VISCO-ELASTIC PIPE SUPPORT EFFECT ON WATER HAMMER INDUCED LOADS

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ABSTRACT

The occurrence of a water hammer event can result in large forces exerted on piping components and associated supports/restraints. In order to better understand this phenomenon, a test facility was designed and built to observe the effects of this type of loading on piping systems. Tests were performed at various levels on both a unrestrained and a restrained system. One type of restraint studied was a visco-elastic damper restraint (ANCO, 1982). Results of this restraint's test were evaluated and compared with results from a rigid restraint system. Results show that the damper unit is capable, if properly sized, to reduce pipe component stresses and accelerations, while holding displacements to an acceptable level. Thus such devices are suitable for use in water hammer environments and can yield significant improvements in seismic resistance while allowing for thermal growth.

NOMENCLATURE

cu-ft	cubic feet
ft/sec	feet per second
in.	inch(es)
mph	miles per hour
psi	pounds per square inch

TEST FACILITY

The water hammer test facility allows full scale pipe runs to be subjected to realistically simulated water hammer loading. Illustrated in Figure 1, the system consists of a set of nitrogen accumulators capable of achieving 3,000 psi "head" with a capacity of 4 cu-ft. These accumulators are separated from the water reservoir (a 6-in. diameter, 8-ft pipe) by a burst diaphragm. Once the diaphragm is ruptured, the water reservoir is subjected to an impulse load which accelerates the water through the test specimen.

At the test specimen termination, one of two conditions exists. First, the exit area can be reduced, which requires that the moving water "slug" impart its momentum to the specimen as it forces itself through the reduced exit. An alternate condition can be obtained by sealing the exit and filling the entire test specimen with water prior to diaphragm rupture. This condition, termed a "hard test", simulates a pressure pulse traveling through a filled pipe, similar to a rapidly closing valve in a moving water stream.

TEST SPECIMEN

Figure 1 also details the test specimen used to observe the effects of the pipe restraints. It consists of a 6-in. diameter, carbon steel, Schedule 40 pipe with two long radius elbows. The exit area is reduced from 6 in. to 3 in.

The test specimen is instrumented with strain gages, accelerometers, displacement transducers and pressure gages. This instrumentation allows one to correlate the various measurements to the movement of the water slug or pressure pulse through the test specimen.

Supports are provided to carry the system dead weight, yet allowing for freedom of movement in the horizontal plane.

PIPE RESTRAINTS

First, a test was conducted using a rigid strut support. The support used was a Grinnell Model 640-2 strut. This was used as a baseline to observe strut loads in order to size the damper unit.

Once the loads were determined, an appropriate damper unit was chosen and installed. Known as the GERB visco-elastic pipe support, it is illustrated in Figure 2. Its operation is based on the movement of a plunger through a highly viscous bituminous fluid. This fluid is contained in a reservoir that is attached to ground. The plunger is attached to the pipe run and is set in motion by pipe displacements. Movement of the plunger through the fluid produces shear loads that resist pipe motion. Prior testing has shown pipe damping to increase to as much as 50% of critical due to introduction of the damper unit (ANCO, 1982 and Stoessel et al., 1987).

The damper unit is frequency dependent, as shown in Figure 2. It also allows thermal expansion movement and is relatively maintenance free due to the absence of moving parts. It has been approved for use in nuclear power plants in West Germany (TUEV, 1984). Its location in the piping run is shown in Figure 1.

TEST PROGRAM AND TESTS RESULTS

The first series of tests were performed on a similar test specimen consisted of an unrestrained system subjected to various pressures up to 1,700 psi. Both hard tests and water hammer tests were performed. A high level test was performed with the visco-damper in place.

This series of tests showed the enormous destructive force of a water hammer event. Displacements measuring feet and elbow strains exceeding 10,000 microstrain were observed during a 1,700 psi test. It was estimated that the water slug was traveling in excess of 200 mph during this test. The visco-damper test, conducted at a lower level than 1,700 psi, resulted in rotation of the pipe clamp and a separating of the two parts of the damper unit. The cause of this was due to improper sizing of the damper unit (too low a load rating). However, the damper unit was not damaged, except for its canvas dust cover.

The next series of tests, of interest in this discussion, consisted of various pressures in the hard and water hammer configuration. The tests comparing the rigid and visco-damper restraints were performed at 100 psi. This low level was chosen for reasons of available visco-dampers and to maintain elastic level loadings.

A summary of the test results for the two different restraints is presented in Table 1.

Table 1

TEST DATA MAXIMUMS

		Maximum Values	
	Elbow Strain*	Pipe Acceleration**	Pipe Displacement†
Rigid Strut	100	7.5	.10
Visco Damper	70	5.9	.30

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* In microstrain at first elbow.
** In g's at pipe exit, x direction.
† In inches at restraint point, y direction.

DISCUSSION OF TEST RESULTS

First, a general discussion of the test is presented. Figure 3 shows typical acceleration time histories for the test with the visco-damper. By observing the pressure gages' time traces, the various loadings of the specimen during water slug travel can be ascertained. Figure 3 includes notations of the times at which maximum pressures were recorded at each pressure gage. It is clear that loading occurs as the water slug moves through the elbows as well as when it reaches the restriction at the end of the specimen. Elbow loading is due to change in momentum as the moving water is forced to change direction. In fact, the maximum acceleration occurs when the water passes through the second elbow.

From the pressure readings, an estimate of the average velocity of the water can be made. For these 100 psi tests, the estimated average velocity was 90 ft/sec or about 60 mph.

As for the particular values reported in Table 1, the visco-damper unit appeared to reduce the peak elbow strain and the peak acceleration at the specimen end. Specimen displacements near the restraints were higher with the visco-damper (as expected) but were still within an acceptable range. It should be noted that the estimated movement of an unrestrained system, based on the previous test series, would have been several inches for a 100 psi test.

Comparing the acceleration time histories of the two tests shows that due to system flexibility and high damping, the visco-damper system underwent less cycles of occillations than the rigid strut system.

No damage was visibly observable during and after the visco-damper test.

CONCLUSIONS

These tests show that a visco-damper can provide protection against water hammer loadings when properly sized to handle the anticipated peak loads. Its performance is at least as good as a rigid strut and is much better than no restraint. Though these tests were performed at low levels, the visco-damper, if properly sized, should follow the same trend as shown in Table 1, since its performance improves with velocity. With its other inherent benefits, such as thermal expansion allowance and seismic protection, it may clearly be beneficial in any design requiring water hammer recognition.

REFERENCES

1. ANCO Engineers, Inc., "Experimental Seismic Study of a Modified TZ Piping System in Three Configurations - Damper Only, Rod Restraints Only, No Damper/No Rods," Report No. R2026.10, October 1982.

2. TUEV Hannover, W. Germany, "Pruefbescheid zu der TUEV Eignungspruefung von Viskoelastischen Schwingungsdaemfern der Fa. Gerb, Berlin," (Qualification Tests by TUEV for Visco-Elastic Dampers Made by Gerb, Berlin), Report No. T08-84-01, March 1984.

3. Stoessel, J.C., et al. "Experiments on a Novelle Piping Restraints," 1987 ASME PVP Conference, San Diego, California.

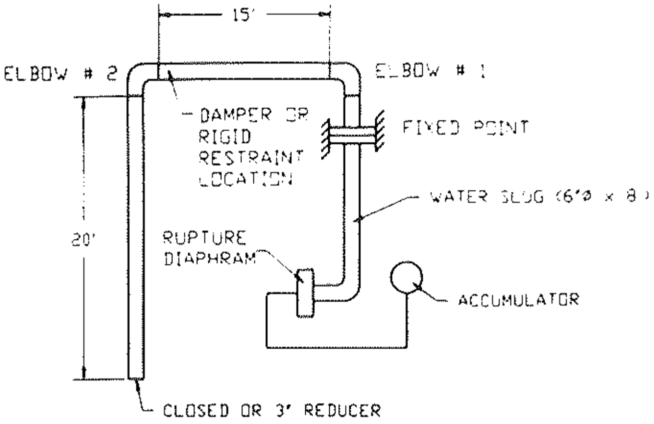
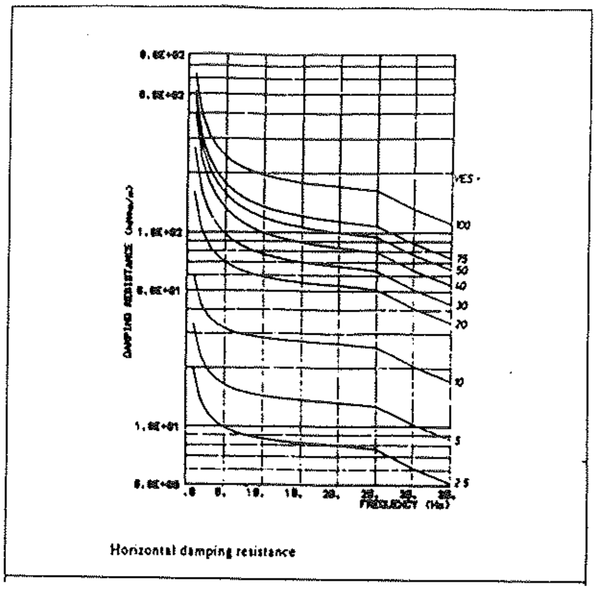


Fig. 1 Water hammer setup



Horizontal damping resistance

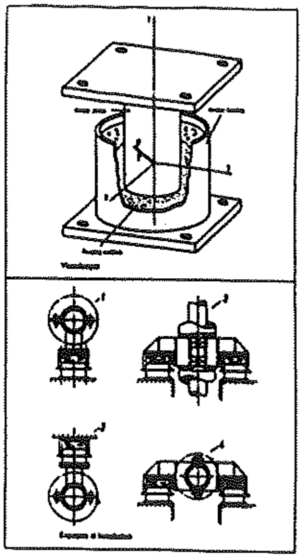
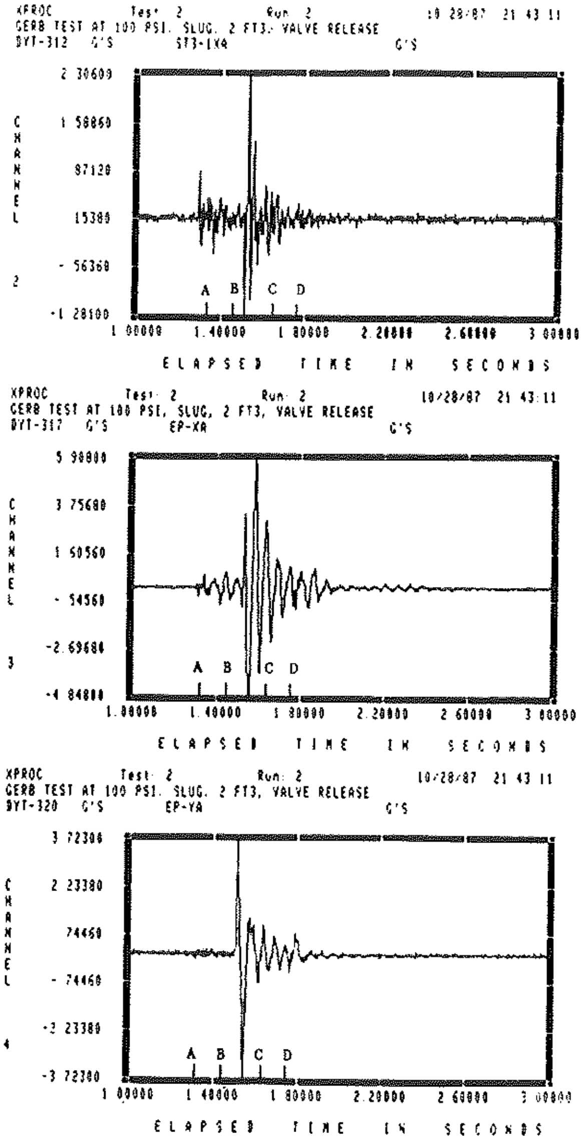


Fig. 2 Visco-elastic damper (VED)



A - Fixed point.
B - At end of first elbow.
C - Start of second elbow.
D - At exit.

Fig. 3 Typical acceleration time histories visco-damper test