

**Transient Response Analysis for Fault Detection  
and Pipeline Wall Condition Assessment in  
Field Water Transmission and Distribution  
Pipelines and Networks**

by

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## **Abstract**

Condition assessment of water distribution pipeline assets has been the focus of water authorities for many years. Transient response analysis, including Inverse Transient Analysis (ITA), provides a new potential method for performing specific non-destructive tests that gives much broader information regarding the condition of pipelines than existing technologies. The basic concept involves inducing a transient in a pipeline and measuring its pressure response. The pressure response is theoretically a function of the condition of the pipeline wall (which is the fundamental characteristic related to the propagation of a transient wavefront) and reflections and damping from any fault that may be present. If an accurate transient model of the pipeline under examination can be developed then it may then be possible to isolate particular parameters in it (relating to the wall thickness of the pipeline or faults such as blockages, air pockets and leaks) and fit these to give optimal matches between the model predicted and measured response of the pipeline. This process is often referred to as inverse analysis (and hence the derivation of the name Inverse Transient Analysis).

While a significant amount of numerical and laboratory investigation has been carried out focussing on the use of ITA for leak detection, few field studies have been undertaken. The goal of this research is to determine whether transient response analysis and Inverse Transient Analysis (ITA) can be applied in field situations to provide useful information regarding the condition of pipeline walls and the presence of specific faults such as blockages, air pockets and leaks. Numerous field tests are conducted on large scale transmission pipelines, small scale distribution pipelines and a distribution network in order to obtain a view of the nature of the measured transient responses at each scale and to identify any common characteristics. The capacity of existing transient models to replicate the measured responses is then assessed and they are found to be generally incapable of replicating the field data. Given the physical complexity of field pipelines, and a number of complex phenomena that have been traditionally neglected, this result is not unexpected. The research proposes the development of transient models that can be calibrated to measured responses. These models incorporate mechanisms for including mechanical dispersion and damping

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and follow precedents developed in other fields of engineering in which damping of transient phenomena is significant. Inverse methods are used to calibrate the proposed transient models using the measured field responses. Similar inverse methods are then used to perform transient response analysis and/or ITA to appraise the wall condition of a transmission pipeline and locate and characterise artificial blockages, air pockets and leaks on transmission and distribution pipelines and networks.

## Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give my consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying.

Signature: .....

Mark Leslie Stephens

Date: .....

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## List of Acronyms

AC – Asbestos Cement Pipe  
ARMA – Auto-Regressive Moving Average Error Model  
AVFP – Air Valve/Fire Plug  
BBM – Balmashanner Branch Main  
BSOLVER – Explicit 1-D Method of Characteristics Transient Solver  
CCE – Complex Evolution Algorithm  
CCTV – Closed Circuit Television  
CH – Chainage  
CI – Cast Iron Pipe  
CICL – Cast Iron Cement Mortar Lined Pipe  
DI – Ductile Iron Pipe  
DICL – Ductile Iron Cement Mortar Lined Pipe  
DGCM – Discrete Gas Cavity Model (for discrete air pockets and entrained air)  
DGCUF – Discrete Gas Cavity with Unsteady Friction Calibration Model  
DWI – Drinking Water Inspectorate, United Kingdom  
EPA – Environment Protection Agency, South Australia  
ESTM – Essex to Suffolk Transmission Main  
FSI – Fluid Structure Interaction  
FSP – Foster Street Distribution Pipeline  
FTM – Forward Transient Model  
GA – Genetic Algorithm  
GASB – Governmental Accounting Standards Board, USA  
GPS – Global Positioning Survey  
HDPE – High Density Polyethylene Pipe  
HTP – Hanson Transmission Pipeline  
ID – Internal Diameter  
ITA – Inverse Transient Analysis  
KCP – Kookaburra Court Distribution Pipeline  
MOC – Method of Characteristics  
MS – Mild Steel Pipe  
MSCL – Mild Steel Cement Mortar Lined Pipe

## List of Acronyms

MTP – Morgan Transmission Pipeline  
NETTRANS – Implicit 1-D Method of Characteristics Transient Network Solver  
NE Valve – North Eastern In-line Gate Valve in Willunga Network  
NLFIT – Non-Linear Regression Program Suite by Professor George Kuczera  
OF or O/F – Objective Function following Least Squares Minimisation  
OFWAT – Office of Water Service, United Kingdom  
PDCR-810 – Druck Pressure Transducer  
PRBS – Psuedo Random Binary Signal  
QSF – Quasi-Steady Friction Calibration Model  
SAHARA – Proprietary Acoustic Leak Detection System  
SCE – Shuffled Complex Evolution Search Algorithm  
SCE-UA – Shuffled Complex Evolution Search Algorithm – University of Arizona  
SE Valve – South Eastern In-line Gate Valve in Willunga Network  
SJTP – Saint Johns Terrace Distribution Pipeline  
SW Valve – South Western In-line Gate Valve in Willunga Network  
SZVCM – Spatially Zoned “Viscous” Mechanical Damping Calibration Model  
UF – Unsteady Friction Calibration Model  
UFVHOB – Unsteady Friction and “Viscous” Mechanical Damping Hanson Pipeline  
and Offtake Branch Calibration Model  
uPVC – Non-Plasticised Polyvinyl Chloride Pipe  
USEPA – United States Environment Protection Agency  
Use of word “inelastic” in Chapter 16 equates to “viscous” elsewhere in thesis  
WT127 – Voltage Signal Amplifier