Appendix N - Acuren laboratory analysis report

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A Higher Level of Reliability

KAMLOOPS REFRIGERATION SYSTEM FATALITY
(RCMP File No. 2022-17544)

BALL VALVE EVALUATION

Prepared for:

TECHNICAL SAFETY B.C.
#600 - 2889 EAST 12TH AVENUE
VANCOUVER, BC
V5M 4T5

Attention: Jeff Coleman P.Eng.

RCMP – SOUTHEAST DISTRICT
GENERAL INVESTIGATION SECTION
2611 NORRIS ROAD
KELOWNA, BC
V1X 7M1

Attention: Constable [redacted]

WORKSAFEBC
2045 ENTERPRISE WAY
KELOWNA, B.C.
V1Y 9T5

Attention: [redacted]

File Number: 60516984 (605-J023973)
EGBC Permit Number: 1001973
Date: September 22, 2022

Bob Milne, P.Eng.
Email: bob.milne@acuren.com
Direct: 604-448-3856
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1.0 INTRODUCTION

A previously disconnected refrigeration system was being moved from a building in Kamloops, BC. An ammonia storage tank with an attached pipe and shutoff valve had been cut from the system with the valve in the closed position. An overall view of the ammonia system showing the installed valve with the lever in the open position is shown in Figure 1 (RCMP photo). The ammonia tank was thought to be empty at the time of the event. A worker opened the valve and ammonia was released directly from the cut pipe in the direction of the worker.

Acuren was asked to document and test the subject valve. The following items were tasked:

1. Document the valve and its condition.
2. Describe the valve's function and operation.
3. Document the damaged locking device.
4. Perform operating tests on comparison valves to replicate damage to the locking device.
5. Does the valve generally conform to its standard (see attached drawing)?
6. Is there any damage to the valve ball, stem, or packing? Comment on the cause of the damage.
7. Does the valve open and close freely? Provide a comparison of the operating force to a new valve.
8. Does the operability of the valve change when frozen?
9. Does the operability of the valve change when under pressure?
10. Perform a pressure test on the valve at 50 psi increments up to 300 psi with nitrogen. Does the valve hold pressure?
11. Is the valve vented/equalized?
12. Does the valve show any signs of cracking/fracture?

The valve was examined and tested at the Acuren Laboratory Facility in Richmond, BC on August 15, 2022. The following personnel were in attendance:

1. Constable [redacted] (RCMP)
2. [redacted] P.Eng. (Acuren)
3. [redacted] P.Eng. (Technical Safety B.C.)
4. [redacted] P.Eng. (Technical Safety B.C.)
5. [redacted] (M.A. Stewart Ltd.)
6. [redacted] (M.A. Stewart Ltd.)
7. [redacted] (Technical Safety B.C.)
8. [redacted] (WorkSafeBC)
9. [redacted] P.Eng. (WorkSafeBC)

2.0 VALVE INVESTIGATION

2.1 Visual Examination

Overall views of the subject valve as received are shown in Figures 2 - 5. The valve is attached to a threaded nipple on one side and a threaded pipe, which had been cut with a saw, on the other side (Figure 2). This valve was arbitrarily labelled #1. The valve was originally mounted vertically on the tank with the outflow side of the valve containing the short section of cut pipe. The valve is marked with the following cast-in identification:

1" (pipe size)
2000 WOG (rated for 2000 psi water, oil, or gas)
209 (lot number)
CF8M (stainless steel alloy 316)
Stylized MAS (M.A. Stewart manufacturer's logo)

The operating lever is bent downward by approximately 20 degrees, as shown in Figure 3. The valve lever was originally bent outward at site (Figure 1) and was likely bent inward by the refrigeration technician to facilitate removal of the valve. The sliding locking mechanism is deformed and contains a single bent tab. Close-up views of the bent locking

device are shown in Figures 4 and 5. The deformation of the tab occurred when a relatively large force was applied to the lever while it was moved from the fully closed position to the fully open position. The observed deformation prevents the locking tab from engaging properly.

A second identical valve from the tank piping is shown in Figure 6. This valve was arbitrarily labelled #2. The lever is not bent with this valve and the locking mechanism is intact (Figure7). The #2 valve lever is roughly parallel to the longitudinal axis of the valve body.

The nipple and pipe ends were removed from the #1 valve with a pipe wrench. The nipple and pipe appeared to be properly installed and took considerable force to remove them. The #1 valve and #2 valve are shown side by side in Figure 8. The only visible difference between the two is the bent lever and the deformed locking device with the subject #1 valve.

The subject valve was found in the fully open position. The valve operated normally (by feel) under what would be considered normal operating loads when compared with the loads required to operate a new valve (new valve supplied by M.A. Stewart).

The interior of the valve was examined through both end openings. The plastic seal on the exit end of the valve (cut pipe) was deformed and extruded past the opening as shown in Figure 9. The inlet side of the valve appeared normal with the seal opening concentric (Figure 10).

2.2 Mechanical Testing

2.2.1 Pressure Tests

The valve was subjected to pressure tests using compressed nitrogen gas. The valve was connected to a calibrated 500 psi pressure gauge and tested in 50 psi increments up to 300 psi. A typical leak test is shown in Figure 12. The pressurized valve was placed in a bucket of water and examined for leaks at each pressure increment. No leaks were found with the valve at any pressures up to the maximum 300 psi.

2.2.2 Operating Load Tests

The loads required to close the subject valve under various loading conditions were measured using a load cell applied approximately 1" from the end of the lever (Figure 11). The lever was straightened to the parallel position (equal to a new valve) prior to the test. The tests produced the following results (video recorded in some instances and examined one frame at a time):

Table 1: Opening/Closing Loads

Pressure	Temperature (°C)	Opening / Closing	Maximum Load (lb)
atmospheric	24	Closing	13.5 (video)
atmospheric	24	Opening	13.0 (approx.)
50 psi	24	Closing	10.0 (video)
50psi	24	Opening	11.0 (approx.)
atmospheric	-33	Closing	3.5 (video)
50 psi	-33	Closing	3.5 (approx.)

The friction force between the valve seats and the ball, and the stem and the packing, needed to be overcome before the ball could move. It was noted that overcoming static friction was highest just before the ball moved. Once the ball started moving, the load required to keep the ball moving was less. This was true while both opening or closing the valve. The cold temperature test showed that the friction force required to move the ball while at both atmospheric pressure and 50 psi was dramatically reduced.

3.0 DISMANTLING OF SUBJECT VALVE

The subject valve was dismantled to gain access to the stem, valve ball, seals, and internal valve body surfaces. Overall views of the opened valve components are shown in Figures 13-16.

The seals from the outlet and inlet sides of the valve are shown in Figure 13. The exit seal (left side of photograph) is permanently deformed while the inlet side is concentric. Both seals contain considerable amounts of dirt and oil on the sealing surfaces.

A close-up view of the deformed exit side seal is shown in Figure 14 with the ball and lever at the 45 ° position. The deformation on the seal is most pronounced at the partial ball opening position (arrow, Figure 14).

A Keyence microscope was used to examine the deformed seal at high magnification. Slight tearing is visible at the location shown with the arrow in Figure 15. A closer view of the tear is shown in Figure 16. The small inside edge tear has taken place at a point of high edge tensile stress adjacent to the most deformed part of the seal. This type of tearing would only occur under high strain rate loading conditions. Slow strain rate loading, such as that produced by long-term sustained loads, would likely extrude the seal material, but not cause tearing.

4.0 NON-DESTRUCTIVE TESTING OF VALVE BODY

Liquid Penetrant (LP) testing was performed on the dismantled valve body castings. The test results are shown in Appendix C. No defects of any kind were found.

5.0 OPINIONS AND FACTS WITH RESPECT TO QUESTIONS ASKED

The following opinions and facts are based on the laboratory examination of the subject valve:

1. The valve lever was bent in the flat direction toward the central axis of the valve body to an angle of approximately 20°. One (1) locking tang was bent and deformed and could not function as intended. The locking tang was deformed when the lever was moved from the fully closed to the fully open position. The observed locking tang deformation was replicated by the full effort of a man using one arm. The outlet end seal was permanently deformed. A small tear was found adjacent to the most deformed part of the seal. The greatest seal deformation aligned with the ball opening as it was rotated into a partially open position.

2. The ball valve functions as an "on-off" valve for liquids and gases. It is not designed as a "throttling" valve. The valve ball is operated through a keyed stem which is sealed with plastic packing. A tabbed locking device slides up and down the lever to prevent accidental opening or closing of the valve ball. The locking device is moved "up" the lever to unlock the valve lever. When in the fully open position, the valve provides flow matching the pipe size to which it is mated (1" diameter in this case).

3. The damage to the locking device is documented in Figures 4 and 5. The deformation damage was created by overstressing the tab past the yield strength of the austenitic stainless-steel locking tab material while moving the valve handle from the fully closed to the fully open position.

4. Simulation tests showed that locking tab damage identical to that found with the subject valve could be created by applying the full effort of a man to the lever (using one arm) with the lock in the "locked" position. The condition of the locking tab on the subject #1 valve (right side) and the #2 valve after simulating the locking tab damage mechanism is shown in Figure 17.

5. The valve generally conforms to the drawing standard shown in Appendix B.

6. The valve was found in the fully open position and was aligned with the stem and lever.

7. The valve stem was intact and did not show any evidence of deformation or impact.

8. The valve opens and closes freely with a force similar to that required to operate a new valve (supplied by M.A. Stewart).

9. There is no way of knowing if the valve was frozen prior to the event. The valve was likely frozen while the ammonia was venting to atmosphere. Operational tests at -33 °C showed that the force required to operate the valve was measurably less than at room temperature.

10. The valve holds pressure in 50 psi increments up to 300 psi, in spite of deformations found with the outlet seal.

11. The valve is not vented (equalized). The stem connection hole in the ball provides some relief at a slow rate but is not intended to be a "vent".

12. Liquid penetrant examination (LP) did not show any sign of cracking or fracture with the valve body or valve end fitting.

13. The valve required 13.5 lb of force to close the pressurized valve (50psi) at a pulling position 1" from the end of the lever. This is 3.5 lb more force than required with the valve open to atmosphere.

14. The valve was much easier to close when frozen at the ammonia boiling temperature of -33°C. The measured closing load required was 3.5 lb at a pressure of 50 psi.

A large number of photographs were taken of the valve and valve components that are not included in this report. These photographs are stored permanently (electronically) on the Acuren server and are available upon request.

The subject valve components were returned to RCMP, Kamloops Detachment, "Attention Cpl. [redacted]", by courier on August 26, 2022.

Please call at your convenience if you have any questions.

Yours truly,

ACUREN GROUP INC.

Bob Milne, P.Eng.

BM/ds
Appendixes

APPENDIX

FIGURES 1 - 16

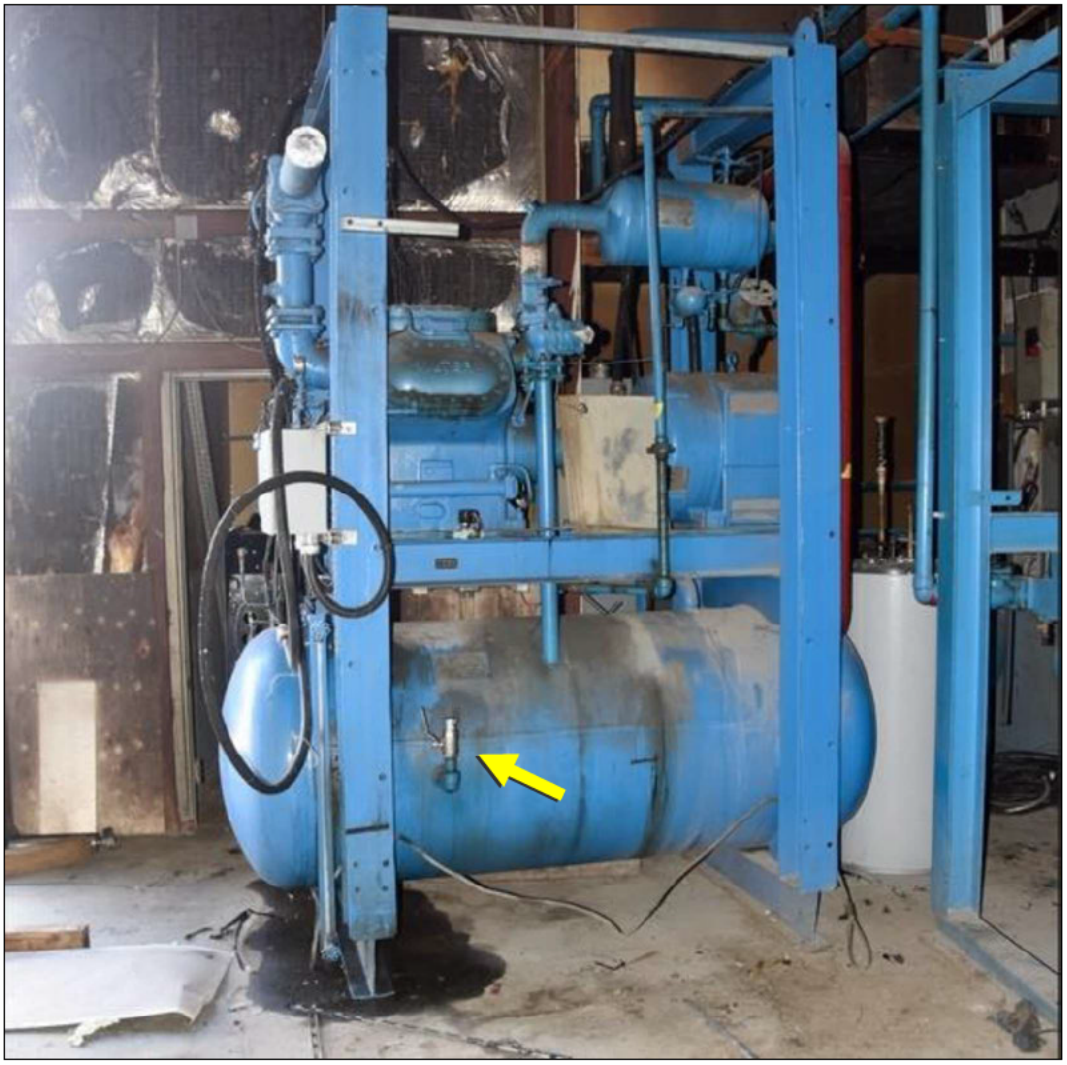


Figure 1 Overall view of subject valve installed vertically on ammonia tank (arrow). Lever is in "open" position with outlet side of valve in the upward position (site photo).

Figure 2 Overall view of subject valve with attached fittings and pipe segment. Valve was mounted vertically with pipe segment in the "up" position.

Figure 3 View of valve showing downward permanent bend in lever of approximately 20°.

Figure 4 View of deformed locking tab showing deformation preventing proper sliding and positioning of the locking tabs; however, the valve can be opened and closed normally.

Figure 5 Close-up view of deformed locking tab. Tab can slip by cast-in stop.

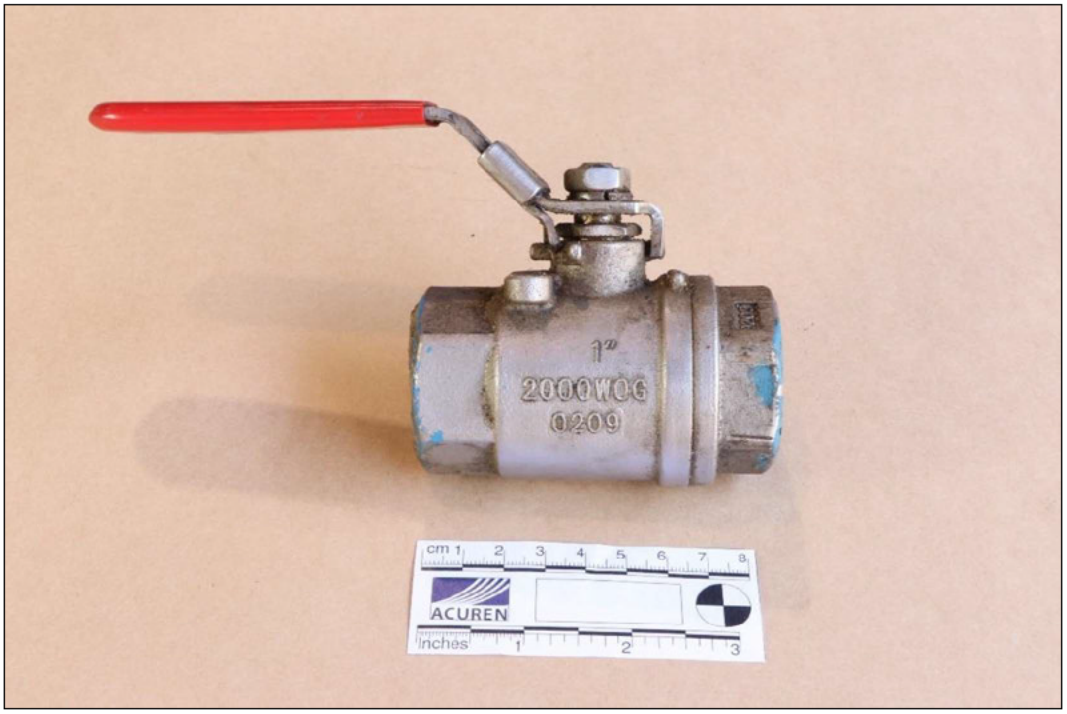


Figure 6 Undamaged valve #2 showing straight lever.

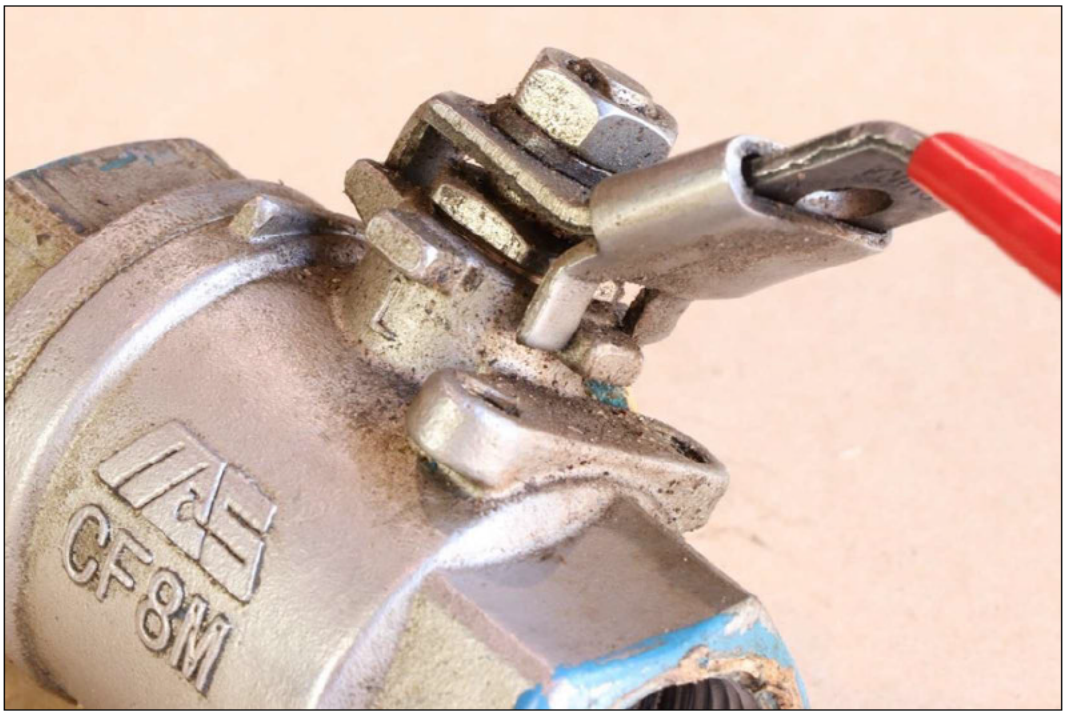


Figure 7 Undamaged locking device on valve #2.

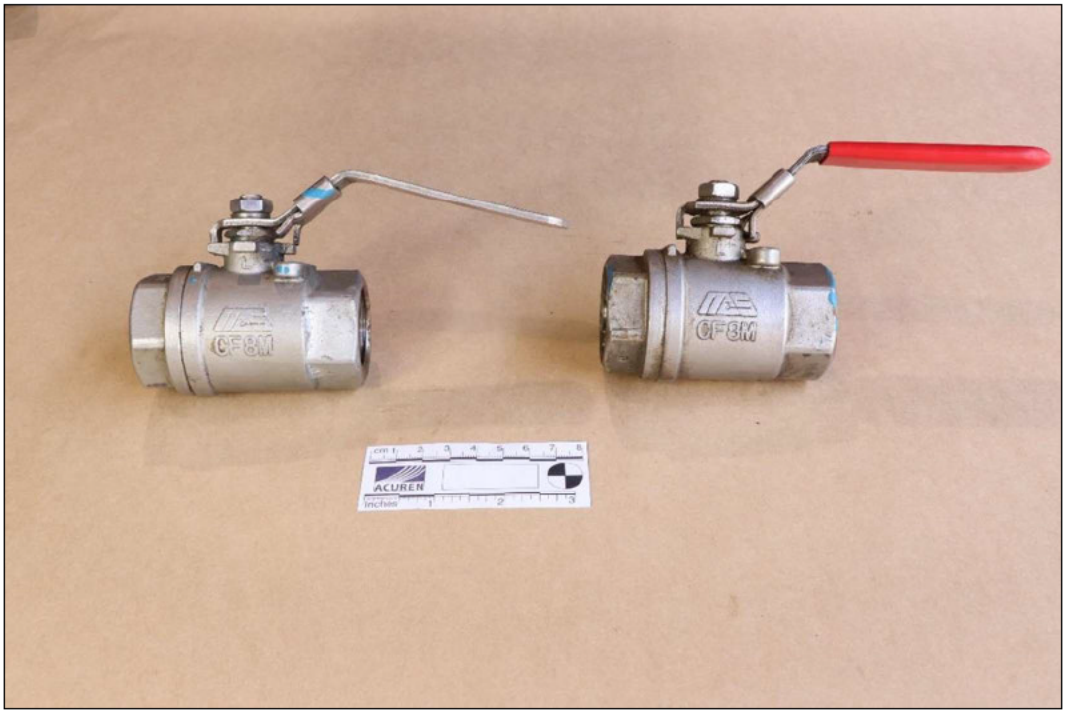


Figure 8 Subject Valve #1 and Valve #2 side by side showing permanent bend in Valve #1 lever.

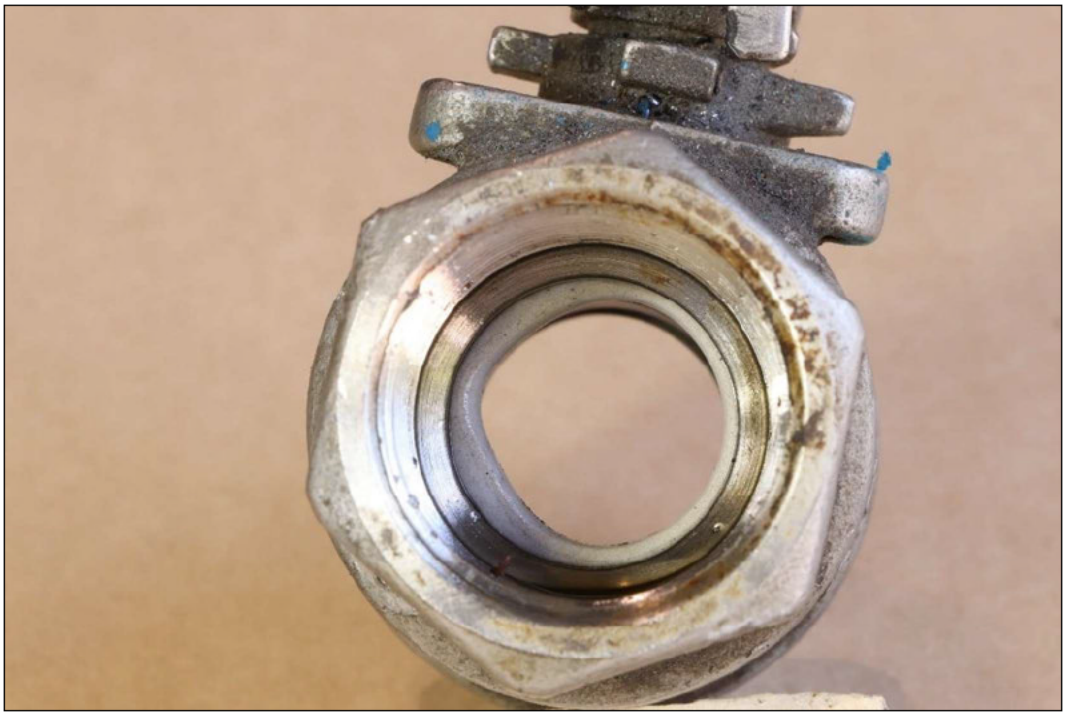


Figure 9 Deformation in outlet seal partially blocking 1" diameter hole.

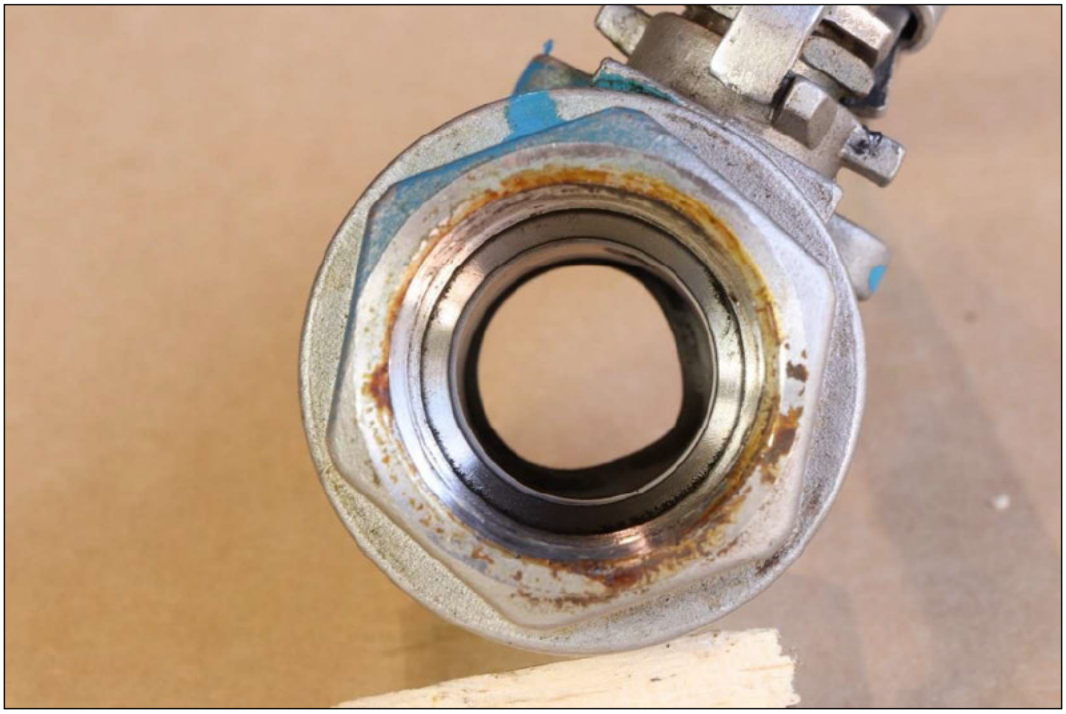


Figure 10 Concentric seal on inlet seal.

Figure 11 Load measuring system used for determining operating loads on valve.

Figure 12 Typical leak test @ 200 psi.

Figure 13 Seals removed from subject valve. Deformed outlet valve is on left.

Figure 14 Valve opening at 45° lever movement. Note maximum seal deformation is at location of partial opening.

Figure 15 Close-up view of cleaned outlet seal. Most severe deformation is at upper right. Small tear is at arrow.

Figure 16 Close-up view tear shown at arrow in Figure 15.

Figure 17 Simulated overload of locking device on #2 valve (left side). Subject #1 valve shown on right for comparison.

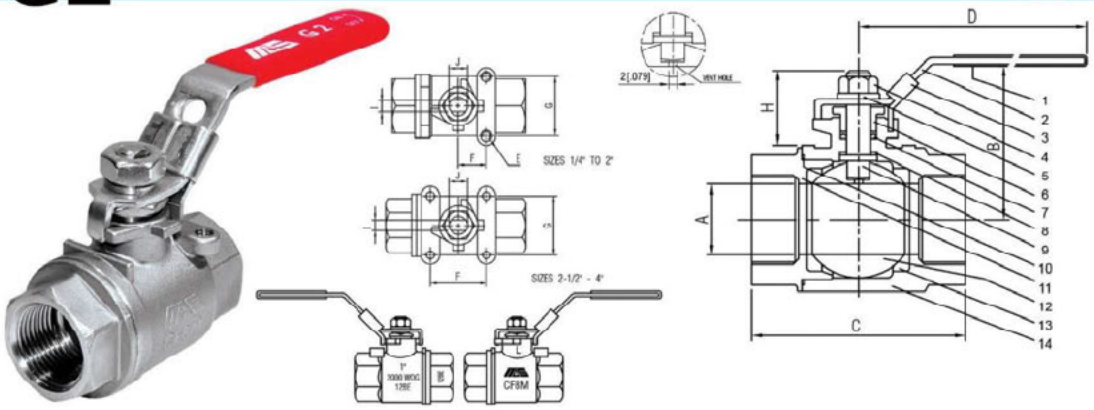
APPENDIX B

DRAWING

M. A. Stewart & Sons Ltd.
VALVES AND FITTINGS

G Series
Investment Cast Stainless Steel
Two Piece Full Port
2000 WOG
Ball Valves

G2

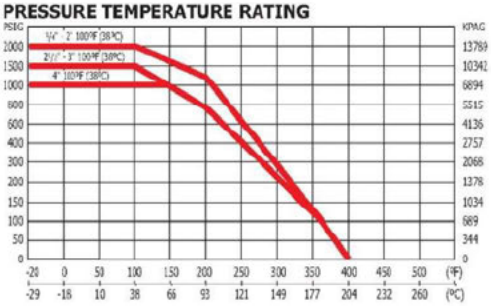


- Full port
- NPT threads to ANSI B1.20.1
- Two piece body
- Floating ball
- Blowout proof stem
- Adjustable packing nut
- Locking lever handle
- Actuator mounting pad
- Complies to NACE MR-0103
  Complies with manufacturer requirements of NACE MR0175/ISO15156
- 2000 PSI, WOG 1/4" to 2"
- 1500 PSI, WOG 2-1/2" to 3"
- 1000 PSI, WOG 4"

- **Available with Oval handle for size range: 1/4"-2"**
- **1/4" & 3/8" have non-tapped reserve holes cast in**
- **1/2" to 2" mounting pads are tapped**
- **2 1/2" to 4" mounting pads are dimpled at the drilling locations**

NAME / MATERIAL		
NO.	PART NAME	MATERIAL
1	Handle Grip	Vinyl
2	Handle	A276 TYPE 304
3	Locking Device	A276 TYPE 304
4	Handle Nut	A276 TYPE 304
5	Stem Washer	A276 TYPE 304
6	Gland Nut	A276 TYPE 304
7	Packing	PTFE
8	Thrust Washer	R-PTFE 15% GLASS-FILLED
9	Stem	A276 TYPE 316
10	Gasket	PTFE
11	Cap	A351 GRADE CF8M
12	Ball	A351 GRADE CF8M
13	Seat	R-PTFE 15% GLASS-FILLED
14	Body	A351 GRADE CF8M

PRESSURE TEMPERATURE RATING



NOTE 1 Untapped
NOTE 2 Dimpled at drilling locations

DIMENSIONS														
SIZE		mm/in A	mm/in B	mm/in C	mm/in D	E	mm/in F	mm/in G	mm/in H	mm/in I	mm/in J	CV	WEIGHT KGS/ LBS
8	1/4	9.6	50.28	55.80	96	NOTE (1)	12.7	25.4	20.78	5.52	8.00	7	0.230
		0.378	1.980	2.197	3.780		0.5	1.00	0.818	0.217	0.315		0.506
10	3/8	9.6	50.28	55.80	96	NOTE (1)	12.7	25.4	20.78	5.52	8.00	7	0.225
		0.378	1.980	2.197	3.780		0.5	1.00	0.818	0.217	0.315		0.495
15	1/2	12.5	52.6	60.5	96	M5	12.7	25.4	23.1	5.55	8.00	15	0.280
		0.492	2.071	2.382	3.780		0.5	1.00	0.909	0.219	0.315		0.616
20	3/4	20	59.25	72.5	119	M6	15.80	29.40	28.75	6.50	10	45	0.520
		0.787	2.333	2.854	4.685		0.622	1.157	1.132	0.256	0.394		1.144
25	1	24.7	62.35	85.5	119	M6	15.80	29.40	27.85	6.50	10	65	0.765
		0.972	2.455	3.366	4.685		0.622	1.157	1.096	0.256	0.394		1.683
32	1 1/4	32	79.90	93	149	M8	17.68	35.35	36.20	8.07	12.00	125	1.292
		1.260	3.146	3.661	5.866		0.696	1.392	1.425	0.317	0.480		2.842
40	1 1/2	38.1	84.8	110.5	149	M8	25	49.50	37.30	8.07	12.00	175	1.864
		1.5	3.339	4.350	5.866		0.984	1.949	1.469	0.317	0.480		4.101
50	2	50	94.6	128	174	M8	23.6	50	36.1	10.00	14.00	380	3.170
		1.969	3.724	5.039	6.850		0.929	1.969	1.421	0.394	0.551		6.974
65	2 1/2	63.50	122.05	153.8	244	NOTE (2)	72.10	72.10	45.35	12.00	16.00	500	5.796
		2.500	4.805	6.055	9.606		2.839	2.839	1.785	0.472	0.630		12.751
80	3	76	131.55	175.5	244	NOTE (2)	70.00	73.00	44.85	12.00	16.00	900	8.285
		2.992	5.179	6.909	9.606		2.756	2.874	1.766	0.472	0.630		18.227
100	4	100	178.6	233	321	NOTE (2)	102	102	64.5	18	23	1250	20.5
		3.937	7.031	9.173	12.637		4.015	4.015	2.539	0.708	0.905		45.194

APPENDIX C

NONDESTRUCTIVE EXAMINATION REPORT
(Dated August 22, 2022)

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Fax: 604.274.7235

A Higher Level of Reliability

NONDESTRUCTIVE EXAMINATION

CLIENT: **TECHNICAL SAFETY B.C**
600 – 2889 East 12th Avenue
Vancouver, BC
V5M 4T5

DATE: Aug 22, 2022
ACUREN JOB #: 605-J030173
REPORT #: 605-J030173-Technical safety BC-08 22 2022-SA01
CONTRACT/PO: TBA WO:
WORK LOCATION: Acuren Shop- Richmond, BC

ATTENTION: **BOB MILNE**
PROJECT: Stainless steel valve
ITEM(S) EXAMINED: Internal and external surfaces

PART #: MATERIAL: Carbon steel THICKNESS: Various

SCOPE: Conduct visible water washable liquid penetrant inspections on 100% of internal and external surfaces on a small stainless steel valve body.

TYPES OF INSPECTION: Liquid Penetrant

TEST DETAILS: LIQUID PENETRANT

ACCEPTANCE STANDARD: Clients info/Crack detection REVISION: 2019
PROCEDURE/TECHNIQUE: CAN-PT-14P001 REVISION: 17

TYPE: Visible		METHOD: Solvent Removable	
FAMILY BRAND: Magnaflux		LIGHTING EQUIPMENT: Troublelight	
PENETRANT: SKL-SP2	DWELL TIME: 20 Min.	BLACKLIGHT MAKE: N/A	S/N: N/A
PENETRANT REMOVER: Cleaner. SKC-S	DRY TIME: 15 Min.	LIGHT METER S/N: 11010292	CAL DUE: Oct 26, 2022
DEVELOPER: SKD-S2	DWELL TIME: 15 Min.	LIGHT INTENSITY: > 100 fc (1076 lx)	
DEVELOPER TYPE: Non Aqueous			
BATCH NOS. (WHEN REQUIRED): PENETRANT: ---		REMOVER: ---	DEVELOPER: ---
TEST SURFACE CONDITION: As Welded/As ground		TEST SURFACE TEMPERATURE: 9°C to 10°C	

RESULTS:

As requested, visible water washable liquid penetrant inspections were conducted on 100% of internal and external surfaces on a small stainless steel valve body.

No indications were found.

CLIENT: _____ (CLIENT PRINTED NAME) _____ (CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY)

ACUREN TECHNICIAN: Sam Alikhani
1st Technician
CGSB UT1, PT2, SNT UT1, PT2
CGSB Reg. #12640

2nd Technician

REVIEWER:

	TOTAL HOURS	S.T.	O.T.	SHIFT
1ST TECHNICIAN:	2		2	Day ☒
2ND TECHNICIAN:				PM ☐

KILOMETRES: 0 OTHER CHARGES: YES ☐ NO ☒
(IF YES, SEE DAILY OR PROJECT TIME REPORT)

(Generated Using: CAN-QUA-02F007 R09 - 02/26/2020)

Photo 1:

An overview of the LPI results of the stainless steel valve.

No indications were found.