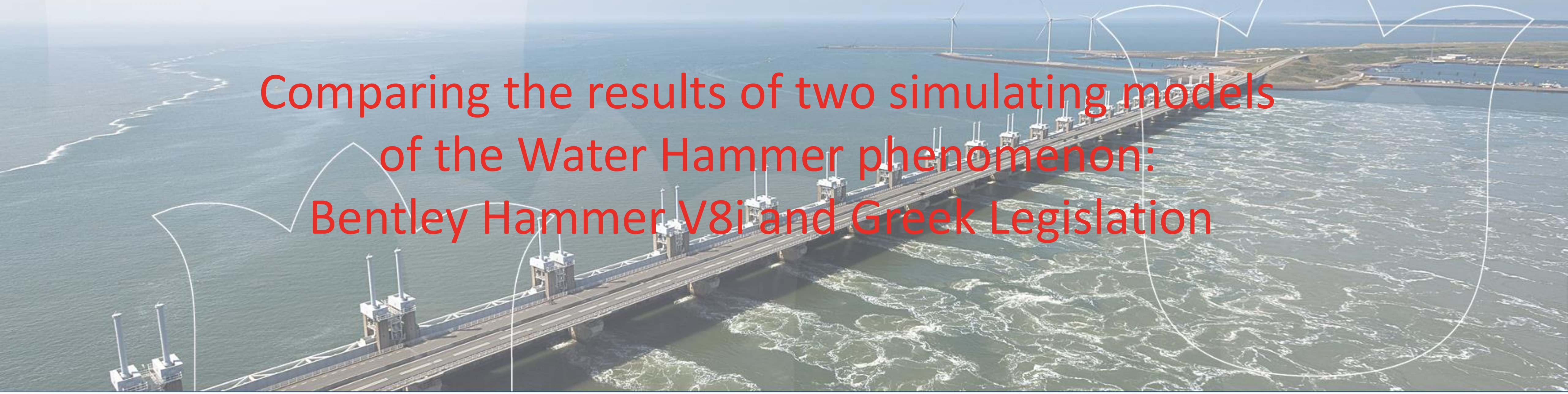
amsterdam

FIG WORKING WEEK 2020

10 – 14 MAY

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT

Comparing the results of two simulating models of the Water Hammer phenomenon: Bentley Hammer V8i and Greek Legislation



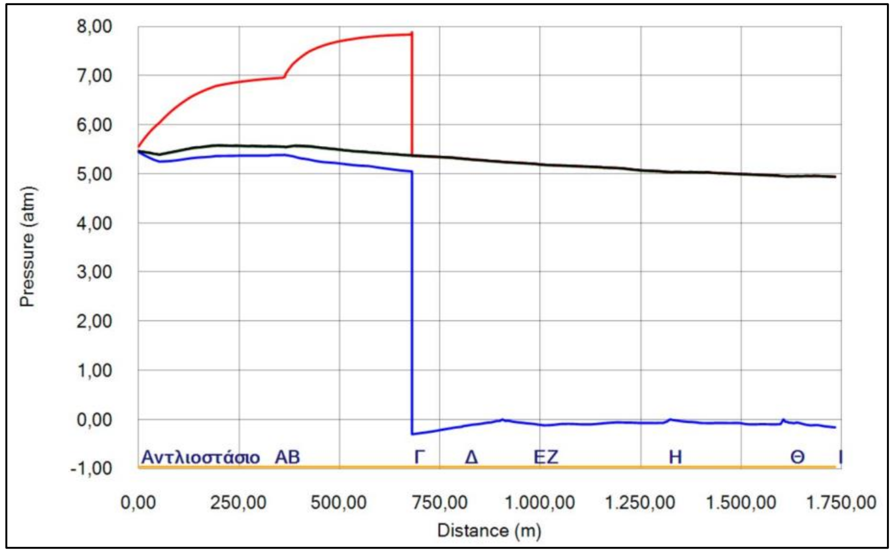
ORGANISED BY FIG Geo-Informatie Nederland kadaster ITC UNIVERSITY OF TWENTE.

PLATINUM SPONSORS Trimble. esri THE SCIENCE OF WHERE

Comparing the results of two simulating models of the Water Hammer phenomenon: Bentley Hammer V8i and Greek Legislation

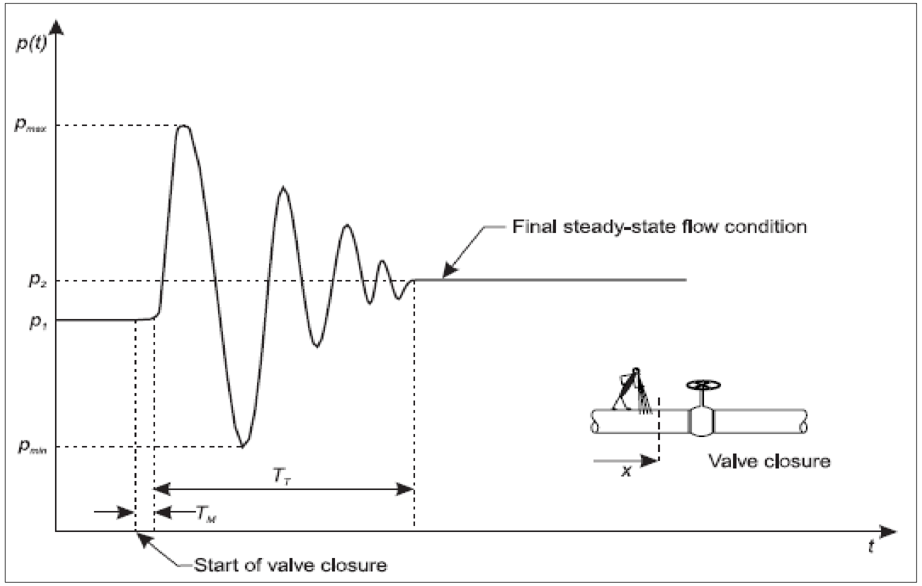
Dimos Theodoros Touloumidis, Nikolaos Charisoudis, Christos Evangelidis and Georgios Papaevangelou

(Aristotle University of Thessaloniki)



WATER HAMMER

- Hydraulic shock or water hammer is a temporary phenomenon that is regarded as the result of sudden changes in discharge of a liquid or gas in a closed piping system.
- Causes of Water Hammer
  - Rapid opening or sudden closure of control valves or pumps
  - Change in the continuity of the network
  - Change of boundary conditions
- Results of Water Shock
  - Cavitation, Suction, Leak, Downgrade water quality, Damage, Vibration
- Prevention techniques and protection devices
  - Techniques: Optimizing pipes' diameter, route, elasticity
  - Devices: Pump bypass layout, protection devices (Air chambers, surge tanks and combined devices)



MATHEMATICAL MODEL

- Method of characteristics: The partial differential equations of motion (1) and continuity (2) into particular total differential equations (3) and (4).

$$\frac{\partial p}{\partial t} + V \cdot \frac{\partial p}{\partial x} + \rho \cdot \mathrm{a}^2 \cdot \frac{\partial V}{\partial x} = 0 \qquad (1)$$

$$\frac{dV}{dt} = \frac{\partial V}{\partial t} + \frac{\partial V}{\partial x} \cdot \frac{dx}{dt} \qquad (2)$$

$$\frac{dH}{dt} = \frac{\partial H}{\partial t} + \frac{\partial H}{\partial x} \cdot \frac{dx}{dt} \qquad (3)$$

$$\frac{\partial V}{\partial t} + V \cdot \frac{\partial V}{\partial x} + \frac{1}{\rho} \cdot \frac{\partial p}{\partial x} = \frac{f \cdot V \cdot |V|}{2 \cdot D} + g \cdot \sin(a) \qquad (4)$$

- The equations can be intergraded to lead to the numerically handled finite difference equations (5) – (8).

$$\frac{dV}{dt} + \frac{g}{a} \cdot \frac{dH}{dt} = -\frac{g \cdot V}{a} \cdot sina - \frac{f \cdot V \cdot |V|}{2 \cdot D} \qquad (5)$$

$$\frac{dx}{dt} = V + a \qquad (6)$$

$$\frac{dV}{dt} - \frac{g}{a} \cdot \frac{dH}{dt} = +\frac{g \cdot V}{a} \cdot sina - \frac{f \cdot V \cdot |V|}{2 \cdot D} \qquad (7)$$

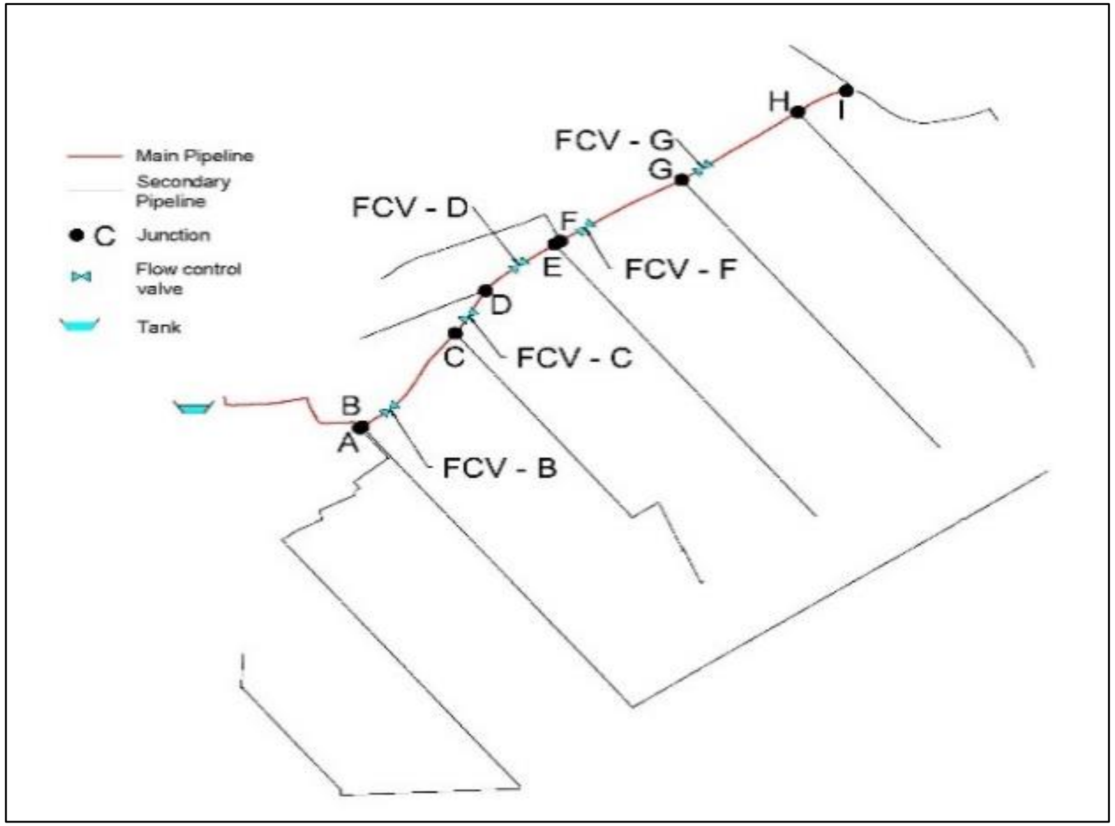
$$\frac{dx}{dt} = V - a \qquad (8)$$

- The Courant – Friedrichs – Lewy condition :

$$\Delta t \leq \frac{\Delta x}{|V \pm \mathrm{a}|} \qquad (9)$$

CASE STUDY: THE PRESSURIZED IRRIGATION NETWORK OF LIMNOCHORI

- One (1) main pipeline and ten secondary pipes with total length about 11 km
- Pipes are polyethylene PE, 12.5 PN and the installed nozzles are providing discharge of 7.5 l/sec
- Five (5) flow control valves on the main pipe
- One (1) tank that implements the operation of pumps



BENTLEY HAMMER V8i

- Software's assumptions:
- Fluid is homogeneous
- Elasticity of pipeline and fluid follows linear pattern
- The flow is unidimensional and fluid is incompressible
- The pipe is full of the fluid
- The average velocity is used
- The head loss because of the viscosity is the same during the steady and the unsteady flow

- Input parameters in the software:

Pipe	Pipes Material	HDPE 3rd generation	–
	Roughness Coefficient **k**	0.01	mm
	Pipe's Elasticity **E**	0.785	GPa
	Factor Poisson **μ**	0.45	–
Fluid	Viscosity **v**	$1.004 \cdot 10^{-6}$	m^2/s
	Acceleration of the gravity **g**	9.98	m/s^2
	Fluid's Temperature **T**	20	ºC
	Fluid's Elasticity factor **K**	2.188	GPa
Calculation Method	Calculation Time step **Δt**	0.025	sec
	Vaporization pressure	Discrete Vapor Cavity	–
	Head loss (steady flow)	Darcy – Weisbach	–
	Head loss (transient flow)	Unsteady – Vitkovsky	–

GREEK LEGISLATION'S FORMULA

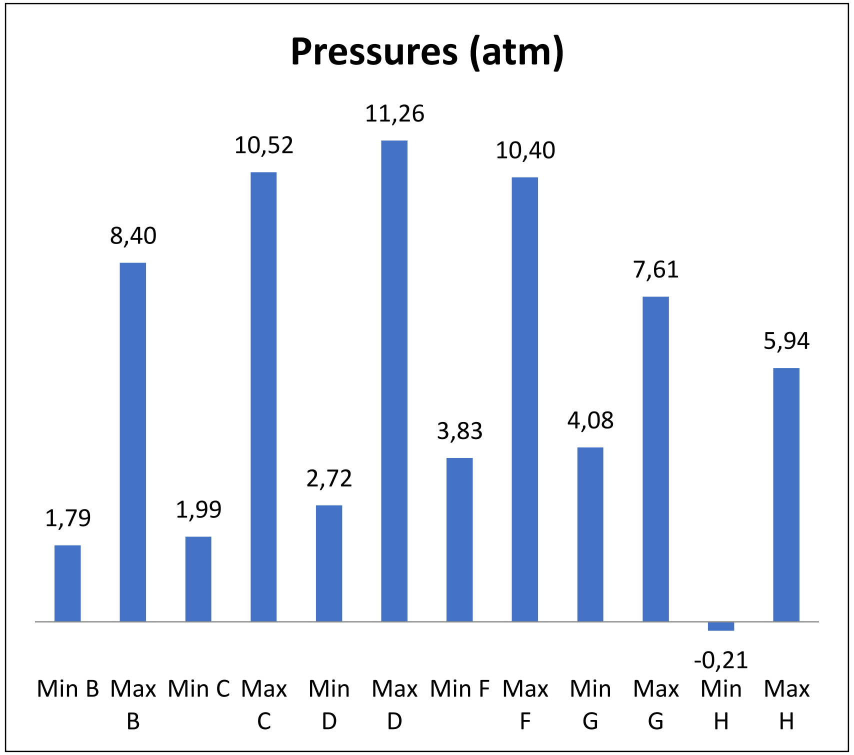
- The circular letter D.22.200/30 – 07 – 1977 that was published by the Ministry of Public Works suggests that formula to calculate the maximum transient pressure that is being developed during the phenomenon is the Joukowski formula.

$$\Delta p = \frac{\mathrm{a} \cdot \Delta V}{g}$$

- Calculated maximum pressure – sudden closure of the valve
- The calculation of the minimum pressures is not available

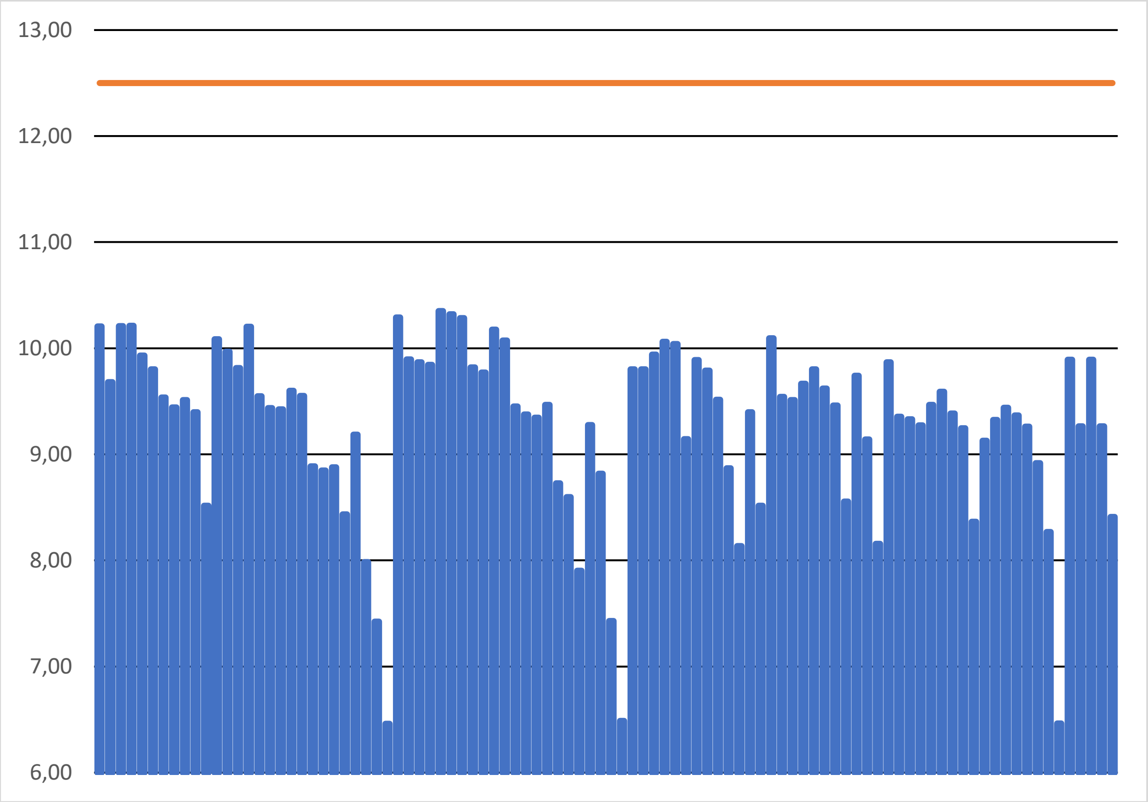
RESULTS – BENTLEY HAMMER V8i

- Implementation of five (5) different scenarios for each of (5) control valves:
  - Valve Close within 0 seconds
  - Valve Close within 30 seconds
  - Valve Close within 45 seconds
  - Valve Close within 60 seconds
  - Valve Close within 90 seconds
- The results of the pressures developed on main pipe during the sudden close of each valve



RESULTS – GREEK LEGISLATION

- Implementation the scenario of the sudden closure of a valve at each pipe
- The results of the pressures developed on main pipe during the sudden close of each valve

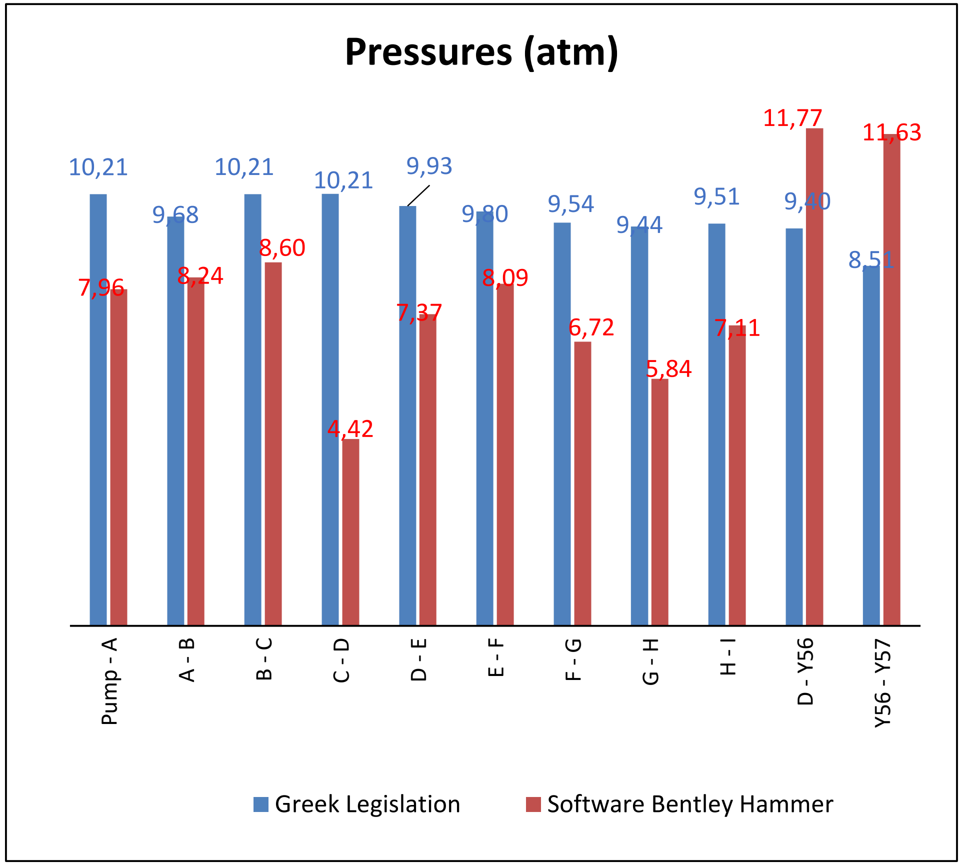


COMPARISON

Comments:

- The Joukowski formula is sufficient for the calculation of the maximum pressures through the main pipe.
- The maximum pressure calculated by Joukowski's formula for specific secondary pipes is being exceeded by the calculated pressures using the software. The statistics of that case are:

Mean	Max	Min	St. Dev	n
(atm)	(atm)	(atm)	(atm)	(atm)
0.670	1.804	0.148	0.590	11



REFERENCES

- Babajimopoulos, C. T. G., 2008. Μη μόνιμη ροή σε κλειστούς αγωγούς, Το υδραυλικό πλήγμα [Unsteady Flow in closed conduits. Water hammer Phenomenon]. Θεσσαλονίκη: Εκδόσεις Τμήματος Γεωπονίας.
- Bentley Systems, 2016. Bentley HAMMER V8i Edition User's Guide. Watertown, Massachusetts: Bentley Institute Press.
- Bentley Systems, W. T. M. C. V. S. D. A. G. W. S. B. E. K., 2007. Advanced water distribution modeling and management. Exton, Pennsylvania USA: Bentley Institute Press.
- Chaudhry, M. H., 2014. Applied Hydraulic Transients. 3η Έκδοση ed. Columbia, SC, USA: Springer.
- KSB AG., 2006. Water hammer. Frankenthal: KSB.
- Papaevangelou, G. E. C. T. C., 2010. A new explicit relation for friction coefficient f in the Darcy – Weisbach equation. Protection and Restoration of the Environment, July, pp. 166-174.
- Tzimopoulos, C., 1975. Μαθήματα υδραυλικού πλήγματος κριού, Θεωρία – Εφαρμογές [Water hammer phenomenon courses, Theory - Examples]. Thessaloniki: Department of Rural and Surveying Engineering.
- Wylie, E. B. L. V., 1978. Fluid transients. Boston, Massachusetts: McGraw-Hill.