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UNITED STATES GOVERNMENT

HYDRAULICS BRANCH OFFICIAL FILE COPY

Memorandum

Memorandum

Head, Hydraulics Research Section

1 Charles Duren

FROM : J. Charles Givens

Denver, Colorado DATE: August 13, 1975

SUBJECT:

Test of Clayton Automatic Valve 50G-01 20 to 200 lb/in for Water-hammer Relief Applications - Open and Closed Conduit Systems Program

Introduction

This particular relief valve was proposed for application to water-hammer problems of an irrigation district. The water-hammer could occur when fire fighting equipment is connected to the irrigation system. The fire fighters use quick closing valves on lines straight off the system to a valve at the nozzle, or through a pumper that has the ability to come on the line in a short time. The relief valve was tested to see if it would react quickly enough to a pressure surge to prevent damage to a pipeline. The results were compared to a dead ended line, and to a line with a standpipe.

The main component of the test valve is referred to as the relief valve. The pressure control valve which is referred to as the control valve is used to adjust the relief pressures.

Test Facility

The High Head Pump Facility in the Hydraulics Branch was used to produce the required test pressures. These pressures included the calibration of the relief valve through the manufacturer's range of operation of 20 to 200 lb/in, and the waterhammer tests at 90 lb/in.

The system for the testing was set up on the end of a 1-inch line on the facility downstream from a venturi, but upstream of a multijet sleeve valve and chamber. This arrangement allowed the operator to set the line pressure from the control board. A 1-1/2-inch tee was installed at the end of the 5-foot-long 1-inch line. The relief valve was in line with the 1-inch line and a quick closing valve was placed 90° to the 1-inch line (see figures 1 and 2). Modifications included replacing the relief valve with a plug (see figure 1, detail A, and figure 3). A standpipe was placed between the tee and the quick-closing valve (see figure 1, detail B, and figure 4). The standpipe included a 1-1/2-inch-diameter pipe with a gage glass for determining the length of the air column in the pipe. An external air supply was connected to the standpipe to adjust the length of the air column.

The pressure in the line was adjusted at the control board. The pressure for the water-hammer system was measured in the 1-inch line 1 inch



upstream from the tee. The pressure transducer was connected to a Sanborn series 350 chart recorder. A Kistler transducer (0 to 200 lb/in²) was used to calibrate the control valve on the relief valve. When the first tests were made the Kistler's range was not adequate. A Pace (0 to 500-lb/in² range) transducer was substituted and used throughout the water hammer tests.

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The Clayton Automatic Valve was calibrated in the range 20 to 200 lb/in. The relief valve was set to zero by backing out the adjustment bolt on the control valve until the bolt could be turned by hand. The bolt was then screwed in until it touched the spring. The pressure was brought up to 30 lb/in. The bolt was tightened until the leaking stopped, then it was loosened until leaking started. The line pressure was increased at 10-lb/in increments using the same procedure for determining relief pressure versus number of turns from zero (see table 1 and figure 5).

For the water hammer tests, the line pressure was set at 90 lb/in². The relief valve was set to relieve at line plus 10 percent or 99 lb/in². The quick-closing valve was opened to let water flow freely to the atmosphere for 10 to 15 seconds, then slammed shut. The same procedure of setting line pressure and operation of the quick-closing valve was used for the relief valve, the plug, and the standpipe.

Results

With quick closure of the valve:

- a. The pressure surged to $445 \, \mathrm{lb/in}^2$ with the relief valve in place (see figure 6 for pressure recordings).
- b. The pressure surged to 450 lb/in² with the relief valve replaced by a plug (see figure 7 for pressure recordings). Note that secondary pressure surges occurred at values approximately at half of the maximum peak.
- c. The pressure surged to 150 lb/in² with the standpipe in place (see figure 8 for pressure recordings). During the free flow condition the length of the air column was adjusted at 24 to 26 inches in the 36-inch standpipe.
- d. Calculations show that a peak of 450 $1b/in^2$ was possible. The 450 $1b/in^2$ maximum depends on the method or location

of study. A range of 420 to 2,609 lb/in² was calculated (see appendix for calculations).

e. For comparison a test was made with the standpipe installed and the quick closing valve was closed over a longer period of time (3.6 s). The pressure surged to maximum of 104 lb/in. This maximum was 15.6 percent over the line pressure of 90 lb/in (see figure 9 for pressure recordings).

Conclusions

The relief valve does not react quickly enough to handle the waterhammer that occurs from rapidly closing a valve. The standpipe appears to be a solution. The size of the pipe and method of keeping a specified amount of air in the standpipe should be determined by the design group involved.

Copy to: 224 (Warden)

410 (Yocum)

1530 1532 250 PROCEDURE: The High Head Pump Facility was used because of the high pressures involved. The pressure was increased in 10-1b/in increments. The valve was adjusted until leaking stopped, then the bolt was loosened until leaking started. The amount that was leaking was continuous and carried out 2 to 3 inches horizontally before dropping. The zero point for adjustment was determined by completely adjusting the bolt out until it could be turned by hand. The bolt was then tightened by hand until it touched the spring.

NOTE: A test was made to check 100-1b/in factory setting. The valve began leaking at 90 lb/in and was full open at 100 lb/in.

Table 1

RECORD NUMBER OF TURNS VERSUS PRESSURE

Trial	. 1	Trial	. 2	Trial	3
Pressure 1b/in		Pressure 1b/in		Pressure 1b/in ²	Number of turns
30*	11/12	30	1	30	1
40	1-1/3	40	1-1/4	40	1-1/3
50	1-3/4	50	1-3/4	50	1-3/4
60	2-1/12	60	2-1/6	60	2-1/6
70	2-1/2	70	2-1/2	70	2-1/2
80	2-11/12	80	2-5/6	80	2-11/12
90	3-1/4	90	3-1/4	90	3-1/4
100	3-2/3	100	3-2/3	100	3-2/3
110	4	110	4	110	4
120	4-5/12	120	4-5/12	120	4-5/12
130	4-5/6	130	4-5/6	130	4-3/4
140	5-1/3	140	5-1/6	140	5-1/6
150	5-1/2	150	5-1/2	150	5-1/2
160	5-11/12	160		160	
170	6-1/6	170		170	
180	6-7/12	180		180	
190	6-1/4	190		190	
200	7-1/4	200		200	

*NOTE: 26 lb/in^2 was lowest pressure available so testing began at 30 lb/in^2 .

7-1654 (7-73) Bureau of Reclamati	on	COMPUTATION SHEET	Fig.
ВҮ	DATE	PROJECT	
CHKD BY	DATE	OPEN CLOSED CONDI	NT STUDY
		GENERIZ LANGUT	OF THET FHEILT
DETAILS			
	250 UP Pump	Rugg	
	FLOW	AT THE	Rugy
	J.	1/2 da ×3'	The state of the s
ressure on		Brertical pir.	
introl Board			1
AGE ST	4		
L	1		/ 25-111
	V=4.71	DETAIL B	PETAIL A
	VIENT	IRI (STAND PIPE)	(P2UG)
	77	\	/
		14" Nipple	
6" line			Jely relief VALVE
		PRESSURE TAP	-12 Tec
			-12" QUICK CLUSING VIL
			12 12181=
		E I"LINE	4
	C	LINE	COUTLET TO ATMOS
			DIA 1.4"
MULTI- JE	T VALVE ASSE	MELY	
	1		
	1		

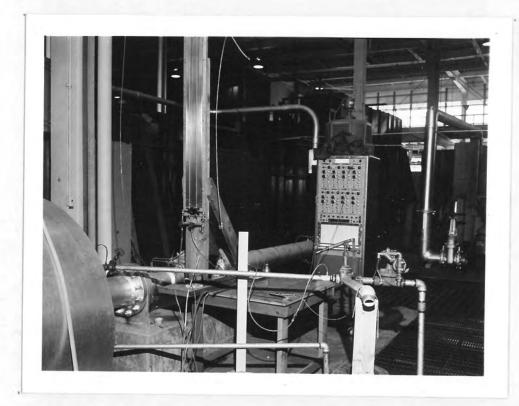


Figure 2. - Test setup with relief valve installed. Photo H-1762-2

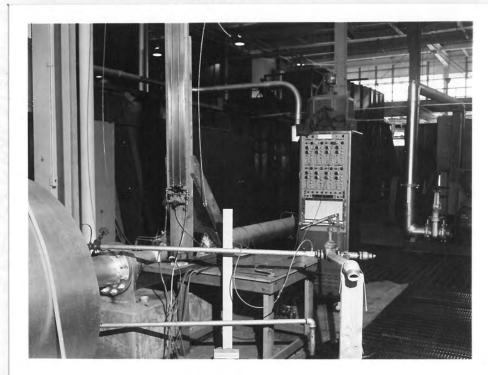


Figure 3. - Test setup with relief valve replaced by a plug. Photo H-1762-3

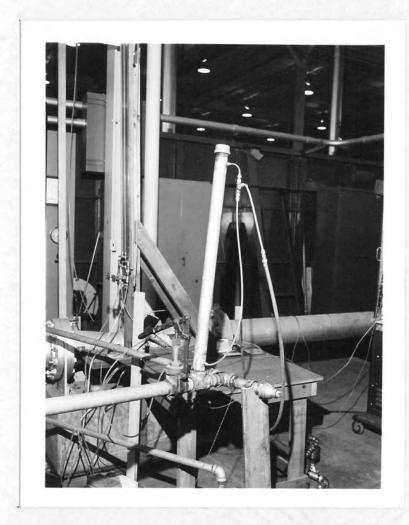


Figure 4. - Test setup with a standpipe installed upstream of the quick-closing valve.

Photo H-1762-4

7-1654 (7-73) Bureau of Reclamation PROJECT DATE SHEET OPEN-CLOSED CONDUIT STINN 4-29-75 GIVENS FEATURE CHKD BY DATE ALIBRATE CLAYTON AUTUMNIC VALVE 506-01 20-200 ZERO SETTING ON SPRING WAS DETERMINED BY TOUCH-THE HIM TOUT THEST TOUCHED THE STRING DETAILS -1-1 190 150 8 110 10 8 8 30 3 0 2 = 2 0 ADJUSTMENT SCREW - NUMBER OF TWENTZULAA

COMPUTATION SHEET

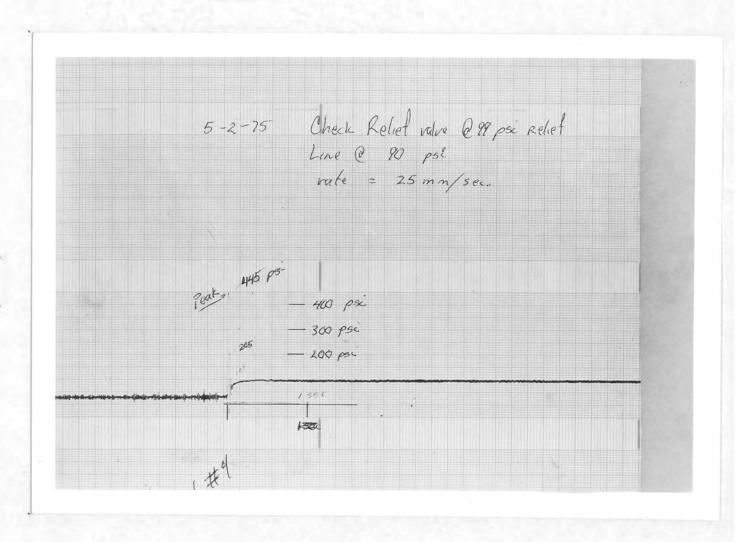


Figure 6. - Pressure rise for quick closure with pressure relief setting of 99 $1b/\mathrm{in}^2$.

5-2-75 NO RELIETE
Line @ 90 psi
Dante of paper = 25 m m/sev 400 psi 300 psi 144 200 psi Figure

igure crosure with pipe plug

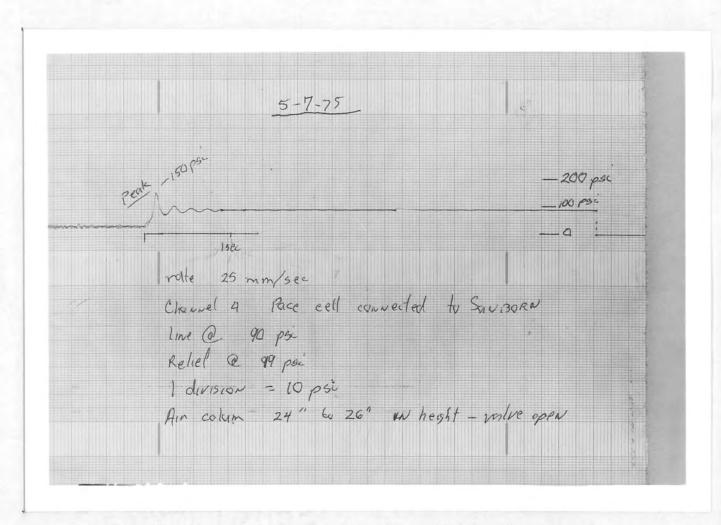


Figure 8. - Pressure rise for air column standpipe in place of pressure relief valve.

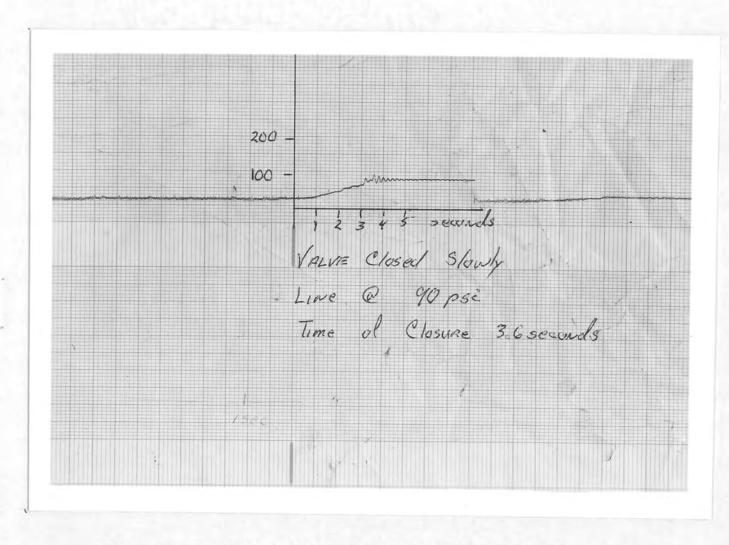


Figure 9. - Pressure rise for slow valve closure with standpipe.

7-1654 (7-73) Bureau of Reclamation COMPUTATION SHEET

Dureau or rectama	cion		
ВУ	DATE	PROJECT	SHEET OF
CHKD BY	DATE	FEATURE	
DETAILS			

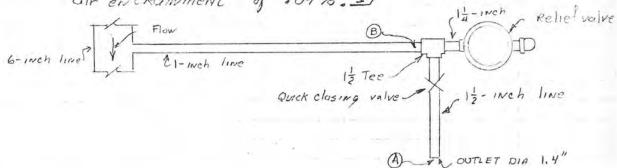
APPENIDIX

COMPUTATION SHEET

ВҮ	DATE	OPEN-CLOSED CONDUIT STUDY SHEET A-1 OF
CHKD BY	DATE	Water corner - measured flow

Gwen: The discharge of the system was determined by measuring the weight of water during an clasped time.

Determine: Water hammer by edecidating a velocity for the measured flow. The velocity of the pressure wave in water a, is equal to 4500 fps for no air entrainment and 1100 fps for on air entrainment of .04%. I



EQUATIONS $Q = \frac{W_2 - W_1}{R}$ t $W_1 = \text{initial wt of tare}$ $W_2 = \text{final wt}$ t = time elasped $P = 62.4 \text{ 1b Ift}^3$ $V_A = Q/A_A$ $V_B = Q/A_B$ $V_A = Q/A_$

H = kay

H = kay

An, An Area of pipe (a) 11 # B + t

k conversion feet of water to psi 14.7/34.0

H = maximum pressure

a velocity of wore in water

g = gravitational constant 32.2 1/sec²

TEST	. Wa	W,	ΔW	t	Q	VA	VB		hamme	or Hyr	psi.
TRIAL	1 b.	16.	16	sec	Al3/sec	H/sec	fi bec	9= 4	500 fps	q = /	100 fps
								+11	HB	HA	HE
1	351	52	299	15	.3194	29.88	58.56	1805.41	3538,31	4411.32	864.92
2	391	93	288	15	.3077	28.78	56.41	1738.95	3408.40	425.08	933.17
3	394	66	328	17	.3092	28.92	56,68	1747.40	3424.72	427.14	237.15
ava						29.33	57.22	1772.18	3457,35	433.20	845.13

1 "Hydraulic Transients" Streeter and Wylie pg. 8 Fig 15

COMPUTATION SHEET

BY	DATE	OPEN-CLOSED CUNDUIT STUDY	SHEET <u>A-2</u> OF
CHKD BY	DATE	Worder hammer eaused by Valocity	under free flow
DETAILS			

Given: Live pressure at 90 psi under static compitions and a line pressure of 25 psi under free flow conditions. (see Fig 6)

Determine: Water Hummer AT points A and B where the water velocity. V = \$\sqrt{23H} \tand H = aV/g where q=1100 \mathref{4500} \frac{2}{ps}.

$$V_{B} = \sqrt{2g h}$$

$$= \left[2(32.2) \ 25 \left(\frac{34}{14.7}\right)\right]^{\frac{1}{2}}$$

$$V_A = \frac{V_A A_A}{A_B}$$

$$H_A = \frac{a V_A}{g} \left(\frac{H.7}{34} \right)$$

$$q=1100 \text{ fps}$$
, $H_A = (1100)(31,45)(14.7) = 464.51 (32.2) (34.0)$

$$\alpha = 1100 \text{ fps}, H_B = 1100(61.66x(14.7)) = 917.71$$
 $32.2 (34.0)$

$$a = 4500 fps, HB = \frac{4500(61.66)(14.7)}{(32.2)} = \frac{3725.62}{(34.0)}$$

ВУ	DATE	OPEN CLOSED CONDUIT STUDY SHEET A-3 OF
CHKD BY	DATE	Impulse Momentum balance
DETAILS		

Given: L = 5-FEET TO QUICK- CLOSING VILVE, The CONDITIONS

AT B OF PREE FLOW P = 25 psi, and for an estimated closing time of .0275 seconds the peak pressure is 445 psi (see Fig 6)

Discussion: The water hammer pressure relationship, H- aV/2 applies only up to the time that a wave is reflected back . 2 The time it takes for the ware to return is determined by the period, 21/a. for a wave velocity a= 4500 the time is .002 sec. for a wave velocity a = 1000 the time is . Ol seconds. The operator of the test estimated the valve classing time of .5 seconds. The test charls showed a peak occuring at a time of .0275 seconds (see Fig 6) The wave has been reflected before the valve has closed and before the pressure surge has had time to build to its theoretical maximum OF 3500 psi. (see COLC. SHEET A-1) This reflected wave counteroct's the initial surge and stops it of 445 psi (see Fig 6). If the relationship of H = aV/g does not apply the change in momentum caused by decreasing the velocity to zero should be equal to the impulse of Force over the time it takes to decreace the velocity to zero This force F is defermined by the area under the curve from time equals zero to the peak pressure. The Impulse is equal Txt where force = } presture times the end area of the pipe. (see F/6 6)

EQUATIONS:

Mass
$$M = W/g$$
 $W = weight of water = Volume × 62.4$

$$V = \sqrt{2gH}$$

$$Momentum = M \times V$$

BY	DATE	PROJECT	SHEET A-4 OF
CHKD BY	DATE	FEATURE	
DETAILS			

IMPULSE MAMENTUM CONTINUED.

$$W = \left[\frac{3}{4} (1)^{2} (60) \right] \cdot 62.4 \frac{16}{43}$$

$$W = 1.702 \quad 16$$

$$V = \sqrt{2gH}$$

$$= \sqrt{2(32.2)} \quad 25 \frac{gy}{14.7}$$

$$M_{\times}V = F_{\times}t$$

 $\frac{1.702}{32.2} \times 61.02 = \frac{1}{3}(445)(\frac{\pi}{4}(1)^2)(.0275)$

3.26 16-sec = 3.20 16-sec agrees

CONCLUSIONS:

The results of the three methods of ealculation support the measured test results. The pressure surge does not attain its theoretical maximum because a combination of a factors. The factors include the possibility of air, friction losses, and the short length of pipe for the test facility.

Form DFC-11 (12-61) Burau of Reclamation

INFORMATIONAL ROUTING

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PAP 325

Menorandum

Head, Hydraulics Research Section

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Denver, Colorado August 13, 1975

J. Charles Givens

Tost of Clayton Automatic Valve 50G-01 20 to 200 lb/in for Water-hammer Relief Applications - Open and Closed Conduit Systems Program

Introduction

This particular relief valve was proposed for application to water-hammer problems of an irrigation district. The water-hammer could occur when fire fighting equipment is connected to the irrigation system. The fire fighters use quick closing valves on lines straight off the system to a valve at the nozzle, or through a pumper that has the ability to come on the line in a short time. The relief valve was tested to see if it would react quickly enough to a pressure surge to prevent damage to a pipeline. The results were compared to a dead ended line, and to a line with a standpipe.

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of study. A range of 420 to 2,609 lb/in was calculated (see appendix for calculations).

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Copy to: 224 (Warden) 410 (Youms) 1530 √1532 250

7-1654 (7-73) Bureau of Reclamati	ion	COMPUTATION SHEET	Fig. 1
ВУ	DATE	PROJECT	
CHKD BY	DATE	OPEN CLOSED CONDU	IT STUDY
CHKD BY	DATE	GENTEPIE LANGUY	OF THST FACILIA
DETAILS			
	250 UP Pump	Rugg	/ a.
	FLOW	12 da x3'	Rugz
	₩	vertical pys	The state of the s
ressure on		(8)	
introl Board			
AGE SI	1		
1	1		/
		DETAIL B	PETAIL A
	VIENTO	(STAMO PIPE)	(P2UG)
	£		
		14" Nipple	
6" line	>	4 1111	Jely relief VALVE
		PRESSURE THE)) ' '
			-12 Tee
			-12" QUICK CLUSING MILV
			2 PIPIE
			^
	0	LI"LINE	COUTLET TO ATMOSP
			4 0.0 1.4
MULTI- DE	ET VALVE ASSE	01/827	
	A	BACK PRESSURE	

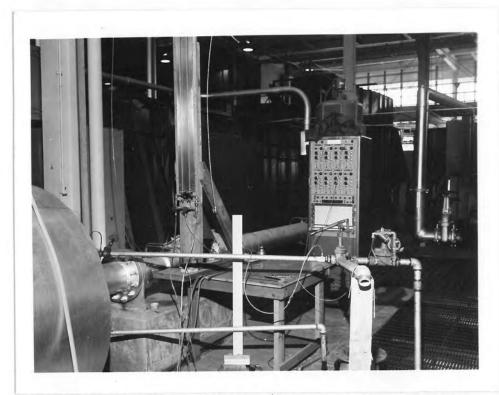


Figure 2. - Test setup with relief valve installed.
Photo H-1762-2

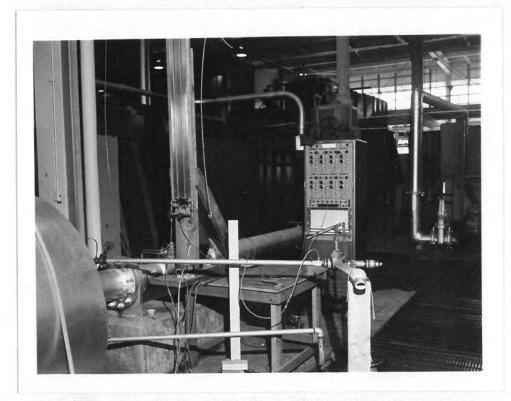


Figure 3. - Test setup with relief valve replaced by a plug. Photo $\mbox{H-}1762-3$

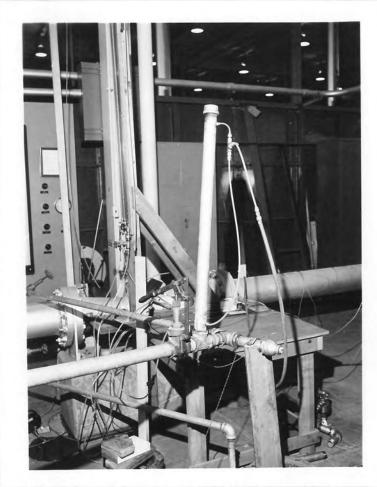


Figure 4. - Test setup with a standpipe installed upstream of the quick-closing valve.

Photo H-1762-4

7-1654 (7-73) Bureau of Reclamation DATE PROJECT SHEET OPEN-CLOSED CONDUIT STUDY 4-29-75 FEATURE CHKD BY DATE PLIBRATE CLAYTON AUTUMNTIC VALVE 506-01 20-200 ZERO SETTING ON SPRING WAS DETERMINED BY TOUCH-THE HANDS THE TRUCKED THE ST 190 160 8 110 210 50 1 12 8 R 110 30 2 0 N 1 5 0 ABJUSTANTANT SCREW - NUMBER OF THENESPLAA

COMPUTATION SHEET

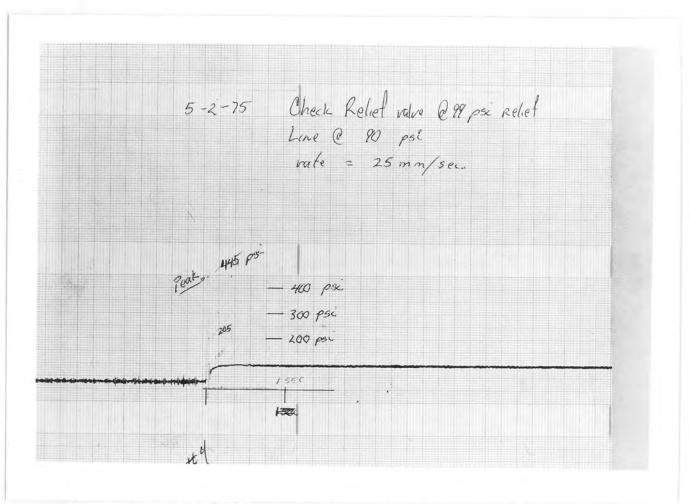


Figure 6. - Pressure rise for quick closure with pressure relief setting of 99 lb/in².

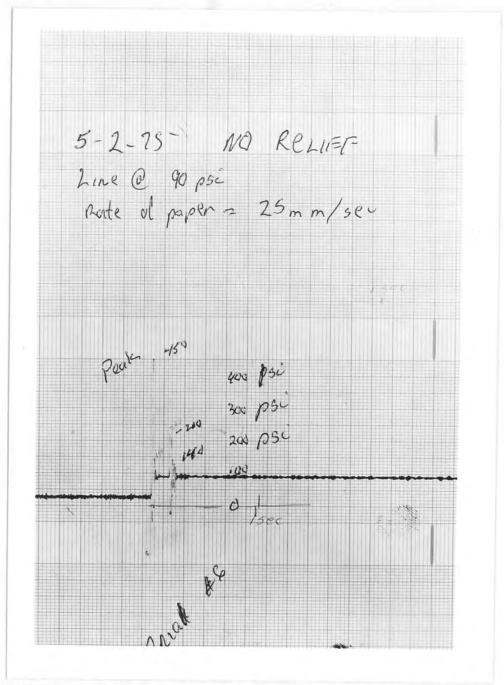


Figure 7. - Pressure rise for quick closure with pipe plug instead of pressure relief valve.

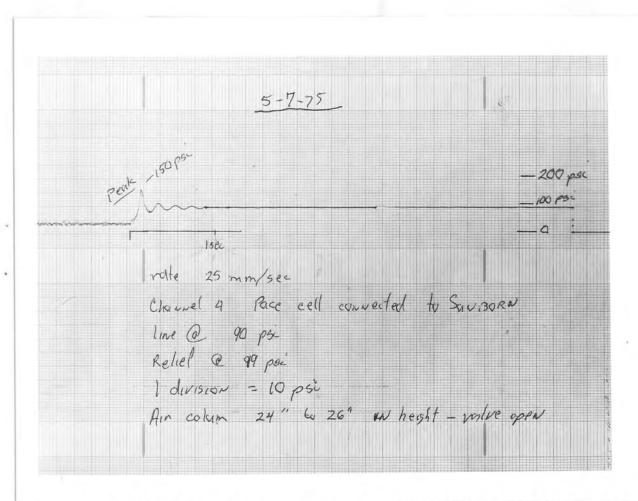


Figure 8.-Pressure rise for air column standpipe in place of pressure relief valve

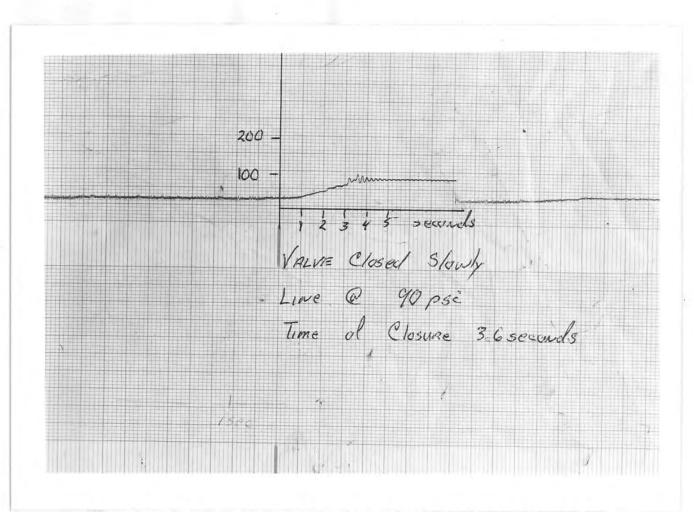


Figure 9. - Pressure rise for slow valve closure with standpipe.

7-1654 (7-73) Bureau of Reclamation

COMPUTATION SHEET

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ВУ	DATE	PROJECT	SHEETOF				
CHKD BY	DATE	FEATURE	•				
DETAILS							

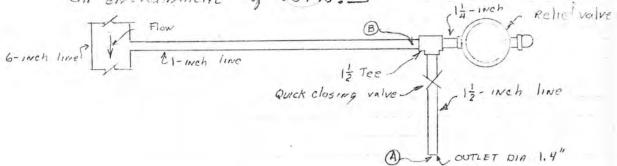
APPENIDIX

COMPUTATION SHEET

ВУ	DATE	OPEN-CLOSED CONDUST STUDY SHEET A-1 OF_
CHKD BY	DATE	Water harmor - measured flow

Gwen: The discharge of the system was determined by measuring the weight of water during an elasped time.

Determine: Water hammer by adoulating a velocity for the measured flow. The velocity of the pressure wave in water a, is equal to 4500 fps for no air entrainment and 1100 fps for on air entrainment of .04%. I



EQUATIONS
$$Q = \frac{W_2 - W_1}{R}$$
 t $W_1 = initial$ wt of tare $W_2 = \frac{1}{2} inal$ wt $U_2 = \frac{1}{2} inal$ wt $U_3 = \frac{1}{2} inal$ wt $U_4 = \frac{1}{2} inal$ wt $U_5 = \frac{1}{2} inal$ wt $U_6 = \frac{1}{2} inal$ $U_8 = \frac{1}{2} i$

H = kay

HA, AB Area of pipe @ 11 # B ft2

k conversion feet of water to psi 14.7/34.0

H maximum pressure

a velocity of wore in water

g = gravitational constant 32.2 4/sec2

TEST	Wa	W.	NA	t	Q	VA	VB	Water	hamme	or Hy	psi.
TRIPL	1 b.	16.	16	sec	At3/sec	fl/sec	fi box	q= 4	500 fps	a = /	100 fps
								+11	HB	HA	HE
1	351	52	299	15	.3/94	29.88	58.56	1805.41	3538.31	4411.32	864.92
2	391	93	288	15	.3077	28.78	56.41	1738,95	3409.40	425.08	833.17
3	394	66	328	17	.3092	28.92	56.68	1747.40	3424.72	427.14	837.15
ava						29.33	57.22	1772.18	3457,35	433.20	845.13

1 "Hydraulic Transients" Streeter and Wylie pg. 8 Fis 1.5

COMPUTATION SHEET

ВҮ	DATE	OPEN-CLOSED CONDUIT STUDY	SHEET <u>A-2</u> OF
CHKD BY	DATE	Wetter hammer caused by Velocity	under free flow
DETAILS		1	7, (

GIVEN: Live pressure at 90 psi under static compitions and a live pressure of 25 psi under free flow conditions. (see Fig 6)

Determine: Water Hummer AT points A and B where the water velocity, V = \$\frac{1}{23}\text{H} and H = aV/g where q=1100 \pm 4500 \frac{2}{9}\text{s}.

$$V_{B} = \sqrt{2g h}$$

$$= \left[2(32.2) \ 25 \left(\frac{34}{14.7}\right)\right]^{\frac{1}{2}}$$

$$V_A = \frac{V_A A_A}{A_B}$$

$$H_A = \frac{a V_A}{g} \left(\frac{H.7}{34} \right)$$

$$\alpha = 1100 \text{ fps}, H_B = 1100(61.66(14.7)) = 917.71$$
 $32.2 (34.0) = 917.71$

$$a = 4500 fps$$
, $H_B = \frac{4500(61.66)(14.7)}{(32.2)} = \frac{3725.62}{}$

ВҮ	DATE	OPEN CLOSED CONDUIT STUDY SHEET A-3 OF.		
CHKD BY	DATE	Impulse Momentum balance		
DETAILS				

Given: L = 5-FEET TO QUICK- CLOSING VALVE. The CONDITIONS

AT B AT PREE FLOW P = 25 psi, and for an estimated closing time of . C275 seconds the peak pressure is 445 psi (see Fig 6)

Discussion: The water hammen pressure relationship, H= aV/2 applies only up to the time that a wave is nelterted back. The time it takes for the wave to return is determined by the period, 21/a. For a wave velocity a=1000 the time is .002 sec. for a wave velocity a=1000 the time is .01 seconds. The operator of the lest estimated the valve closing time of .5 seconds. The test charts showed a peak occurring at a time of .0275 seconds (see Fig. 6). The wave has been reflected before the valve has closed and before the pressure surge has had time to build to its theoretical inagimum of 3500 psi. (see colc. sheet AI) This reflected wave counteriots the initial stage wave of stages it at 1445 psi (see Fig. 6). If the relationship of H = aV/g does not apply the afaires in momentum caused by decreasing the velocity to zero should be egual to the impulse of force over the time it takes to decrease the velocity to zero this force F is defermined by the area under the curve from time equals zero to the peak pressure times the end area of the pipe. (see Fig. 6)

EQUATIONS:

Mass
$$M = W/g$$
 $W = weight of water = Volume × 62.4$
 $V = \sqrt{2gH}$

Momentum = MXV

Impuzse = Fxt

ВҮ	DATE	PROJECT	SHEET A-4 OF
CHKD BY	DATE	FEATURE	
DETAILS			

Impulse Momentum continues.

$$W = \left[\frac{\pi}{4} \right] (1)^{2} (60) \right] - 62.4 \frac{16}{1723} \qquad \text{Area} = .7854 \text{ in}^{2}$$

$$W = 1.702 \quad 16$$

$$V = \sqrt{2gH}$$

$$= \sqrt{2(32.2)} \quad 25 \frac{gy}{14.7}$$

$$V_{B} = 61.02 \quad fps$$

$$time t = .0275 \quad sec$$

$$M_{\times}V = F_{\times}t$$

$$\frac{1.702}{32.2} \times 61.02 = \frac{1}{3} (445) \left(\frac{\pi}{4} (1)^2\right) (.0275)$$

Poak = 445 psc

CONCLUSIONS:

The results of the three methods of ealculation support the measured test results. The pressure surge does not allam its theoretical maximum because a combination of a factors. The factors include the possibility of air, friction losses, and the short length of pipe for the test facility.

Form DFC-11 (12-^{C1}) Bureau of Reclamation

INFORMATIONAL ROUTING

Denver, Colorado
August 13, 1975

Memorandum

Head, Hydraulics Research Section

J. Charles Givens

Test of Clayton Automatic Valve 50G-01 20 to 200 lb/in for Water-hammer - - Relief Applications - Open and Closed Conduit Systems Program

Introduction

This particular relief valve was proposed for application to water-hammer problems of an irrigation district. The water-hammer could----occur when fire fighting equipment is connected to the irrigation system. The fire fighters use quick closing valves on lines straight off the system to a valve at the nozzle, or through a pumper that has the ability to come on the line in a short time. The relief valve was tested to see if it would react quickly enough to a pressure surge to prevent damage to a pipeline. The results were compared to a dead ended line, and to a line with a standpipe.

The main component of the test valve is referred to as the relief valve. The pressure control valve which is referred to as the control valve is used to adjust the relief pressures.

Test Facility

The High Head Pump Facility in the Hydraulics Branch was used to produce the required test pressures. These pressures included the calibration of the relief valve through the manufacturer's range of operation of 20 to 200 lb/in, and the waterhaumer tests at 90 lb/in.

The system for the testing was set up on the end of a 1-inch line on the facility downstream from a venturi, but upstream of a multijet sleeve valve and chawber. This arrangement allowed the operator to set the line pressure from the control board. A 1-1/2-inch tee was installed at the end of the 5-foot-long 1-inch line. The relief valve was in line with the 1-inch line and a quick closing valve was placed 90° to the 1-inch line (see figures 1 and 2). Modifications included replacing the relief valve with a plug (see figure 1, detail A, and figure 3). A standpipe was placed between the tee and the quick-closing valve (see figure 1, detail B, and figure 4). The standpipe included a 1-1/2-inch-diameter pipe with a gage glass for determining the length of the air column in the pipe. An external air supply was connected to the standpipe to adjust the length of the air column.

The pressure in the line was adjusted at the control board. The pressure for the water-haumer system was measured in the 1-inch line 1 inch

upstream from the tee. The pressure transducer was connected to a Sanborn series 350 chart recorder. A Kistler transducer (0 to 200 lb/in²) was used to calibrate the control valve on the relief valve. When the first tests were made the Kistler's range was not adequate. A Pace (0 to 500-lb/in² range) transducer was substituted and used throughout the water harmer tests.

Test Procedure

The Clayton Automatic Valve was calibrated in the range 20 to 200 lb/in. The relief valve was set to zero by backing out the adjustment bolt on the control valve until the bolt could be turned by hand. The bolt was then screwed in until it touched the spring. The pressure was brought up to 30 lb/in. The bolt was tightened until the leaking stopped, then it was loosened until leaking started. The line pressure was increased at 10-lb/in increments using the same procedure for determining relief pressure versus number of turns from zero (see table 1 and figure 5).

For the water hammer tests, the line pressure was set at 90 lb/in². The relief valve was set to relieve at line plus 10 percent or 99 lb/in². The quick-closing valve was opened to let water flow freely to the atmosphere for 10 to 15 seconds, then slammed shut. The same procedure of setting line pressure and operation of the quick-closing valve was used for the relief valve, the plug, and the standpipe.

Results

With quick closure of the valve:

- a. The pressure surged to 445 lb/in² with the relief valve in place (see figure 6 for pressure recordings).
- b. The pressure surged to 450 lb/in² with the relief valve replaced by a plug (see figure 7 for pressure recordings). Note that secondary pressure surges occurred at values approximately at half of the maximum peak.
- c. The pressure surged to 150 lb/in² with the standpipe in place (see figure 8 for pressure recordings). During the free flow condition the length of the air column was adjusted at 24 to 26 inches in the 36-inch standpipe.
- d. Calculations show that a peak of 450 lb/in was possible. The 450 lb/in maximum depends on the method or location

of study. A range of 420 to 2,609 lb/in was calculated (see appendix for calculations).

e. For comparison a test was made with the standpipe installed and the quick closing valve was closed over a longer period of time (3.6 s). The pressure surged to maximum of 104 lb/in. This maximum was 15.6 percent over the line pressure of 90 lb/in (see figure 9 for pressure recordings).

Conclusions

The relief valve does not react quickly enough to handle the waterhammer that occurs from rapidly closing a valve. The standpipe appears to be a solution. The size of the pipe and method of keeping a specified amount of air in the standpipe should be determined by the design group involved.

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7-1654 (7-73) Bureau of Reclamati	ion	COMPUTATION SHEET
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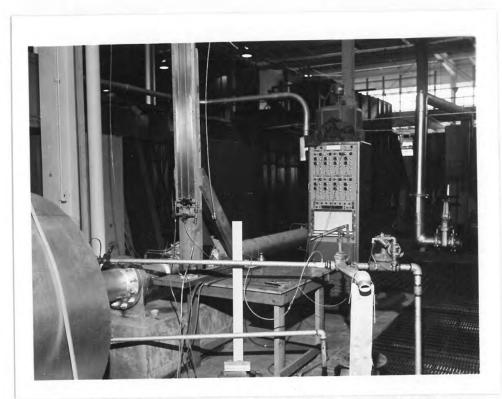


Figure 2. - Test setup with relief valve installed.
Photo H-1762-2

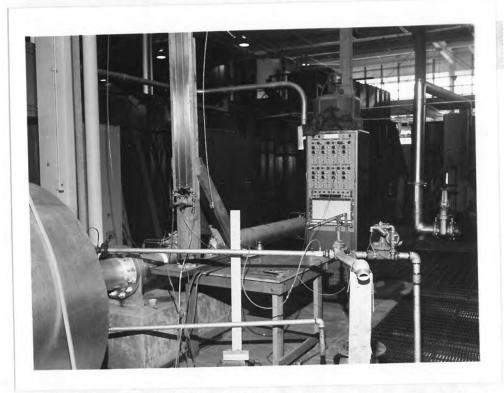


Figure 3. - Test setup with relief valve replaced by a plug. Photo H-1762-3

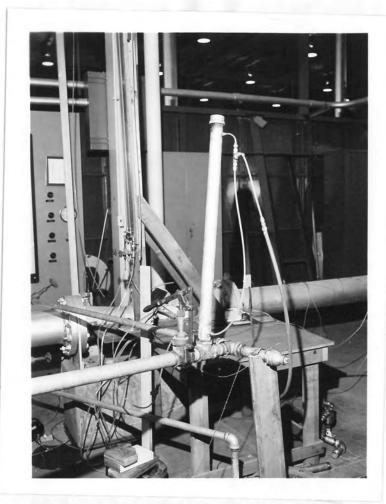


Figure 4. - Test setup with a standpipe installed upstream of the quick-closing valve.

Photo H-1762-4

COMPUTATION SHEET 7-1654 (7-73) Bureau of Reclamation DATE PROJECT SHEET DPFN-CLOSED CONDUIT STUDY 4-29-75 FEATURE CHKD BY DATE APLIBRATE CLAYTON AUTOMINTIC VALVE 506-01 20-200 DETAILS ZERO SETTING ON SPRING WAS DETERMINED BY TOUCH-THE WAR ISDLY FIRST TOUCHED THE ST 200 061 160 196128 SUNG 140 13 120 110 100 108 1 10 8 PLIBONTON 8 30 3 0 1 2 1 00 9 M N ABJUSTANT SCREW - NUMBER OF TWENTRULAA

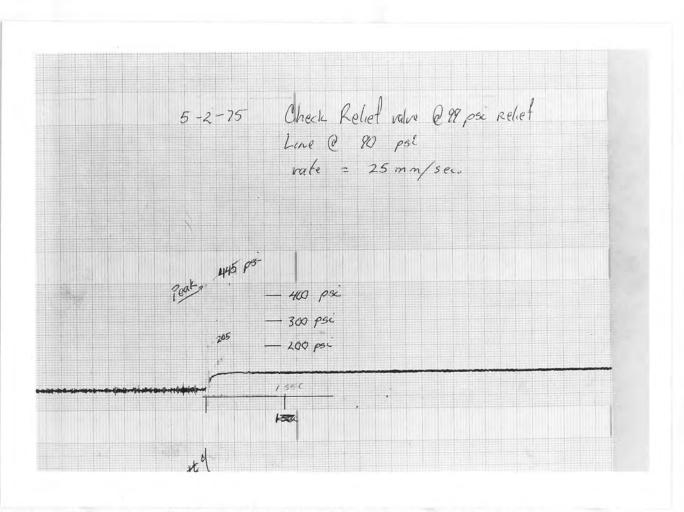


Figure 6. - Pressure rise for quick closure with pressure relief setting of 99 lb/in².

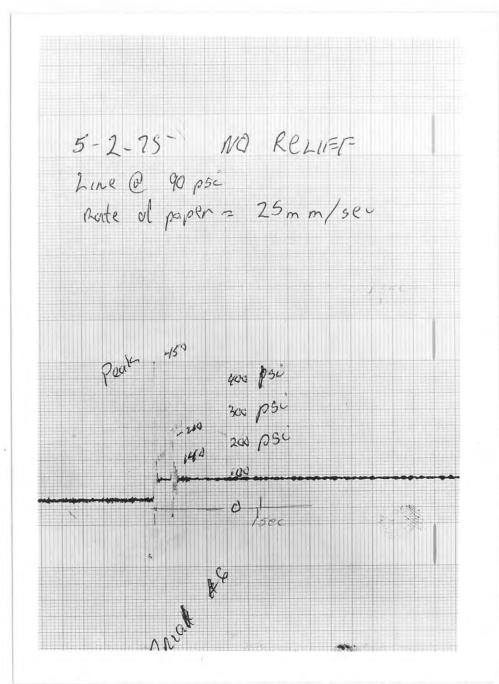


Figure 7. - Pressure rise for quick closure with pipe plug instead of pressure relief valve.

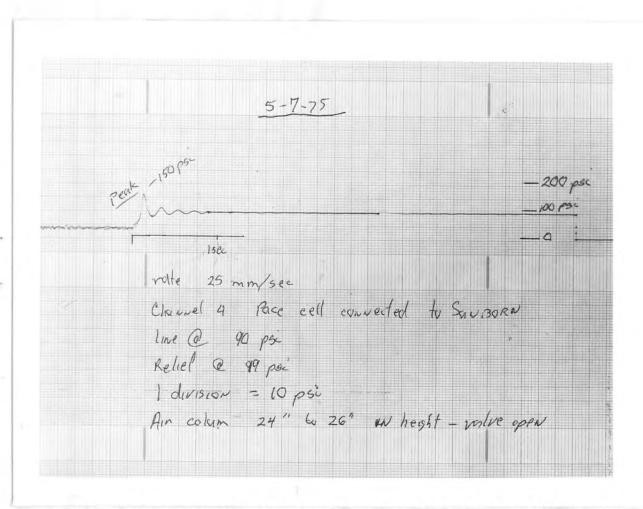


Figure 8.-Pressure rise for air column standpipe in place of pressure relief valve

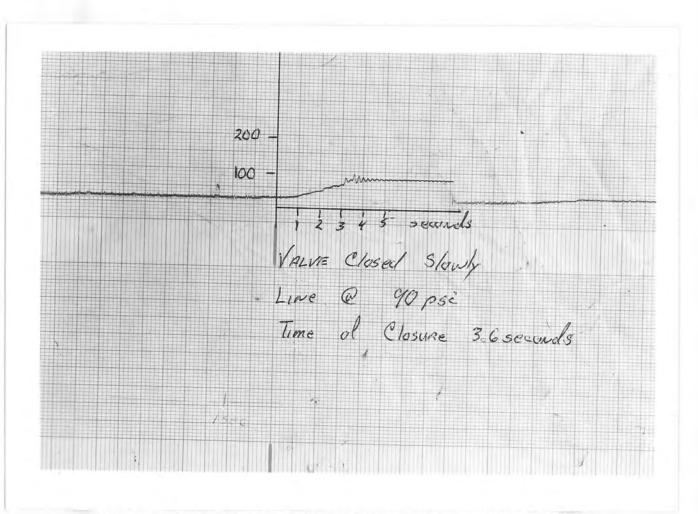


Figure 9. - Pressure rise for slow valve closure with standpipe.

7-1654	(7-	73)
Bureau	of	Reclamation

COMPUTATION SHEET

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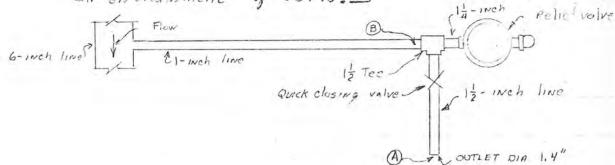
APPENIDIX

COMPUTATION SHEET

ВҮ	DATE	OREN-CLOSED CONDUIT STUDY SHEET A-1 OF_
CHKD BY	DATE	Water how war measured flow

Given: The discharge of the system was determined by measuring the weight of water during an elasped time.

Determine: Water hammer by edecidating a velocity for the measured flow. The velocity of the pressure wave in water a, is equal to 4500 for for no air entrainment and 1100 fps for an air entrainment of .04%. I



EQUATIONS
$$Q = \frac{W_2 - W_1}{R}$$
 t $W_1 = initial$ who of tare $W_2 = final$ who $W_2 = final$ who $W_3 = final$ who $W_4 = final$ who $W_4 = final$ who $W_4 = final$ who $W_4 = final$ where $W_4 = final$ w

VA. VB velocity of water @ A & B. - 65

VB = Q/AB

AA, AB Area of pipe @ 11 & B. - 12

K conversion feel of water to psi 14.7/34.0

H = kaV

A welocity of wave in water

g = gravitational constant 32.2 3/50.2

TEST	Wo	W,	AW	t	Q	VA	VB	Water	hamm	or Hy	psi.
TRIAL	1 b.	16.	16	sec	Al 3/sec	Al/sec	2: Box	q= 4	500 Ps	0 = 1	100+125
								+11	HB	HA	He
1	351	52	299	15	.3194	29.88	58.56	1805.41	3538.31	441.32	864,92
2	391	93	288	15				1738.95			
3	394	66	328	17	.3092	28.92	56.68	1747.40	3424,72	427.14	8,37.15
ava						29.33	57.22	1772.18	3457,35	433.20	845.13

1 "Hydraulic Transients" Streeter and Wylie pg. 8 Fis 1.5

COMPUTATION SHEET

ВҮ	DATE	OPEN-CLOSED CONDUIT STUDY	SHEET A-2 OF
CHKD BY	DATE	Wester hammer caused by Value Ly	under free flow
DETAILS		Worter hammer eaused by Velocity	under free f

GIVEN: Live pressure at 90 psi under static compitions and a line pressure of 25 psi under free flow conditions. (see Fig 6)

Determine: Water Hummer 47 points A and 3 where the water velocity, V = \$129 H and H = ally where q=1100 \$4500 fps.

$$V_B = \sqrt{2g h}$$

$$= \left[2(32.2) \ 25 \left(\frac{34}{14.7}\right)\right]^{\frac{1}{2}}$$

$$H_A = \frac{a V_A}{9} \left(\frac{H.7}{34} \right)$$

$$q = 1100 \text{ fps}$$
 , $H_A = (1100)(31,45)(14.7) = 464.51$

$$\alpha = 1100 \text{ fps}, H_B = 1100(61.665(14.7)) = 917.71$$
 $32.2 (34.0) = 917.71$

$$a = 4500 fps$$
, $H_B = \frac{4500(61.66)(14.7)}{(32.2)} = \frac{3725.62}{(34.0)}$

BY	DATE	OPEN CLOSED CONDUIT STUDY SHEET A-3 OF_
CHKD BY	DATE	Impulse Momentum balance
DETAILS		

GIVER: L = 5-FLET TO QUICK- CLOSING VALVE. The CONDITIONS

AT B AT PREE FLOW P = 25 poi, and for an estimated closing time of .0275 seconds the peak pressure is 445 poi (see Fig 6)

Discussion: The water hammer pressure relationship, H=aV/g applies only up to the time that a wave is neltected back. The time it takes for the wave to return is determined by the period, 21/a. For a wave velocity a=1000 the time is .002 sec. for a wave velocity a=1000 the time is .01 seconds. The operator of the lest estimated the valve closing time of .5 seconds. The test charts showed a peak occurring at a time of .0275 seconds (see Fig. 6). The wave has been reflected before the valve has closed and before the pressure surge has had time to build to its theoretical inagimum of 3500 psi (see colc. sheet AI). This reflected wave counteracts the initial strage and slope it at 1445 psi (see Fig. 6). If the relationship of H = aV/g does not apply the change in momentum caused by decreasing the velocity to zero should be equal to the impulse of force over the time it takes to decrease the velocity to zero. This force F is defermined by the area under the curve from time equals zero to the peak pressure. The impulse is equal tax where force = \frac{1}{2} pressure. The impulse is equal tax where force = \frac{1}{2} pressure.

EQUATIONS:

Mass
$$M = W/g$$
 $W = weight of water = Volume × 62.4$

$$V = \sqrt{2gH}$$

$$Momentum = M \times V$$

Impuzse = Fxt

ВҮ	DATE	PROJECT	SHEET <u>A-4</u> 0F
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Impulse Nomentum continues
$$W = \left[\frac{\pi}{4} (1)^{2} (50) \right] 62.4 \frac{16}{843} \qquad \text{Area} = .7854 \text{ in}^{2}$$

$$W = 1.702 \text{ lb}$$

$$V = \sqrt{2}gH$$

$$= \sqrt{2}(32.2) 25 \frac{34}{14.7}$$

$$V_{B} = 61.02 \text{ fps}$$

$$time t = .0275 \text{ sec}$$

$$\text{Poak} = .445 \text{ psc}$$

$$M_{\times}V = F_{\times}t$$

 $\frac{1.702}{32.2} \times 61.02 = \frac{1}{3}(445)(\frac{\pi}{4}(1)^2)(.0275)$
 $\frac{3.26}{16-5ec} = \frac{3.20}{16-5ec}$

CONCLUSIONS:

The results of the three methods of ealculation support the measured test results. The pressure surge does not allaw its theoretical maximum because a combination of a factors. The factors include the possibility of air, friction losses, and the short length of pipe for the test facility.