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## **Transient Pressure Monitoring in El Paso**

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### ***Abstract***

El Paso Water Utilities, which serves one of the nation's fastest growing metropolitan areas, faced a daunting future in 1989, with dire predictions of water supply exhaustion, a growing water demand, and limited financial resources. The high population growth rate, arid climate, scarce water resources, aging water infrastructure, and growing economy combined to challenge the resourcefulness of the EPWU staff and policy makers. EPWU's asset management program includes the use of advanced condition assessment technologies and the installation of a state-of-the-art SCADA system to monitor and control water facilities. Like many pumped water systems, EPWU's is prone to transient pressures; and to detect the transient pressures, EPWU implemented the most intensive transient pressure monitoring program in the US, which at present consists of 19 continuously monitored stations. The details of this system, as well as the results and benefits are discussed.

### ***The Water System***

The El Paso Water Utilities Public Service Board (the "Utility") recognizes it exists to serve a large population situated in an arid climate and has been aggressively planning for the future to insure an adequate long-term water supply. Major steps taken include passing a stringent water conservation ordinance, establishing a rate structure designed to encourage conservation, completion of a comprehensive Water Resource Management Plan, and the development of a Drought and Water Emergency Management Plan while continuing to increase reliance on the recycling of wastewater. The Utility is also expanding development of surface water supplies (a renewable source) to decrease demand on ground water aquifers. The Utility operates 160 wells, 70 reservoirs, 50 booster pump stations, two surface water treatment plants, one desalination plant, three arsenic treatment plants 11 wellhead reverse osmosis treatment units and over 2,400 miles of pipelines. The Utility also operates 7 reservoirs, 8 pump stations and 26 miles of pipelines comprising the reclaimed water system.

The Franklin Mountains divide the City but water supplies are geographically spread throughout. Historically, 40 percent of the annual usage has been from the Hueco Bolson aquifer which extends from Southern New Mexico, through east El Paso and into Mexico. About 15 percent of the historical annual usage has been from the renewable Mesilla Bolson aquifer west of the mountains. A further 45 percent comes from the Rio Grande. The mountainous terrain has

created the need to separate the water distribution system in to 21 major pressure planes and 35 minor pressure planes. Water is pumped as many as six times from the river elevation to the upper system reservoirs.

The Utility's 40 million gallon per day (MGD) Robertson/ Umbenhauer surface water treatment plant, originally built in 1943, is centrally located in the City. The second surface water plant, the Jonathan W. Rogers surface water treatment plant, with a capacity of 60 MGD, started production in early 1993. It is located further downstream to serve the City's eastside and expanding lower valley area. Together, they produce 100 MGD, which represents approximately 45 percent of total annual demand. Both surface water

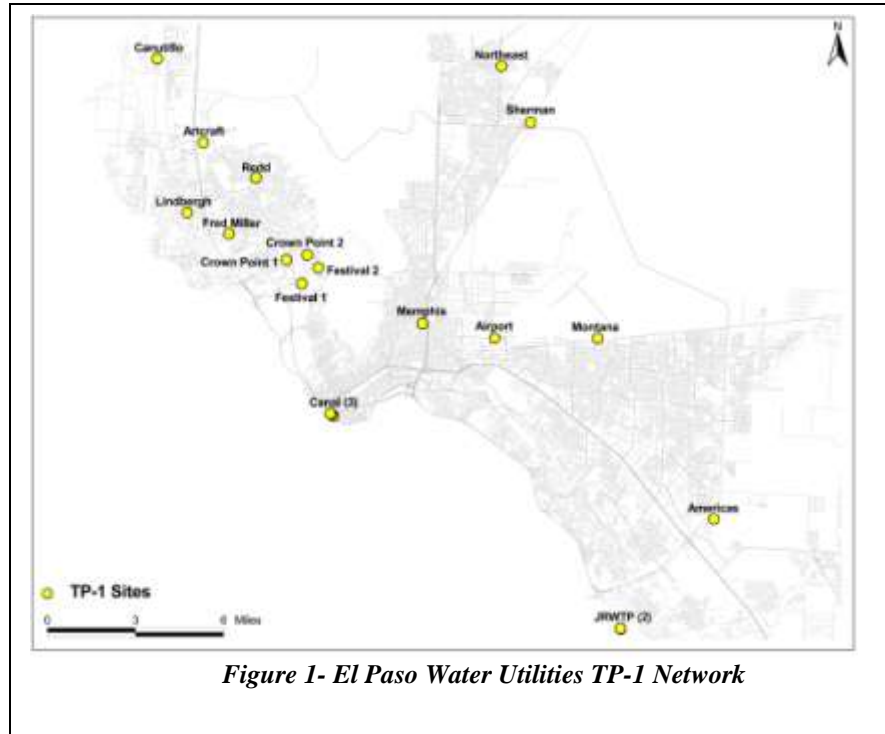


Figure 1- El Paso Water Utilities TP-1 Network

treatment plants operate during the seven-month irrigation season when Rio Grande Project water is available. However, the Utility is developing a plan to obtain river water throughout the year. Water demand for the Utility was at 203 gallons per person per day (gpcd) in 1989 prior to institution of an aggressive water conservation program, but has been declining rapidly since. The current level is less than 140 gpcd.

In 1995, the Public Service Board was designated as the Regional Planner for El Paso County by the State Legislature. This has resulted in a coordinated approach in developing water resources for this region. In addition, the Public Service Board is actively pursuing joint water resources planning with several New Mexico entities. One of the Utility's long-term water management plans is the El Paso-Las Cruces Regional Sustainable Water Project. This project is a unique regional cooperative effort to ensure that there is a reliable water supply to protect the economy, environment and quality of the life for the residents in the region bordering the Rio Grande River. The goal of the Project is to provide greater utilization of Rio Grande surface water, to better protect the quality of ground and surface water; to preserve the Hueco and Mesilla ground water bolsons (basins), to implement a year-round delivery system of surface water, and to increase surface water supply through efficient delivery and water treatment.

A number of measures have been taken by EPWU to manage and monitor their extensive water system assets, and this paper will focus on one of those measures – probably the most intensive system of transient pressure monitoring systems in the world today. This system presently

consists of 19 installed stations which monitor continuously to detect and record pressure transients at critical points in the EPWU water system.

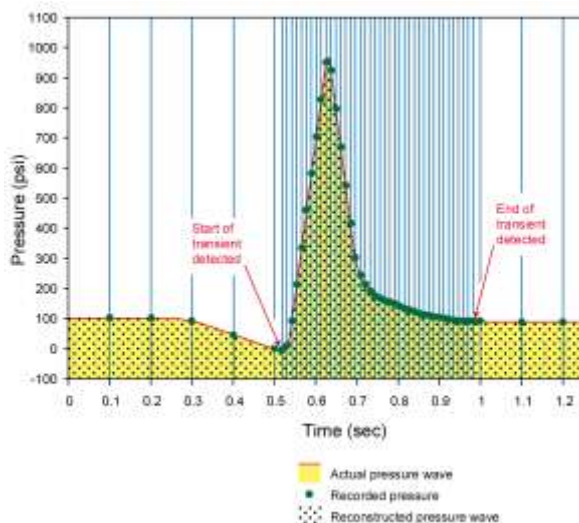
### ***Technical Discussion of the Transient Pressure Monitoring Program***

Transient pressures are variously known also as “surge” or “water hammer” events, and are the result of a sudden change in velocity in the liquid within a pipeline. The term “water hammer” is reserved by some to denote those transient events that include negative pressures, cavitation, and collapse of the cavitation vacuum. Traditional methods of detecting and recording transients include graph recorders and more conventional digital data loggers.

Pressure changes are a normal part of pipeline operation and are incorporated into a pipeline design. As long as these surge events are within the pipeline design, they are not of concern. In monitoring for transients, however, the events that will be of concern to us are those that:

- ✓ Exceed the allowable design pressure of the pipe material
- ✓ Vary significantly from hydraulic model prediction
- ✓ Cause negative pressures
- ✓ Are not explained by normal pipeline operations
- ✓ Show a fluctuating, pulsating, or unstable pressure

Digital technology has enabled the development of a system that is capable of monitoring over extended period of time in a “snoozing” mode, recording background pressure at any interval desired by the user, yet detecting and recording any transient in detail. This system, the TP-1 Transient Pressure Monitoring System, is very busy even in the “snoozing” mode, statistically analyzing the pressure data, which has been digitized at up to 1 kHz. It continuously computes a running average, and when a pressure is detected that differs significantly from the average – in other words when a transient is detected - alarm clock that goes off that “wakes up” and records all data at another user-set rate up to 100 Hz. This continues until the transient has passed, at which time the system goes back to the “snoozing” mode. The concept is shown graphically in Figure 2.



*Figure 2 – The TP1 Transient Pressure Monitoring System Concept*

The TP-1 Transient Pressure Monitoring System is comprised of a controller or signal processor, a pressure transducer, and a communication device such as a hand-held PDA (Personal Digital Assistant). One of the El Paso installations is shown in Figure 3.



Figure 3 – TP1 Transient Pressure Monitoring System Installation

The TP-1 was under development for nearly 2 years, was first deployed in July 2004. Since then it has been installed on a variety of projects, all of which have been to diagnose problems where transient pressures have been suspected to occur. A graphic depiction of a water hammer event is depicted in Figure 4, illustrating the capabilities of the TP-1 system.

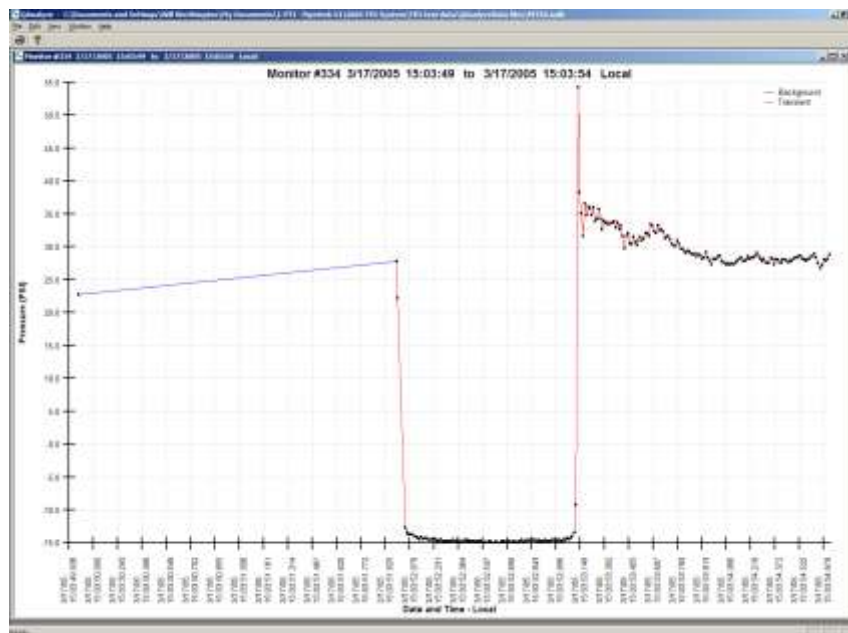


Figure 4 – Five-second graph showing water hammer event

This figure depicts an event produced by the Advantica physical model used for instructional purposes, and shows (in blue) an operating pressure of 25 psi, with a sudden drop of pressure to roughly one atmosphere (minus 14.7 psi) following the sudden closure of a solenoid-operated valve immediately upstream of the transducer. The pressure remains at one atmosphere (minus 14.7 psi) for 1.13 seconds during which time the water vapor “bubble” is visible in the physical model. Upon the collapse of the bubble, a positive transient momentarily rises to 55 psi. This momentary rise has duration of 0.05 seconds, from minus one atmosphere to the return to normal operating pressure.

***Data Management and Review Methods***

Pressure data is recorded in digital form within the 23 megabyte memory of the TP-1, which at optimum recording settings will hold several months of data. This data is normally collected wirelessly from the 19 recording sites semi-monthly by EPWU personnel, and is transmitted to Pipetech International for review. Although EPWU has the capability of accomplishing the data review in-house, a timelier and more convenient review is provided by the vendor. Data is deleted from the TP-1 field units once it is uploaded and the uploaded file storage is confirmed. Occasionally an event will occur that warrants a more immediate review, such as a pipeline break. In such an instance, the data is collected and analyzed as soon as possible.

Review of the data begins with the transfer of the data to a standard Microsoft Database file which facilitates graphical and statistical reviews. The data can also be loaded into an Excel spreadsheet if desired. The review continues with a complete graphical analysis of the data from each site for the period, with a more detailed review of the most severe transients observed at that site. A memorandum of this review is prepared for EPWU that begins with a one-page summary of the data from the 19 sites, and follows with a graphical review of each of the sites. An extract of the summary data is shown in the following table.

<b>TRANSIENT PRESSURE DATA SUMMARY TABLE</b>							
<b>Location</b>	<b>Monitor ID</b>	<b>New Files &amp; size</b>	<b>Review Page</b>	<b>Total Transients</b>	<b>High This Period</b>	<b>Previous High/Date</b>	<b>Comments</b>
Artcraft	4001	282 KB	3, 4	5	158	185 on 8/31/07	OK
Canal Street	1	367 KB	4, 5	3	310	129 on 6/15/07	OK, new high
Festival 2	2	184 KB	11, 12	13	124	131 on 6/30/07	OK
Etc for 19 sites							

The notation “OK” indicates the TP-1 at this site performed normally and valid data was collected throughout the period. Other brief comments here might note that a new high pressure for this site was recorded, or that there was a gap in the data, or that water hammer events were recorded.

The graphic review for each site follows, for example the graph below depicts data from the entire review period for the “Artcraft” site. Steady state pressures are in blue, while transient events are in red. Note the pronounced drop in pressure at the right edge, which might be of interest.

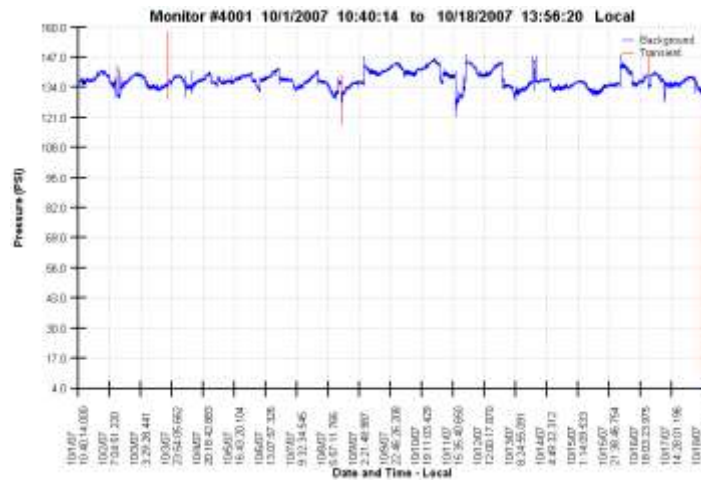


Figure 5 – Graph of 18 days of data

For this transient event, a more detailed graph is readily available as is shown below.

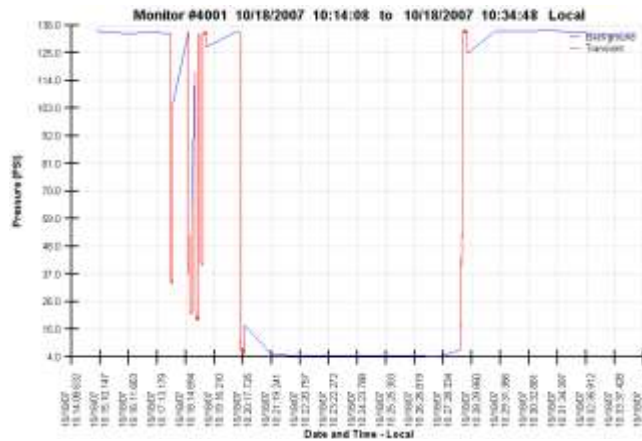


Figure 6 – A more detailed graph showing 30 minutes of data

This event is seen to include a number of lesser transients of a few seconds duration, immediately prior to a drop to 4 psi that lasted for about 10 minutes. Still greater detail on each of these events is possible if desired.

The data review memorandum is then transmitted electronically to the EPWU management by Pipetech International, with a target turnaround of 48 hours.

## ***Results of Transient Pressure Monitoring, Analyses, and Actions Taken***

Prior to the installation of the TP-1 monitoring devices, EPWU had undergone a progressive program attempting to reduce pressure transients without having any real knowledge of where they were occurring or what equipment was causing them. These efforts include the purchase and installation of soft starts on electric pump motor controls, valve actuators hard-wired for long opening and closing times and some globe style check valve installations. Where gas engine drive pumps were installed, they were programmed to start from idle and to ramp up to full speed over a period of several minutes.

In spite of these measures main breaks continued to occur due to transient pressures. The purchase and installation of the TP-1 units allowed EPWU for the first time to correlate transients with actual changes in system configuration. Several important discoveries came from the effort to install TP-1s and the subsequent analysis of the information produced.

For example, in installations where globe-type check valves had been installed to control pressure transients related to pump starts, some TP-1s showed pressure transients were still being produced. Analysis of the data showed significant and regular spikes. After a field visit to the site, it was discovered that the check valves had been replaced at some point with conventional swing checks. Further investigation revealed that maintenance crews routinely replaced globe-type check valves with swing checks because the globe-type were leaking and the swing checks were thought to be maintenance-free.

Pump stations equipped with soft-starts were shown not to be immune to pressure transients. Field investigation revealed that while soft-starts improved performance, that is to say they reduced the number and amplitude of pressure transients, they did not eliminate them. Conversely, pump installations with variable speed drives were shown to be transient free. The variable speed drives were clearly doing a better job of eliminating pressure transients. As a result, nearly all pump systems are specified for variable speed drives. Many soft start installations have been retrofitted with variable speed drives and many pump stations with neither soft starts nor variable speed drives will be so equipped.

All pumping installations with gas engine driven pumps were programmed to ramp pump speed up and down very slowly so as not to generate pressure transients. However, after a series of main breaks on a 24" steel cylinder concrete pipe, a TP -1 unit was installed on a pump station with two large gas engine driven pumps. Immediately, the TP-1 unit showed the pump station was generating pressure spikes significantly higher than the pressure rating of the pipe. The control system strategy showed a start command to the pump would start the pump at idle and ramp up to the full 800 rpm speed over a six minute period of time. The TP-1 showed a significant pressure transient upon starting the gas engine driven pumps. Only after field personnel stood next to the gas engine when the start command was sent through the SCADA system was the mystery revealed. Upon receiving the start command, the mechanical engine controller started the engine and immediately revved up to maximum rpm before dropping back to idle speed and then allowing the PLC to ramp up the engine speed. The mechanical engine control was negating all the programming and safeguards built in to prevent the generation of pressure transients.



## *Conclusions and Recommendations*

EPWU's experience with their extensive network of TP-1 systems has been a great benefit to the agency, providing a unique capability to deal with transient pressures that has not existed before. The program of transient pressure monitoring has revealed or confirmed a number of important aspects of pipeline operation.

- Damaging transient pressures do occur in pipeline systems at unexpected locations and for unexpected reasons and at unexpected times.
- The existing pressure chart and digital recorders are not capable of adequately detecting and recording many of these events.
- Some of these events are triggered by maintenance personnel who do not recognize the consequences of actions they take, such as the substitution of one valve model for the original model.
- Other events occur as a result of installation shortcomings, such as start up sequence of pumps and control systems
- The TP-1 system is a valuable addition to the tools available to pipeline owners, allowing the detection of any transient pressure regardless of duration and random occurrence
- The cost/benefit of the use of the use of the TP-1 has been enormous, and includes reduced maintenance costs and improved reliability.
- The use of a transient detection system such as the TP-1 system is suggested for these purposes:
  - During the commissioning of any new pipeline, commencing with the first fill and continuing until a full range of operational conditions has been monitored
  - Upon the completion of any maintenance activity that involves valves of any kind, or pumps.
  - On a periodic or continuous basis for any pipeline system that is critical in a municipal or industrial water system
  - At the location of any pipeline failure during accomplishment of repairs to disclose any transient pressures that may be occurring at this location, contributing to the pipe failure problem.

The TP-1 system is perhaps the ultimate quality assurance measure available to pipeline owners now with respect to transient and static pressure recording. The accuracy, reliability, and flexibility of the system have proven to be capable of solving the mystery of transient pressures and have been a great asset to EPWU.



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