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EVALUATION OF A REDUCED PRESSURE BACKFLOW PREVENTER USING ACTIVATION ANALYSIS

By
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January 9, 1963

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Date Issued

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ABSTRACT

Despite its advantages of economy and convenience, the reduced pressure principle backflow preventer has been only partially accepted as a substitute for air-gap separation in preventing pollution of potable water.

To evaluate the protection provided by a reduced pressure principle backflow preventer, a unit was tested under the following static conditions; ionic diffusion, lower pressure on the supply side than on the discharge side, vacuum on the supply side, water hammer on the supply side, and water hammer on the discharge side.

Using a solution of manganese and potassium nitrates as a nonradioactive tracer, backflow from the discharge side to the supply side was not detectable by activation and radiochemical analyses having a sensitivity of ~0.2 parts per billion of manganese.

The protection factor for the device is defined as:

$$P.F. = \frac{\text{Reagent concentration in the discharge zone}}{\text{Reagent concentration in the supply zone due to backflow}}$$

The minimum protection factor proven in these tests based upon the limit of the sensitivity of manganese analysis is 6.5×10^8. This factor provides a rational basis for installation where the concentration of radioactivity or other contaminant can be estimated, measured, or limited.

The potassium analyses also showed no detection of backflow but with a lesser sensitivity.

Details of activation analysis are discussed by Y. Wellwart, L. C. Bate, W. T. Mullins, J. R. Stokely, and G. W. Leddicotte in ORNL Report TM-372, "Stable Isotope Trace-Activation Analysis Methodology: Use in Water Flow Studies."

1.0 INTRODUCTION

The Oak Ridge National Laboratory since the early 1950's has maintained a policy stated: "It is the policy of the Laboratory to provide separate distribution systems for potable and process water and to maintain positive physical and mechanical separation of the system." (1)

As new buildings and facilities were constructed farther from the central complex, it became increasingly difficult to extend completely separated potable and process water systems within the appropriations allotted. A reliable means of safely separating potable and process water systems within a building or facility while maintaining pressure became extremely desirable, and the reduced pressure principle backflow preventer was investigated.

The different attitudes exhibited toward this device by health authorities raised some questions.

The State of California recognizes the use of reduced pressure principle backflow preventers as follows:

> "7604. Type of Protection. The protective device required shall depend on the degree of hazard as tabulated below:
>
> (1) . . .
>
> (2) . . .
>
> (3) . . .
>
> (4) At the service connection to any premise on which any

material dangerous to health or toxic substance in toxic concentration is or may be handled under pressure, the public water supply shall be protected by an air-gap separation. The airgap shall be located as close as practicable to the service cock, and all piping between the service cock and receiving tank shall be entirely visible. If these conditions cannot reasonably be met, the public water supply shall be protected with either an approved reduced pressure principle backflow prevention device, or an approved double check valve assembly, providing the alternative is acceptable to both the water purveyor and the local health department.

(5) At the service connection to any sewage treatment plant or sewage pumping station the public water supply shall be protected by an air-gap separation. The airgap shall be located as close as practicable to the service cock, and all piping between the service cock and receiving tank shall be entirely visible. If these conditions cannot be reasonably met, the public water supply shall be protected with an approved reduced pressure principle backflow prevention device, providing this alternative is acceptable to both the water purveyor and local health department. Final decision in this matter shall rest with the State Department of Public Health." (2)

In other words, California accepts approved and properly maintained reduced pressure principle backflow preventers as alternates to air-gap separation even in installations where an extreme hazard to life is possible if backflow should occur. These installations include hospitals, mortuaries, morgues, canneries, chemical plants, and film laboratories. (3)

Reduced pressure principle backflow preventers have also been approved by the North Carolina Board of Health. (4)

In contrast, seventeen states expressly prohibit any type of cross-connection to a potable water supply, and several others prohibit cross-connections with certain exceptions. (5)

In an effort to gain first-hand information about backflow preventers, ORNL representatives K. E. Cowser and W. J. Boegly, Jr., of the Health Physics Division, and W. S. Hornbaker and W. R. Sanford of the Engineering and Mechanical Division, visited installations in the Los Angeles, California, and Los Alamos, New Mexico, areas during the period May 31 through June 6, 1959. Backflow preventer installations were viewed at Union Oil Company, Los Angeles Refinery (42 RPPBP devices), Spencer Kellogg & Sons, Long Beach Naval Shipyard, Harbor Department area, Terminal Point bay area, McGuire Terminal Company, Catalina Fish Company, Los Angeles Fish & Oyster Company, Los Angeles Water and Power Harbor Steam Plant, Harvey Mfg. Company, Douglas Aviation Company, University of California at Los Angeles, and Los Alamos Scientific Laboratory (approx. 40 RPPBP devices).

Conferences were held with municipal sanitary engineers to discuss installation, inspection, testing, and maintenance of RPPBP devices. An official test of two backflow preventers conducted by Prof. E. K. Springer at the University of Southern California Engineering Center (USCEC) was witnessed in company with officials of the Los Angeles Departments of Water and Power, Building and Safety, and Health. This trip has been described in ORNL internal communications. (6)(7)(8)

One of the recognized specifications for reduced pressure principle backflow preventers is USCEC Report 48-101. (9) This document establishes materials of construction, design features, workmanship, allowable pressure losses, hydrostatic tests, and test procedures for laboratory use and for six-month and three-year field tests. The tests outlined therein rely primarily on pressure gauge or differential manometer readings and appropriate draining from the relief zone as evidence of proper operation.

While the over-all requirements of this report should guarantee an excellent device, it is doubtful if the gauge measurements would positively prove the absence of backflow within the narrow limits permissible in nuclear operations.

In one test reported a backflow preventer failed to gain approval because it permitted backflow to occur through malfunction deliberately induced by placing chips on the check valve seats and removing the loading spring of the diaphragm-actuated relief valve. (10)

None of the test data available seemed particularly appropriate to the tight shutoff and intermittent flows characteristic of nuclear research and batch-type operations, nor was the data of such a nature that it could be used as a safe guide by health physicists in considering installation in radioactive processes.

Consequently, despite the widespread acceptance of backflow preventers in California, in view of their limited acceptance elsewhere, and the inconclusiveness of existing test data and upon recommendation by health physicists, the installation of such devices was expressly forbidden by the Deputy Director of Oak Ridge National Laboratory, "until it is demonstrated that backflow preventers are safe for ORNL service . . " (11) The Engineering and Mechanical Division and the Health Physics Division were urged to make a cooperative test to establish the acceptability of backflow preventers.

Beginning in August, 1959, the Reduced Pressure Backflow Preventer Committee, consisting of representatives from these two divisions, the Inspection Engineering Department, and Health Division, met periodically to consider all aspects of the application of backflow preventers in nuclear and radioactive service. During this period another test was reported in which a backflow preventer was subjected to deliberate maltreatment such as the cutting of holes in the relief valve diaphragm and the insertion of foreign bodies to hold the check valves open. (12) Apparently the intent of such tests was to determine the number of internal elements which must malfunction simultaneously with external system malfunctions so as to permit backflow.

The Committee eliminated maltreatment tests from further consideration because of the existing data and because of the consequences of radioactive contamination are so severe that only properly functioning backflow preventers frequently inspected and properly maintained can be tolerated.

The Reduced Pressure Backflow Committee submitted a major report on April 20, 1961. (13) The principal features were:

1. A recommendation that the five following feasibility tests be performed under rigidly controlled conditions by a properly equipped and reliable testing laboratory.

   a. Ionic diffusion.

   b. Backflow due to lower pressure on the supply side than on the downstream side.

   c. Backflow due to vacuum on the supply side.

   d. Backflow due to water hammer on the supply side.

   e. Backflow due to water hammer on the downstream side.

   Tentative test procedures were outlined.

2. A recommendation that radioactive tracers, specifically Na^{24} or K^{42} be used to trace possible backflow.

3. A recommendation that certain modifications be made to existing models of backflow preventers as additional safeguards.

4. A procurement specification for backflow preventers.

5. A listing of design criteria for installation.

6. Acceptance and field inspection tests.

7. A recommendation that, dependent upon favorable feasibility test results, "limited use of backflow preventers in ORNL water supply piping is justified."

A later committee recommendation that the testing be conducted within the Laboratory was approved by ORNL management who provided funds for the tests and designated the Engineering and Mechanical Division to conduct them. While reviewing tentative piping arrangements and test procedures employing radioactive tracers, the committee decided to investigate the possible use of activation analysis. Following a description of this method and its advantages by G. W. Leddicotte at its January 26, 1962, meeting, the committee agreed that a nonradioactive tracer solution containing manganese and potassium would be used in the tests and that the resulting samples would be subjected to activation analysis.

The following advantages were anticipated:

1. A much more concentrated tracer solution would be used which would make backflow more readily detectable;
2. The test apparatus could be assembled in a more convenient location since it would not be necessary to use the existing designated radioactive zones;
3. No shielding of the apparatus or samples nor other precautions necessary with radioactive compounds would be required;
4. The apparatus would not require decontamination after the tests were completed;
5. Since radioactive decay would not be a factor, neither the duration time of the testing nor the elapsed time between sampling and analysis would require careful consideration; and
6. The sensitivity of activation analysis would greatly exceed that of analysis using radioisotopes--possibly by a factor of 1000.

These advantages were, in fact, realized in the tests which were performed during the period March through June, 1962. The tests were made using procedures approved by the committee.

The Committee believes that these tests, performed under carefully controlled conditions and using detection methods of highest sensitivity, have evaluated the degree of protection provided by a properly functioning reduced pressure principle backflow preventer when installed between a potable water supply and a radioactive process and subjected to the type of flow and pressure abnormalities which might be encountered in practice.

Appreciation is expressed for valuable guidance from the Reduced Pressure Backflow Preventer Committee: G. A. Cristy, Chairman; W. S. Hornbaker and W. R. Sanford, all of the Engineering and Mechanical Division; R. L. Clark and K. E. Cowser of the Health Physics Division; R. W. Schneider and C. E. Childress of the Inspection Engineering Department; and N. E. Bolton of the Health Division. Valuable suggestions have been received from L. F. Lieber and G. J. Angele. Senior Analysts under George W. Leddicotte (formerly of the Analytical Chemistry Division) provided valuable technical advice, the chemical reagents, and the analytical service.

2.0 PRELIMINARY TESTS

2.1 Test Procedure

Essentially, the tests consisted of confining a chemical solution in the discharge end of the device, filling the supply zones with potable water, and conducting the water hammer, vacuum, or other tests. If the chemical concentration in the supply zone after the test were greater than that in a potable water sample taken before the test, then backflow would be indicated.

The full test procedures are included in Appendix 7.4. They were very carefully developed to prevent the chemical solution in the discharge zone from contaminating the upstream zones, either during the filling manipulations prior to testing or the sampling manipulations following testing.

2.2 Sampling

Thorough efforts were made to maintain integrity of the samples. The drain tubes from the different zones were washed off and then rinsed with distilled water prior to sampling. The concentrated chemical solution was so handled as to eliminate spillage. In sampling, the relief and supply zones were drained completely into two-gallon and one-gallon bottles, respectively, which held the entire contents of each zone. This eliminated any loss of contents.

During the water hammer and low pressure tests, a two-gallon bottle was kept under the relief drain outlet to retain the water discharged at each actuation. This water was then composited with the contents of the relief zone after the test. All sample bottles were new polyethylene bottles, well rinsed with distilled water prior to use.

2.3 Test Results

The results from activation analysis of the first series of samples are tabulated in Appendix 7.1. The chemical solution for this series contained about .5 grams per liter of manganese and 1.0 grams per liter of potassium.

The principal anomaly in these tests is that manganese buildup in the intermediate relief zone in most instances was less than that in the supply zone. Since a backflow of chemicals would have to traverse the relief zone and become diluted before reaching the supply zone where it would again be diluted, the presence of backflow would require that the manganese content in the relief zone exceed that in the supply zone. The latter zone is of principal interest since it is connected directly to the potable water supply.

The manganese concentrations found in both the relief and supply zones of the seven-day ionic diffusion test were almost ten times those resulting from the other tests which were of shorter duration. This raised the question of whether these concentrations were caused by true diffusion or as the result of a longer contact time with materials of construction.

2.4 Auxiliary Tests

Auxiliary tests were performed to ascertain:

1. Manganese pickup from the plastic sample bottles,
2. Manganese fluctuations in the potable water, and
3. Manganese pickup caused by materials of construction in the test assembly.

To check the manganese content of the plastic bottles, distilled water was shaken successively in thirty bottles. Analysis showed < 1.0 PPB manganese.

Eighteen potable water samples were taken at different times of the day and under different conditions of water flow during a two-week period. They all analyzed ~ 3 PPB manganese. Water, therefore, should not introduce major inconsistencies in manganese content. For these tests the manganese background has been accepted as no greater than 3.0 PPB.

The seven-day ionic test was repeated substituting water for the chemical solution. The manganese buildup practically duplicated that with chemical solution, confirming the effect of materials of construction. Several step-by-step changes were made in the test assembly, followed by further ionic diffusion tests.

3.0 IMPROVEMENT OF TEST ASSEMBLY

The test assembly had been constructed with materials most readily at hand. Since the actual trace elements had not been definitely chosen at the time of construction, no thought was given to making a manganese-free assembly.

The discharge and supply spoolpieces were stainless steel with a probable manganese content of 2 percent, and iron pipe fittings probably contained 0.03 to 0.65 percent manganese. According to the seller, the backflow preventer casting itself should contain no manganese.

To minimize water contact with manganese bearing metals, the two stainless steel springs in the relief zone were copper plated to a thickness of 0.0045 inch. The supply side spoolpiece was rebuilt using a brass pipe and brass flange with brass nipples. Construction was all brazed using Handy & Harmon BT brazing compound having a composition of 72 percent silver, 28 percent copper. Fritted stainless steel snubbers were removed from the gauge lines in the relief and supply zones, and brass fittings were substituted for iron in these zones.

Because of these steps, manganese buildup decreased to about one-fourth of its former value in ionic diffusion tests (Appendices 7.2 and 7.3).

Notwithstanding the improvements made in decreasing the manganese buildup, the figures in Appendix 7.2 and the slight positive slope of the lower region in Appendix 7.3 indicate a time-dependence, showing that the effect of materials of construction had not been entirely eliminated.

There was no need to make the discharge zone manganese-free since it is used to contain the manganese chemical solution.

4.0 FINAL TESTS

4.1 Improvements in Experimental Procedures

In order to increase the over-all accuracy and sensitivity of the tests, the concentration of manganese and potassium in the chemical tracer solution was increased to the practical solubility limit. By analysis the average value of manganese for all five tests was 126 mg. per ml. or 1.3×10^8 parts per billion. The potassium content averaged 5.80 mg. per ml. or 5.8×10^7 parts per billion. The elements were present as nitrates.

In order to reduce the effect of manganese pickup from materials of construction, it was decided to run each test twice; once with water confined in the discharge zone, and then with chemical reagent confined in this same zone. Under these conditions, corresponding samples would have the same time of residence in the device and be subject to the same conditions of agitation. Thus, the pickup of manganese from materials of construction by the control samples should be very close to that of the prime samples. At least time and agitation would be eliminated as test variables.

The seven-day ionic diffusion test was omitted from the final test because it has no great practical significance and the manganese buildup becomes great enough as to mask any true diffusion. The ten and twenty series of water hammers were omitted because of limited significance. The twenty-four-hour ionic diffusion test and the forty-water-hammer test were retained.

4.2 Criteria for Backflow

In reviewing the data, it should be recognized that two criteria must be satisfied simultaneously if backflow is to be proven.

1. The concentration of chemical in the supply zone must be greater in the test using chemical reagent than in the control test using water as a reagent.
2. In each test using the chemical reagent, the concentration of chemical in the relief zone must exceed to a significant extent that in the supply zone.

Obviously, under the first criterion, unless the chemical test results in more manganese or potassium in the supply zone than the control test, then only background has been observed and no backflow could have occurred.

However, the mere fact that after a test the supply zone contains manganese or potassium in excess of control background does not prove that backflow through the preventer has occurred. True backflow through the preventer must first traverse the intermediate relief zone and then enter the supply zone where it would be diluted. Therefore, if backflow truly exists, the chemical concentration must be higher in the relief zone than in the supply zone. In fact it should be high enough to account for any increase in the supply zone concentration after dilution.

Reference to the piping schematic (Appendix 7.5) and to photographs (Appendices 7.6 and 7.7) shows that about eight feet of one-inch iron bypass piping and three valves separate the discharge zone containing 1.3×10^8 PPB or manganese from the supply zone containing water with only 3 PPB. During two of the tests only one of these valves is closed, and during a third test only two are closed. Conceivably, minute traces of chemicals might diffuse through the bypass system into the supply zone. If so, they should not be considered backflow through the backflow preventer.

It should be noted that the relief zone is considered a contaminated zone by the manufacturer of the backflow preventer; hence, the presence of chemical reagent in this region is not detrimental, especially since this zone is maintained at a lower pressure than the supply zone. Only backflow into the latter zone is detrimental.

4.3 Test Results

Manganese data are shown in Table I and potassium data in Table II. Each test produced one set of samples. Each sample was analyzed for each element separately in duplicate.

4.4 Discussion of Results

Manganese was employed as the primary tracer element because: its concentration in potable water is only about 3 parts per billion; highly concentrated reagent solutions can be prepared because of the excellent solubility of the nitrate; and activation analysis techniques can detect concentrations within 0.2 parts per billion.

Potassium was employed as a second and confirmatory tracer element. Potassium data in these tests are of secondary value because the potassium concentration in potable water is comparatively high (~ 1200 parts per billion); analytical methods for its detection have a precision of only about 80 parts per billion; and its solubility in water as the nitrate is less than manganese so that its reagent solutions are less concentrated.

In reviewing the manganese data in Table I and applying the two criteria relating tracer element concentrations to indicate backflow, it is apparent that there was no detectable backflow indicated by any of the tests. Although a slight increase in concentration occurred in the supply zone during the chemical tests involving vacuum and water hammer on the downstream side, the differences shown fall within the limits of accuracy of the analytical method. Therefore, no backflow is indicated.

The manganese data reported for the five final tests still appear to be somewhat time dependent despite the fact that all reasonable steps had been taken to prevent manganese buildup due to materials of construction. For example, the ionic diffusion and low pressure tests, both of which lasted twenty-four hours, produced the highest manganese concentrations. The lowest manganese concentrations resulted from the vacuum test which lasted slightly over one minute. The two water hammer tests, lasting about thirty-five minutes produced intermediate values.

The potassium data in Table II also indicate that no backflow occurred based on the two criteria. The confirmatory nature of this data is especially significant since it displays no time dependence characteristics because potassium is not present in the materials of construction.

TABLE I

TESTS OF REDUCED PRESSURE BACKFLOW PREVENTER

SUMMARY OF FINAL SERIES

ANALYSIS OF CONTENTS IN PARTS PER BILLION OF MANGANESE

Test	Reagent	Description	Relief Zone	Supply Zone	Backflow
21AC	Chemical	Ionic diffusion	6.3 - 6.0	5.0 - 5.3	No
21AW	Water	Ionic diffusion	10.5 - 10.4	12.0 - 11.0	
23AC	Chemical	Vacuum	4.9 - 5.0	1.0 - 1.0	No[a]
23AW	Water	Vacuum	0.6 - 0.6	0.9 - 0.9	
24AC	Chemical	40 W.H. Supply Side	4.5 - 4.6	5.1 - 5.0	No
24AW	Water	40 W.H. Supply Side	1.5 - 1.6	2.7 - 2.7	
22AC	Chemical	Low Pressure	7.4 - 7.0	19 - 22	No
22AW	Water	Low Pressure	15 - 16	21 - 22	
25AC	Chemical	40 W.H. Discharge Side	3.4 - 3.6	3.0 - 3.0	No[a]
25AW	Water	40 W.H. Discharge Side	2.5 - 2.6	2.7 - 2.8	

[a] Differences in Supply Zone Analyses fall within the accuracy of method.

ANALYSIS OF POTABLE WATER IN PARTS PER BILLION OF MANGANESE

(Composite of 10 Samples)

Relief Zone	0.9 - 1.0
Supply Zone	0.7 - 0.8

ANALYSIS OF CHEMICAL REAGENT IN PARTS PER BILLION OF MANGANESE

Test	
21AC	1.3×10^8
22AC	1.0×10^8
23AC	1.5×10^8
24AC	1.3×10^8
25AC	1.3×10^8
Average	1.3×10^8

TABLE II

TESTS OF REDUCED PRESSURE BACKFLOW PREVENTER

SUMMARY OF FINAL SERIES

ANALYSIS OF CONTENTS IN PARTS PER MILLION OF POTASSIUM

Test	Reagent	Description	Relief Zone	Supply Zone	Backflow
21AC	Chemical	Ionic diffusion	1.3 - 1.3	1.2 - 1.6	No
21AW	Water	Ionic diffusion	1.3 - 1.3	1.3 - 1.3	
23AC	Chemical	Vacuum	1.2 - 1.1	1.2 - 1.2	No
23AW	Water	Vacuum	1.2 - 1.2	1.2 - 1.2	
24AC	Chemical	40 W.H. Supply Side	1.2 - 1.2	1.2 - 1.3	No
24AW	Water	40 W.H. Supply Side	1.1 - 1.1	1.3 - 1.4	
22AC	Chemical	Low Pressure	1.3 - 1.3	1.3 - 1.3	No
22AW	Water	Low Pressure	1.4 - 1.3	1.1 - 1.2	
25AC	Chemical	40 W.H. Discharge Side	1.3 - 1.3	1.3 - 1.3	No
25AW	Water	40 W.H. Discharge Side	1.2 - 1.2	1.2 - 1.2	

ANALYSIS OF POTABLE WATER IN PARTS PER MILLION OF POTASSIUM

Relief Zone	1.2 - 1.3
Supply Zone	1.3 - 1.2

ANALYSIS OF CHEMICAL REAGENT IN PARTS PER MILLION OF POTASSIUM

Test	
21AC	5.3×10^7
22AC	4.1×10^7
23AC	4.4×10^7
24AC	4.3×10^7
25AC	10.8×10^7
Average	5.8×10^7

5.0 PROTECTION FACTOR

The Reduced Pressure Backflow Preventer Committee of the Oak Ridge National Laboratory, in attempting to develop a guide for properly locating backflow preventers in an operating complex and to express most significantly the test data available, has adopted the following definition of a protection factor (P.F.).

$$P.F. = \frac{\text{Reagent concentration of the discharge zone}}{\text{Reagent concentration in the supply zone due to backflow}}$$

The average manganese concentration of the chemical reagent in the downstream zone as shown in Table 1 is 1.3×10^8 parts per billion by analysis.

Because there was no detectable backflow, the question arises as to what value should be substituted in the denominator so as to reflect most validly the experimental data. Since experimental accuracy and manganese background of the potable water were the principal factors in determining the limits of detection of backflow, it appears reasonable that the denominator should reflect the magnitude of these factors. The experimental accuracy on the manganese results is 6.6 percent total deviation at the 95 percent confidence level. The value used for the manganese content of the water is 3.0 PPB as found in the eighteen samples of the preliminary tests. That this value is a conservative one is indicated by the manganese analyses for the potable water composites taken in the final tests. (Table I)

By applying the accuracy factor of 6.6 percent to the manganese content of 3.0 PPB a value of 0.2 PPB is obtained which represents the limit of detection in these tests.

The numerical value of the protection factor for the backflow preventer, therefore, becomes:

$$P.F. = \frac{1.3 \times 10^8}{2. \times 10^{-1}} = .65 \times 10^9 = 6.5 \times 10^8$$

It should be noted that the numerical value of the protection factor proved herein was indirectly limited by the solubility of manganese nitrate. Had there been a chemical compound having suitable radioactive properties and a much greater solubility, the protection factor would have a much greater over-all magnitude. The backflow preventer is probably considerably better than the above numerical value indicates.

It should be noted also that in these tests the disc of the preventer downstream check valve was completely surrounded with the very concentrated chemical reagent. In a normal industrial installation probably ten to several hundred feet of pipe filled with potable water would lie between the sources of contamination and this same check valve. This length of piping provides a safety factor which was not present in these tests.

The protection factor may be used as a guide in locating a backflow preventer ahead of a contaminated system as follows:

> If the concentration of the downstream radioactive, biological or other contaminant can be measured or estimated, and if the minimum permissible concentration of these materials in potable water has been established, then a ratio can be computed. If this ratio is less than the protection factor established for the backflow preventer, then the latter could be safely employed.

More than one RPPBP device could be used in a series-type installation to afford the desired protection factor.

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7.0 APPENDICES

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APPENDIX 7.1

TESTS OF REDUCED PRESSURE BACKFLOW PREVENTER

SUMMARY OF FIRST "A" SERIES (PRELIMINARY)

April 3, 1962

ANALYSIS OF CONTENTS IN PARTS PER BILLION OF MANGANESE

Test	Description	Discharge Zone After Test	Relief Zone Before Test	Relief Zone After Test	Supply Zone Before Test	Supply Zone After Test
1A	Ionic Diffusion - 24 hours	5.2×10^5	3	15	3	7
1A	Ionic Diffusion - 7 days	4.7×10^5	3	100	3	80
2A	Low Pressure, Supply Side 96 cyc.	4.8×10^5	5	3	3	3
3A	Vacuum on Supply Side, 1 Excursion	5.0×10^5	5	8	5	8
4A	Water Hammer, Supply Side After 40 Hammers	5.2×10^5	3	5	2	7
	After 20 Hammers	--	3	6	2	6
	After 10 Hammers	--	3	5	2	5
5A	Water Hammer, Discharge Cide					
	Water Makeup on Supply Side					
	After 40 Hammers	4.2×10^5	3	7	3	15
	After 20 Hammers	--	3	-	3	3
	After 10 Hammers	--	3	3	3	5

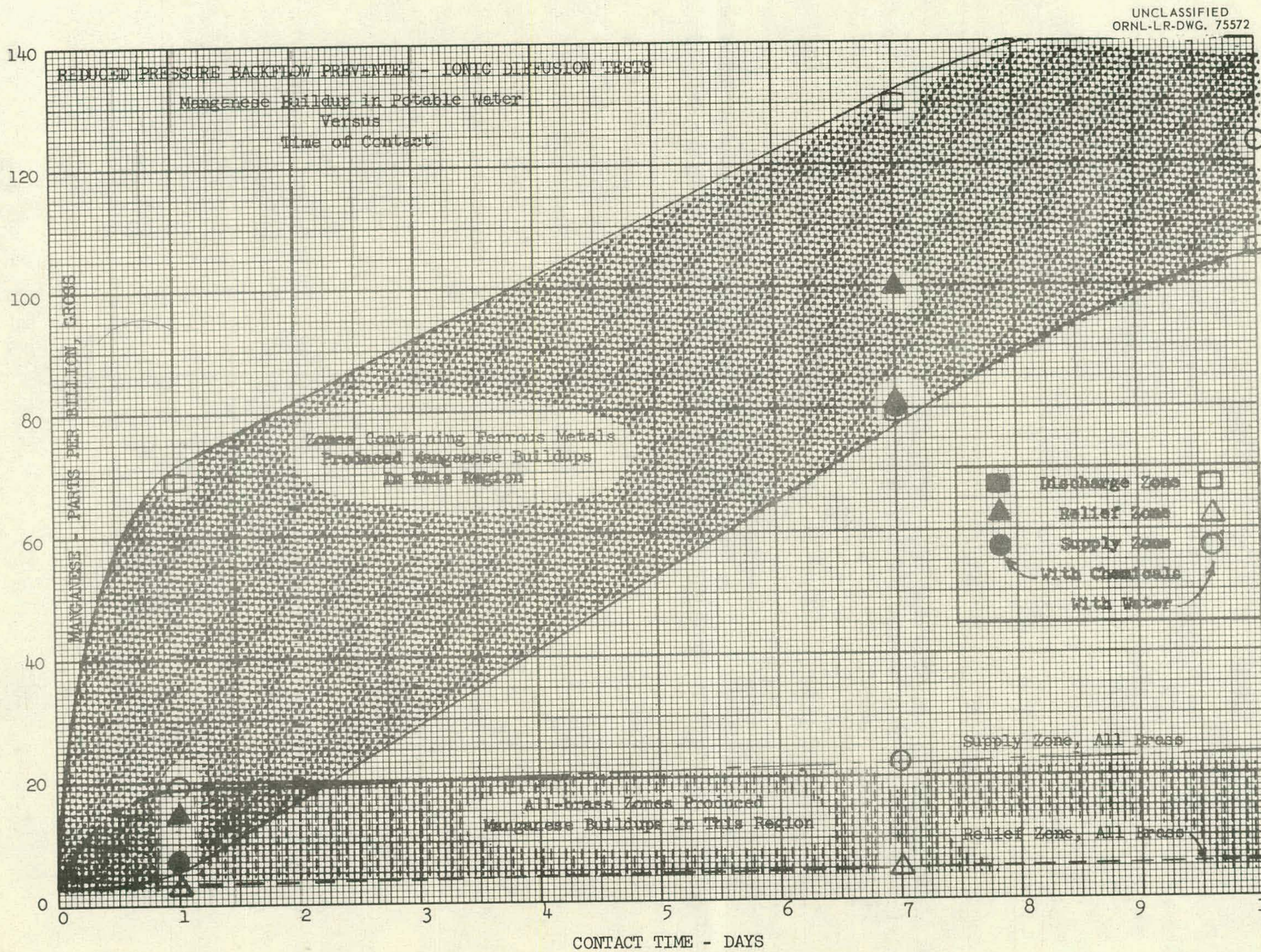
APPENDIX 7.2

IONIC DIFFUSION TESTS

Test		Zone	Manganese Concentration Parts Per Billion: 24-hr. Duration Before	24-hr. Duration After	7-day Duration Before	7-day Duration After	10-day Duration Before	10-day Duration After
1A	Original equipment. Chemical solution in discharge zone.	Discharge	5.2×10^5	Same	4.7×10^5	Same		
		Relief	3	15	3	100		
		Supply	3	7	3	80		
Q1A	Original equipment. Water in discharge zone.	Discharge			2	80		
		Relief			1	81		
		Supply			2	1*		
R1A	Brass was substituted for external ferrous fittings in relief zone. Water in discharge zone.	Discharge					5.3	106
		Relief					2.3	23
		Supply					5.5	123
S1A	Stainless-steel springs in relief zone were copper-plated. Supply zone made all brass, brazed with Cu-Ag compound. Water in discharge zone. Discharge zone unchanged.	Discharge	4	69	1	130		
		Relief	1	3	1	5		
		Supply	1	19	4	22		

*Inexplicable, should be about 80.

APPENDIX 7.3



UNCLASSIFIED
ORNL-LR-DWG. 75572
REDUCED PRESSURE BACKFLOW PREVENTER - IONIC DIFFUSION TESTS
Manganese Buildup in Potable Water
Versus
Time of Contact
Zones Containing Ferrous Metals
Produced Manganese Buildups
In This Region
Discharge Zone
Relief Zone
Supply Zone
With Chemicals
With Water
Supply Zone, All Brass
All-brass Zones Produced
Manganese Buildups In This Region
Relief Zone, All Brass
MANGANESE - PARTS PER BILLION, GROSS
CONTACT TIME - DAYS
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
7
8
9
10

APPENDIX 7.4

TEST PROCEDURES

(As performed in the final tests. See Appendix 7.5 for piping designations.)

Test No. 21A - To Determine if Ionic Diffusion Occurs Through the Device Under Static Conditions

1. Flush complete device as follows:
   a. Run water through device for three minutes with supply and discharge globe valves (4 & 5) wide open.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain supply spoolpiece (2) through valve (24) which also causes relief zone to drain.
   d. Repeat three more times. On the last draining retain samples of water withdrawn from the supply zone and from the relief zone.
2. Fill complete device as follows:
   a. Run water through device for one minute with supply and discharge globe valves (4 & 5) wide open. Valves (21), (6), (7), (30), (15), (17), and (18) are closed.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain completely discharge spoolpiece (3) through valve (20), finally opening vent valve (27) as the pressure approaches zero on gauge (G).
   d. Partially relieve pressure in supply spoolpiece (2) through vent valve (6) until the pressure indicated on gauge (E) is 7 psi. Close valve (6).
   e. Vent relief zone by opening valve (14).
   f. After closing drain valve (20), fill discharge spoolpiece (3) with chemical solution from bottle through valve (15). Stop filling when liquid overflows through valve (27). Close valves (15) and (27).
   g. Add water to relief zone from a bottle through a fill tube connected to cock (B) until relief zone is full. Close valve (14)

and cock (B).

3. Plug drain line from relief zone.
4. Allow RPPBP device to set for time specified with supply spoolpiece vent valve (6), relief zone vent valve (14), and discharge spoolpiece vent valve (27) all open to the atmosphere.
5. One diffusion test will last twenty-four hours. A second test will last seven days.
6. After each test take samples as follows:
   a. Drain relief zone completely into a two-gallon container.
   b. Drain supply spoolpiece completely into a one-gallon container.
   c. Withdraw a one-pint sample of chemical solution from the discharge spoolpiece.

Test No. 22A - To Determine if Backflow Occurs Through the Device Due to Lower Pressure on the Supply Side Than on the Discharge Side with No Flow on the Discharge Side.

1. Adjust pressure switch (PS) to open at 20 psi.
2. Adjust bleed valves so that pressure drops to 20 psi and returns to line pressure in 5 - 15 seconds with a discharge from the relief zone of less than 150 ml. per excursion as follows:
   a. Run water through the device with supply and discharge globe valves (4 & 5) wide open.
   b. Close discharge valve (5). Bleed air from valves (27) and (14), closing them thereafter.
   c. Close supply valve (4) and open wide water valve (30).
   d. Set main timer for 20 minutes and open solenoid valves (29) by electric toggle switch. Adjust valves (28) and (31) until the pressure on gauge (E) reads about 16 psi. Close solenoid valve (29).
   e. Set timer for a 20-second cycle and let system operate automatically, adjusting valves (28) and (31) until the discharge from the relief zone per pressure decrease is less than 150 ml.
   f. Shut off timer and reset for a 15-minute cycle.
   g. Close valve (30).

3. Flush complete device as follows:
   a. Run water through device for three minutes with supply and discharge globe valves (4 & 5) wide open.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain supply spoolpiece (2) through valve (24) which also causes relief zone to drain.
   d. Repeat three more times. On the last draining retain samples of water withdrawn from the supply zone and from the relief zone.
4. Fill complete device as follows:
   a. Run water through device for one minute with supply and discharge globe valves (4 & 5) wide open. Valves (21), (6), (7), (30), (15), (17), and (18) are closed.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain completely discharge spoolpiece (3), finally opening vent valve (27) as the pressure approaches zero on gauge (G).
   d. Partially relieve pressure in supply spoolpiece (2) through vent valve (6) until the pressure indicated on gauge (E) is 7 psi. Close valve (6).
   e. Vent relief zone by opening valve (14).
   f. After closing drain valve (20), fill discharge spoolpiece (3) with chemical solution from bottle through valve (15). Stop filling when liquid overflows through valve (27). Close valves (15) and (27).
   g. Add water to relief zone from a bottle through a fill tube connected to cock (B) until relief zone is full. Close cock (B) and valve (14).

5. Pressurize the discharge spoolpiece to line pressure by opening valve (17) and then closing it.
6. After placing a two-gallon container under the relief zone drain outlet, open valve (30) and place the timer on automatic control.
7. After twenty-four hours (ninety-six cycles) shut off timer, close valve (30), and remove partially filled container from relief drain outlet.

8. Take samples as follows:
   a. Place container of two-gallon capacity under relief drain outlet.
   b. Drain supply spoolpiece completely through valve (24) into a container, finally venting through valve (6).
   c. Vent relief zone through valve (14). Allow relief zone to drain completely. Composite relief samples from the two two-gallon containers.
   d. Collect a one-pint sample from the discharge spoolpiece by draining through valve (20).

Test No. 23A - To Determine if Backflow (Backsiphonage) Occurs Through the Device Due to a Vacuum on the Supply Side with No Flow on the Discharge Side.

1. Flush complete device as follows:
   a. Run water through device for three minutes with supply and discharge globe valves (4 & 5) wide open.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain supply spoolpiece (2) through valve (24) which also causes relief zone to drain.
   d. Repeat three more times. On the last draining retain samples of water withdrawn from the supply spoolpiece and from the relief zone.
2. Fill complete device as follows:
   a. Run water through device for one minute with supply and discharge globe valves (4 & 5) wide open. Valves (21), (6), (7), (30), (15), (17), and (18) are closed.
   b. Close supply (4) and discharge (5) globe valves.
   c. Drain completely discharge spoolpiece (3), finally opening vent valve (27) as the pressure approaches zero on gauge (G).
   d. Partially relieve pressure in supply spoolpiece (2) through vent valve (6) until the pressure indicated on gauge (E) is 7 psi. Close valve (6).
   e. Vent relief zone by opening valve (14).

f. After closing drain valve (20), fill discharge spoolpiece (3) with chemical solution from bottle through valve (15). Stop filling when liquid overflows through valve (27). Close valves (15) and (27).

g. Add water to relief zone from a bottle through a fill tube connected to cock (B) until relief zone if full. Close cock (B) and valve (14).

3. Pressurize the discharge spoolpiece to line pressure by opening valve (17) and then closing it.

4. After placing a two-gallon container under the relief zone drain outlet, apply vacuum to the supply spoolpiece for approximately one minute as follows:

   a. Close cock (12) to about 25 percent open.

   b. Open water valve (13).

   c. Start vacuum pump.

   d. After the vacuum reaches twenty-five inches of mercury as measured on gauge (H), open valve (7) for about the one minute until relief zone drains.

   e. Close valve (7), open vent valve (8), close valve (13), and shut down pump.

5. Take samples as follows:

   a. Remove two-gallon container which holds drainage from relief zone drain outlet.

   b. Vent supply spoolpiece by opening valve (6). Drain through valve (24) into a one-gallon container.

   c. Collect a one-pint sample from the discharge spoolpiece by draining through valve (21).

<u>Test No. 24A - To Determine if Backflow Occurs Through the Device Due to Water Hammer on the Supply Side with No Flow on the Discharge Side</u>

1. Flush complete device as follows:

   a. Run water through device for three minutes with supply and discharge globe valves (4 & 5) wide open.

   b. Close supply (4) and discharge (5) globe valves.

c. Drain supply spoolpiece (2) through valve (24) which also causes relief zone to drain.

d. Repeat three more times. On the last draining retain samples of water withdrawn from the supply spoolpiece and from the relief zone.

2. Fill complete device as follows:

   a. Run water through device for one minute with supply and discharge globe valves (4 & 5) wide open. Valves (21), (6), (7), (30), (15), (17), and (18) are closed.

   b. Close supply (4) and discharge (5) globe valves.

   c. Drain completely discharge spoolpiece (3), finally opening vent valve (27) as the pressure approaches zero on gauge (G).

   d. Partially relieve pressure in supply spoolpiece (2) through vent valve (6) until the pressure indicated on gauge (E) is 7 psi. Close valve (6).

   e. Vent relief zone by opening valve (14).

   f. After closing drain valve (20), fill discharge spoolpiece (3) with chemical solution from bottle through valve (15). Stop filling when liquid overflows through valve (27). Close valves (15) and (27).

   g. Add water to relief zone from a bottle through a fill tube connected to cock (B) until relief zone is full. Close cock (B) and valve (14).

3. Pressurize the discharge spoolpiece to line pressure by opening valve (17) and then closing it.

4. Open globe valve (30) and valve (31) subjecting supply spoolpiece (2) to full-line pressure. Close valve (28).

5. Place two-gallon container under relief zone drain outlet.

6. Open globe valve (18) and open and close solenoid valve (25) with toggle switch 40 times. The timing of opening and closing should be such that all pressure surges are allowed to damp out during the closed position before the valve is reopened.

7. Close globe valves (30) and (18) and remove two-gallon container from relief drain outlet.

8. Take samples as follows:
    a. Place container of two-gallon capacity under relief zone drain outlet.
    b. Drain supply spoolpiece completely through valve (24) into a one-gallon container, finally venting through valve (6).
    c. Vent relief zone through valve (14). Allow relief zone to drain completely. Composite samples from two two-gallon containers.
    d. Collect a one-pint sample from the discharge spoolpiece by draining through valve (20).

Test No. 25A, Revised - To Determine if Backflow Occurs Through the Device Due to Water Hammer on the Discharge Side with No Flow on the Discharge Side

1. Flush complete device as follows:
    a. Run water through device for three minutes with supply and discharge globe valves (4 & 5) wide open.
    b. Close supply (4) and discharge (5) globe valves.
    c. Drain supply spoolpiece (2) through valve (24) which also causes relief zone to drain.
    d. Repeat three more times. On the last draining retain samples of water withdrawn from the supply spoolpiece and from the relief zone.
2. Fill complete device as follows:
    a. Run water through device for one minute with supply and discharge globe valves (4 & 5) wide open. Valves (21), (6), (7), (30), (15), (17), and (18) are closed.
    b. Close supply (4) and discharge (5) globe valves.
    c. Drain completely discharge spoolpiece (3), finally opening vent valve (27) as the pressure approaches zero on gauge (G).
    d. Partially relieve pressure in supply spoolpiece (2) through vent valve (6) until the pressure indicated on gauge (E) is 7 psi. Close valve (6).
    e. Vent relief zone by opening valve (14).

f. After closing drain valve (20), fill discharge spoolpiece (3) with chemical solution from bottle through valve (15). Stop filling when liquid overflows through valve (27). Close valves (15) and (27).

g. Add water to relief zone from a bottle through a fill tube connected to cock (B) until relief zone is full. Close cock (B) and valve (14).

3. Pressurize the discharge spoolpiece to line pressure by opening valve (17).

4. Pressurize the supply spoolpiece to line pressure by opening valves (30) and (31) and then closing them.

5. Place two-gallon container under relief zone drain outlet.

6. Open globe valve (18) and open and close solenoid valve (25) with toggle switch 40 times. The timing of opening and closing should be such that pressure surges are allowed to damp out during the closed position before the valve is reopened. After each closing of the solenoid valve (25), open valve (4) to restore the pressure in the supply zone to full-line pressure and then close valve (4).

7. Close globe valves (17) and (18).

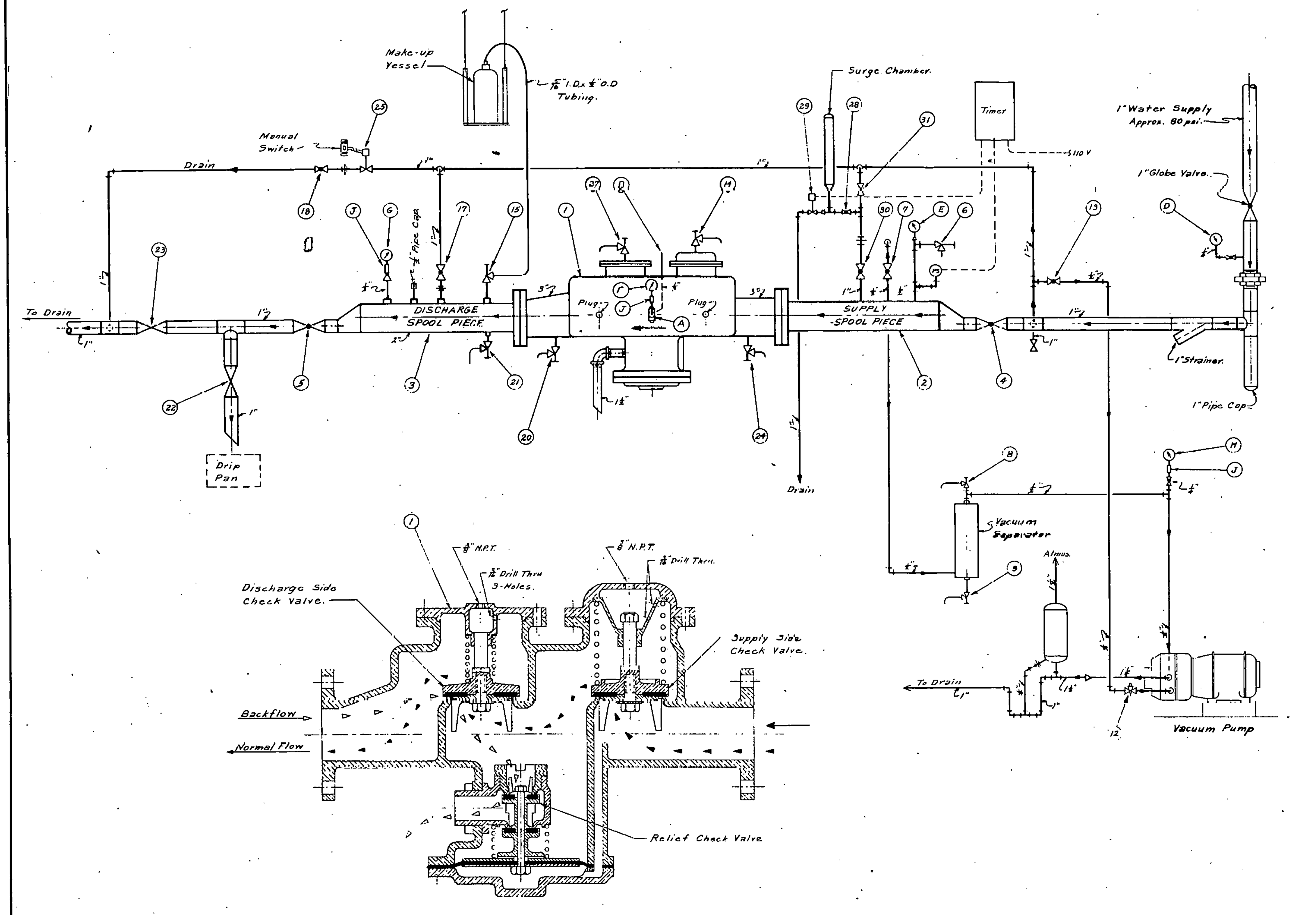
8. Take samples as follows:

   a. Drain supply spoolpiece completely through valve (24) into a one-gallon container, finally venting through valve (6).

   b. Vent relief zone through valve (14). Allow relief zone to drain completely into existing two-gallon container.

   c. Collect a one-pint sample from the discharge spoolpiece by draining through valve (20).

APPENDIX 7.5



① SECTION THRU R.P.B.P. DEVICE

ITEM	SIZE	DESCRIPTION AND LOCATION
1	3"	RPBP DEVICE (BRONZE)
2	2"x1'-0"	SUPPLY TEST SPOOL PIECE (BRASS)
3	2"x1'-0"	DISCHARGE TEST SPOOL PIECE (STAINLESS STEEL)
4	1"	GLOBE VALVE, WATER SUPPLY BYPASS - SPOOL PIECE (BRASS)
5	1"	GLOBE VALVE, WATER DISCHARGE BYPASS - SPOOL PIECE (BRASS)
6	3/8"	KEROTEST VALVE, VENT SUPPLY SPOOL PIECE (BRASS)
7	1/2"	GLOBE VALVE, VACUUM ON SUPPLY SPOOL PIECE (BRASS)
8	3/8"	KEROTEST PACKLESS VALVE, VAC. RELIEVE ON SEPARATOR (BRASS)
9	3/8"	KEROTEST PACKLESS VALVE, DRAIN ON SEPARATOR (BRASS)
10	---	NOT USED
11	---	NOT USED
12	1/2"	PLUG COCK, VACUUM PUMP, WATER SUPPLY (BRONZE)
13	1/2"	GLOBE VALVE WATER SUPPLY TO VACUUM PUMP (BRASS)
14	3/8"	KEROTEST PACKLESS VALVE, VENT RPBP - RELIEF ZONE (BRASS)
15	3/8"	KEROTEST, CHEMICAL SOLUTION ADDITION, DISCHARGE SPOOL PIECE (BRASS)
16	---	NOT USED
17	1"	GLOBE VALVE, WATER SUPPLY BYPASS, DISCHARGE SPOOL PIECE (BRASS)
18	1"	GLOBE VALVE, MANUAL SHUT-OFF TO DRAIN (BRASS)
19	---	NOT USED
20	3/8"	KEROTEST PACKLESS VALVE, DISCHARGE ZONE RPBP DEVICE (BRASS)
21	3/8"	KEROTEST PACKLESS VALVE, SAMPLER, DISCHARGE SPOOL PIECE (BRASS)
22	1"	GATE VALVE, DRAIN LINE (BRASS)
23	1"	GATE VALVE, DRAIN LINE, SHUT-OFF (BRASS)
24	3/8"	KEROTEST PACKLESS VALVE, SUPPLY ZONE RPBP DEVICE (BRASS)
25	1"	SOLENOID VALVE, SUPPLY WATER BYPASS TO DRAIN (BRASS)
26		
27	3/8"	KEROTEST PACKLESS VALVE, VENT DISCHARGE ZONE RPBP DEVICE (BRASS)
28	1"	GLOBE VALVE, ON DRAIN (BRASS)
29	3/4"	SOLENOID VALVE, ON DRAIN (BRASS)
30	1"	GLOBE VALVE, WATER SUPPLY, BYPASS SUPPLY SPOOL PIECE (BRASS)
31	1"	GATE VALVE, WATER SUPPLY BYPASS, SUPPLY SPOOL PIECE (BRASS)
A	1/2"	PLUG COCK, RELIEF ZONE PRESSURE GAUGE (BRASS)
B	1/2"	PLUG COCK, RELIEF ZONE FILL PIPE (BRASS)
C	---	NOT USED
D	1/4"	COMPOUND GAUGE, 0-150 PSI, 0-30" VACUUM, WATER SUPPLY
E	1/4"	COMPOUND GAUGE, 0-150 PSI, 0-30" VACUUM, SUPPLY SPOOL PIECE
F	1/4"	COMPOUND GAUGE, 0-150 PSI, 0-30" VACUUM, RELIEF ZONE, RPBP DEVICE
G	1/4"	COMPOUND GAUGE, 0-150 PSI, 0-30" VACUUM, DISCHARGE SPOOL PIECE
H	1/4"	VACUUM GAUGE, 0-30" VACUUM, VACUUM PUMP SUCTION
J	1/4"	GAUGE SNUBBER, 4 REQUIRED (STAINLESS STEEL)

REFERENCE DRAWINGS	DWG. NO.
Piping Installation Details	D-44282
Piping Installation Plan & Section	D-44281

BACKFLOW PREVENTER TEST — BLDG. NO. 2506

PIPING SCHEMATIC
TEST ASSEMBLY FOR R.P.B.P. DEVICE

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

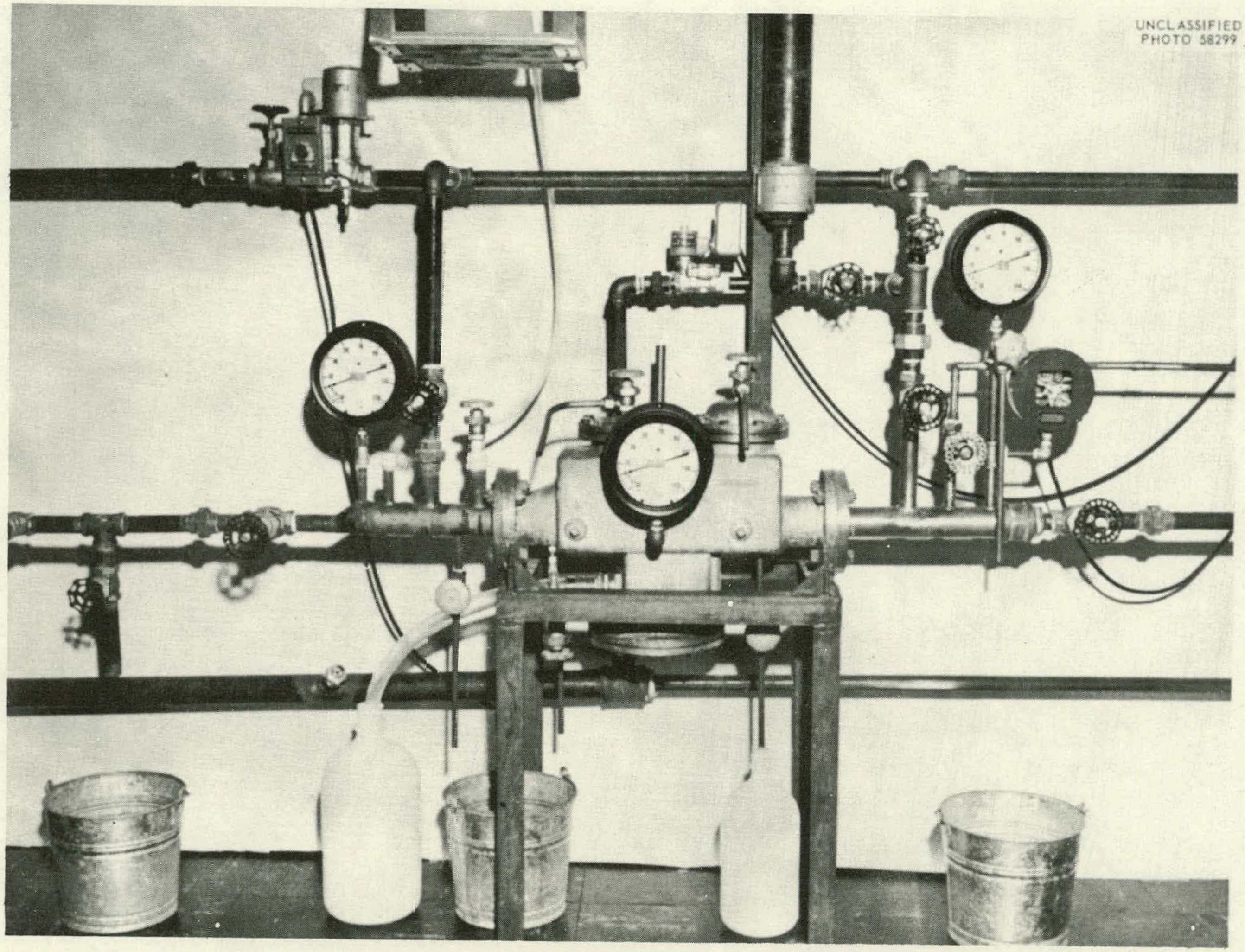
LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED: FRACTIONS ± — DECIMALS ± — ANGLES ± —
SCALE: N.T.S.
SUBMITTED / ACCEPTED / APPROVED
D-44280 REV 1

NO.	REVISIONS	DATE	APPD	APPD
1	As Built	7-12-62		

DRAWN: M.B.B. 2-6-62 — SUBMITTED: 2-28-62
DESIGNED — CHECKED: 1-8-62

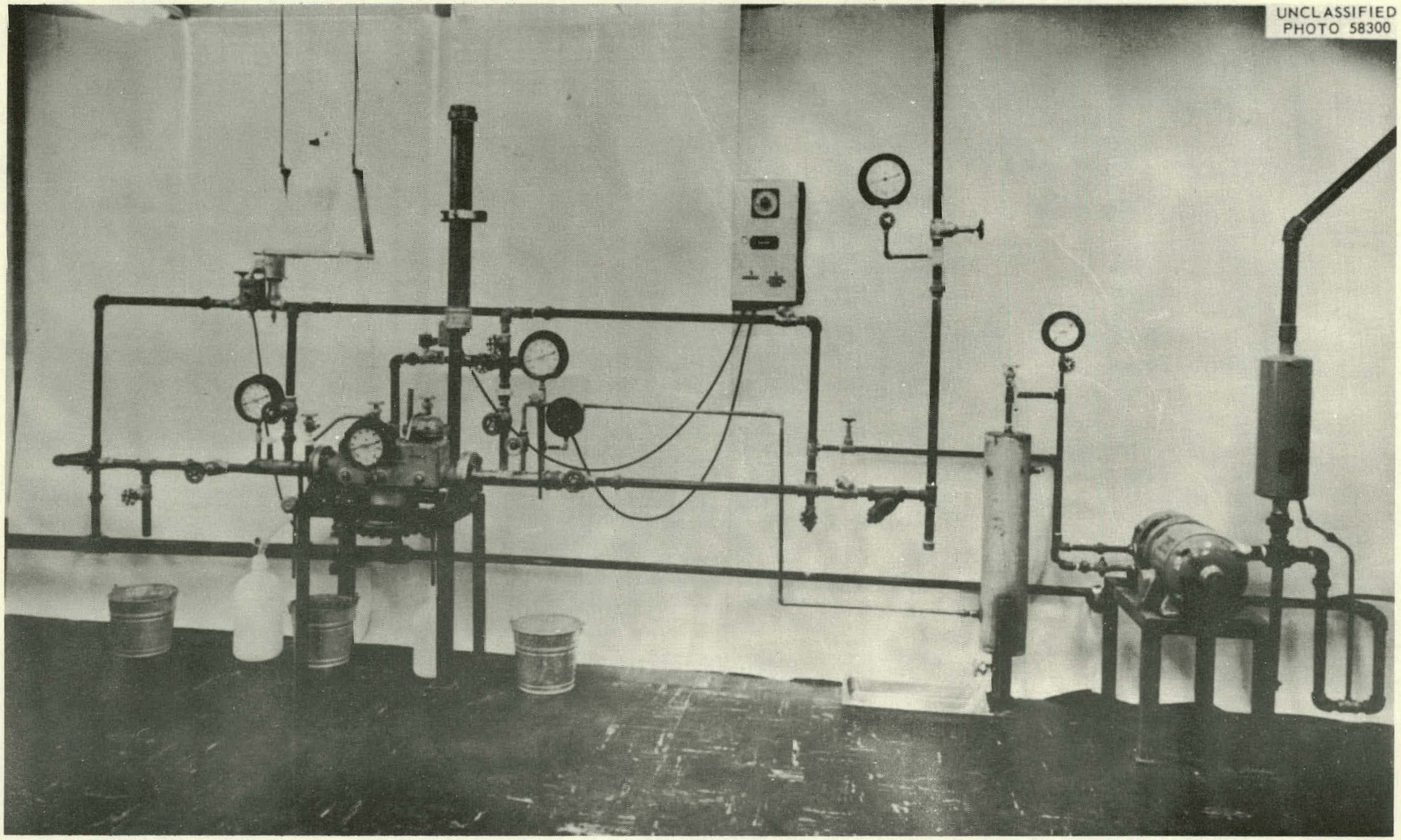
A-70581-11D

APPENDIX 7.6



Backflow Preventer Test Installation, Closeup

APPENDIX 7.7



Backflow Preventer Test Installation, Overall View

APPENDIX 7.8
COMMENTS ON TEST EQUIPMENT

7.8.1 Reduced Pressure Principle Backflow Preventer Device

A three-inch BEECO Model 6C, Serial No. 3BP6C-33 backflow preventer manufactured by the Backflow Engineering and Equipment Company, 5200 East 60th Street, Los Angeles 22, California, was subject to test. This make, model and size had previously received full approval by the Research Foundation for Cross-Connection Control, University of Southern California, Los Angeles, California, following Laboratory tests and six-month and three-year field tests.

A 3/8-inch hole was drilled and tapped in the bottoms of the supply and discharge zones for sample withdrawal. A 3/8-inch hole was drilled and tapped in the cap over each check valve and 3/16-inch holes were drilled in the check valve spring supports. These holes were provided to vent air.

7.8.2 Vacuum Pump

The vacuum pump used was a Nash Hytor, Size MD-673, Test No. AB1499, Rpm-1740.

7.8.3 Piping

The piping installation is shown in the Piping Schematic Drawing D-44280 (Appendix 7.5). The basic tests were made under static conditions, hence a full three-inch flow was not required. One-inch piping provided adequate flow for flushing the device and adequate flow for producing water hammer in the by-pass line.

The piping from the supply cutoff valve (4) through the discharge cutoff valve (5) was considered critical as leaks would endanger the success of the experiments. All small valves in this region were packless Kerotest valves. The one-inch valves were packed brass globe valves which were installed with the discs looking at the preventer regardless of the direction of water flow through the valve. To improve leaktightness, resilient neoprene discs were substituted for the original discs in these valves.

7.8.4 Pressure Testing

After the backflow preventer was installed, the system between the discharge and supply cutoff valves was pressure tested with nitrogen at 120 psig and coated on the outside with soapy water. After minor leaks were stopped, the system was pressurized with nitrogen and shut off overnight. Leakage was minor and within practical limits. These tests were repeated after every major change in the piping.

7.8.5 Pressure Measurements

The gauges were of an industrial type having a six-inch diameter. Before the test began all gauges were calibrated and adjusted within two percent. The gauges were protected with Chemequipt, Catalog No. 25S, snubbers having porosity "D" for oil over 50 SSU. After the preliminary tests it became obvious that the porous snubbers might cause an increase in the manganese content of the water, hence they were removed from the gauges and the pressure switch in the relief and supply zones.

7.8.6 Solenoid Valve

Solenoid valve 25 was especially chosen for quick closing characteristics since the magnitude of water hammer depends upon the speed of stopping water flow. This valve, a General Controls Type K-15B, Catalog No. K15BB2262, Solenoid size 300B, with a one-inch port, appeared to go from fully open to fully closed in less than 1/10 second.

7.8.7 Volumes of Zones

Each of the three zones of the backflow preventer installation was calibrated for sampling and computing purposes. The volumes were as follows:

Supply Zone - 3080 ml.
(Includes volume between supply side check valve and cut-off valve (4)

Relief Zone - 5280 ml.
(Includes volume between supply side and discharge side check valves)

Discharge Zone- 4340 ml.
(Includes volume between discharge check valve and cut-off valve (5)

APPENDIX 7.9

COMMENTS ON TESTS

7.9.1 Test No. 21A - To Determine if Ionic Diffusion Occurs Through the Device Under Static Conditions

Tight shutoff conditions frequently occur in nuclear processing operations, hence the performance of the backflow preventer under these conditions was considered important.

There was a possibility that the resilient neoprene disc of the check valves, when seated under tight shutoff conditions, might act as a permeable membrane permitting ions to diffuse from a zone of high concentration to a zone of lower concentration.

In planning the ionic diffusion test, serious thought was given to eliminating all effects but that of diffusion while operating the system under pressure. However, if the discharge zone were valved off and the supply zone were pressurized by water pressure from the line, fluctuations in line pressure might cause the check valves to lift and permit chemical transfer to occur. Other possible valving arrangements appeared to have this same disadvantage.

In observing operation of the backflow preventer it was noted that with water flowing, the pressure drop across the supply side check valve was 8 psig, and that across the discharge check valve was 1 psig even though the supply water pressure might be varied through the range of 10 - 80 psig. If water flow was stopped by closing a downstream valve, water was confined in the three zones under static conditions, but the pressure drop across the check valves still remained at 8 psig and 1 psig.

Since the hydraulic pressure difference across the check valve seats was independent of the line pressure and rate of flow,

5. The surge chamber consisting of a thirty-inch length of three-inch pipe dampens out any water hammer which otherwise might be produced when the solenoid valve (29) closes.

When the solenoid valve causes the supply zone pressure to drop, the relief zone drains so as to keep its pressure 8 psig below the supply zone pressure. As the supply zone is restored to full-line pressure by the closing of the solenoid valve, the supply side check valve opens momentarily and permits water to flow into the relief zone until the previous drainage is replaced.

The volume of drainage from the relief zone is markedly affected by the amount of entrapped air remaining in the relief zone. When this air was not vented, the drainage from the relief zone approximated 300 ml per excursion. Prior venting of the relief zone through valve (14) reduced the volume of drainage to 22-33 ml per excursion. The lower volume was desirable from the standpoint of sampling convenience.

This indicates that when a backflow preventer is installed in an industrial line and "spits" excessively with pressure fluctuations, the situation could likely be improved by venting entrapped air from the relief zone.

7.9.3 Test No. 23A - To Determine if Backflow (Backsiphonage) Occurs Through the Device Due to a Vacuum on the Supply Side With No Flow on the Discharge Side

The vacuum test may seem to be of exceedingly short duration. However, when the supply zone is subjected to vacuum, the relief valve opens immediately and the contents of the relief zone drain completely in about one minute. Once the relief zone is empty, there is no way for backflow to traverse the empty chamber and pass the supply side check valve. Hence, there is not reason to extend the test period beyond the time required to empty the it appeared reasonable to perform the test at atmospheric pressure, thereby avoiding the effects of line pressure fluctuations. This was done most conveniently by closing the relief zone drain outlet with a rubber stopper and filling the three zones with the proper liquid, then venting them to atmosphere. The backflow preventer then remained quiescent for the specified period.

This test appears to violate a basic principle of backflow preventer installation; i.e., the relief zone outlet must never be blocked. However, to make the test more thorough and to provide ample opportunity for diffusion to proceed, it was necessary that the relief zone remain filled with water throughout the test. This could only be done by blocking the relief zone drain outlet.

7.9.2 Test No. 22A - To Determine if Backflow Occurs Through the Device Due to Lower Pressure on the Supply Side Than on the Discharge Side With No Flow on the Discharge Side

The cycling and duration of the test, 96 cycles in 24 hours, or one cycle every 15 minutes, was chosen to provide ample opportunity for backflow to occur. The pressure in the supply spoolpiece is varied as follows: (See Piping Schematic, Appendix 7.5)

1. The bypass line carries full-line pressure of 80 psig.
2. With valves (30) and (31) open and valves (29) and (28) closed, the full-line pressure is transmitted to the supply spoolpiece.
3. If valve (28) and the solenoid valve (29) are opened wide, the flow through valve (31) goes to the drain; and the pressure transmitted to the supply spoolpiece reaches a very low value.
4. By throttling valve (31) and adjusting valve (28), the pressure in the supply spoolpiece can be set at 16 psig with solenoid valve (29) open. This pressure builds to full-line pressure when the solenoid closes. This solenoid is actuated by the timing devices.

relief zone. The vacuum at the pump (gauge H) was 27 inches of mercury. The gauge reading at the supply zone was 22 inches of mercury.

7.9.4 Test No. 24A - To Determine if Backflow Occurs Through the Device Due to Water Hammer on the Supply Side With No Flow on the Discharge Side

In considering the water hammer tests, separate series of 10, 20, and 40 water hammers were planned to determine the relationship between possible backflow and the number of water hammers. The preliminary tests showed that the manganese content in the supply zone did not increase in proportion to the number of water hammers. Therefore, only the 40-water-hammer series was retained in the final tests, and the lesser series were omitted.

The water hammer in all of the water hammer tests produces a loud audible knock and obvious shaking of the piping.

Typical water hammer tests on the supply side were measured using a calibrated Baldwin-Lima Hamilton SR-4 Pressure Cell, Type P.P.S., 0-1000 psi capacity, screwed into a drain hole in the supply zone. This pressure cell was connected electrically to a calibrated Sanborn Model 127 Recorder. Pressure measurements as taken from gauge readings and the recorder trace are as follows:

	Pressure During Flow in Bypass PSIG	Pressure at Height of Water Hammer Surge PSIG
Supply Zone (Gauge E)	60	100
Supply Zone (Pressure Cell)	60	150

The latter figure is the more accurate and represents a 250 percent pressure surge. This surge occurred in about one second according to the trace. In discussing water hammer in penstocks, Marks' Handbook gives formulas for the increase in pressure, h, following gate closure and comments: "They are quite accurate for pressure rises not exceeding 50 percent of the initial pressure, which includes most practical cases." (14)

The water hammer in the backflow preventer tests therefore exceeded Marks' value by a significant margin.

During the water hammers when the bypass solenoid valve (25) was opened to start a flow of water, a pressure drop was transmitted into the supply zone and caused the relief valve to drain momentarily to reduce the pressure in the relief zone. The relief valve opened again slightly under the impact of the water hammer. The drainage accumulated from both of these actions during the test totalled one gallon.

7.9.5 Test No. 25A, Revised - To determine if Backflow Occurs Through the Device Due to Water Hammer on the Discharge Side with No Flow on the Discharge Side

In the preliminary performance of Test No. 25A water hammer was applied to the discharge zone containing chemical solution with the pressurized supply zone valved off. The static pressure dropped in the supply and relief zones with each successive water hammer until an equilibrium was reached. For example:

Number of Water Hammers	0	1	2	3	4	5	6	7	8	9
Line Pressure (Gauge D) psig	79	79	79	79	79	79	79	79	79	79
Supply Zone (Gauge E) psig	80	56	50	46	44	43	42	41	40	40
Relief Zone (Gauge F) psig	72	50	43	39	37	36	35	34	32	32
Discharge Zone (Gauge F) psig	80	81	80	80	81	80	80	80	80	80

It is noteworthy that the relief zone pressure in every case was less than the supply zone pressure; hence, the safety feature of the device was operating consistently.

The decrease in pressure in the relief zone is attributed to the pressure of the shock wave on the discharge side check valve. Through compression of the resilient neoprene disc, the pressure surge was partially transmitted into the relief zone and caused the relief valve to open briefly and drain out a small volume of water which was partially replaced by forward flow from the supply zone. The draining continued further with each hammer until the check valve disc could force no more fluid from the relief zone.

This diminishing of pressure with successive water hammers had not been foreseen and the test as planned called for full-line pressure in the supply zone. This condition would more nearly simulate the conditions of an actual installation.

Therefore, in performing the final tests, valve (4) was opened momentarily after each water hammer to pressurize the supply zone to full-line pressure, and the relief zone pressure rose to its normal value of 72 psig. Under these conditions, the drainage from the relief zone outlet average 8.0 ml per water hammer.