few identifiable steadily moving targets but it is a speculative research project to apply these techniques to a collection of large numbers of turbulently moving targets as in sewage flow.

Geometrical Array and FFT System

The alternative method of defining whereabouts in the flow that a velocity measurement refers to is to arrange the geometry of the transducers so that the transmit and receive beams only cross in predictable positions. To achieve this one transmit transducer is used with two, three or four receive transducers.

The receiver electronics is multiplexed between the receive transducers and is based on a fast fourier transform (FFT) technique. This technique analyses the doppler returns into all the constituent frequencies and is the optimum signal processing approach under noisy conditions or with very weak returns from clean liquors. Instruments using this technique are now commercially available from U.S.A. companies as clamp on systems for closed pipe flow.

Arrays have been built with mountings for three and four transducers and used with a four channel receiver unit to record the doppler signals with a four channel tape recorder. These signals were then analysed using laboratory instruments. Gathering data has proved to be the most difficult part of the exercise. The results have been referred to velocity measurements made with a hand held e.m. positioned in the measurement volumes.

The current state of the project is that a prototype array suitable for production has been designed and assembled and the electronic design for the new FFT based digital signal processing electronics is underway. Field tests using the tape recorder and laboratory based analysis equipment are continuing

to develop the software algorithms to run on the new electronics.

The initial results are promising and a velocity measurement repeatable to a few percent should be practical for a new monitor based on the transducer array and FFT processing.

Further Developments

When the velocity profile of the sewer flow can be estimated to an accuracy of a few percent it remains to be able to calculate the sewer cross section to a similar precision. For large, often old, sewers the outline below the normal water level is uncertain and the depth of silt etc. unknown. WRc have developed a short range sonar for the accurate geometrical profiling of submerged sewers which can measure the outline including silt to $\pm$ 5mm.

With this accuracy of cross section measurement then improved methods of depth measurement should be considered, both the below the surface ultrasonic depth gauge and the new generation silicon chip based differential pressure cells could be utilised in the future.

Finally there is a need to find or install, and calibrate, permanent flow meters or structures in the real sewer network to provide references to establish the actual accuracy of flow monitor packages under a full range of liquors and flow rates.

1.2 Development of Doppler Flow Measurement - D Pinkard WRc

K. McGregor - Hydroscan

Pulse Doppler range gating ambiguity is a recognised problem. There exist solutions which are not speculative but still difficult. However, does the effort justify the result?

Intersection beam continuous wave doppler with fixed geometry infers spatial location of velocity at known points. Is this better than existing averaging techniques used in conventional doppler OCFMs? Hydraulic regimes in large sewers change and are non steady. Therefore a fixed doppler system which when installed and calibrated at certain hydraulic conditions could potentially be totally inaccurate if regime changes without sensible integration of velocity array. What research has been undertaken on this?

Ans: As I mentioned in my presentation the existing doppler OCFMs do not necessarily or ever measure the mean velocity in the sewer due to both the acoustic propagation problems and the doppler signal processing limitations. The median range for the ultrasonic returns varies from centimetres to metres depending on the levels of solids and gas present and the simple counting way of estimating doppler flow gives errors of a few percent. Also this simple signal processing scheme limits the range of condiitons, particularly clean liquors, in which the instrument measures the bulk flow velocity rather than the surface ripple effects. Our new system will define where the measurement is taken and work for a wider range of flows.

The new array will not require individual calibration on site and it is intended that the post-processing software will make use of the different velocity results to apply a sensible flow velocity profile equation.

We are at present carrying out work on correlating volume flow to the velocity results, now that the prototype array equipment is operational.

D. Dring - Wessex Water

Developments in measurements of the partial components of flow seem to have reached a plateau. Further improvements seem to herald the law of diminishing returns. If improved velocity measurement (the most difficult variable to measure) is calibrated by E.M. methods, why not channel the research effort into similar "direct" methods of measuring flow instead of tackling the variable which has such implicit inherent difficulties in measuring and defining mathematically?

Presumably electricity supply precludes E.M. at most sites.

Ans: I agree that the ideal is some form of direct measurement of volume flow. However for survey installations in large sewers it is difficult to see how suitable structures could be fitted. Large cross section E.M. flow meters need considerable power and in fact only measure something related to mean velocity anyway. The area measurement is then used to derive volume flow.

Also time of flight systems give good estimates of mean velocity but are not very practical for portable installations.