

**Flow Control Division**

*Anchor/Darling Valves
BW/IP Valves
Edward Valves
Valtek Control Products
Worcester Valves*

July 1, 2022

US Nuclear Regulatory Commission
Document Control Desk
11545 Rockville Pike
Rockville, MD 20852-2746

Subject: Solenoid Coil Failure of Model 38878-8 Solenoid Valve at Catawba Nuclear Station for use on FWIV Actuator

Attachment 1 – As-Found Inspection Report
Attachment 2 – Ohmega Failure Analysis Report
Attachment 3 – Shipment Data

This letter is to notify the US Nuclear Regulatory Commission that, in accordance with the provisions of 10CFR Part 21, we have concluded our assessment and are reporting the results below.

Description:

On February 2, 2022, Flowserve was informed by Duke Energy that a Model 38878-8 solenoid valve installed on a feed water isolation valve actuator failed a routine coil resistance test due to low resistance at the customer site. The solenoid valve was returned to Flowserve for evaluation.

Evaluation:

Flowserve received the solenoid valve and completed an initial inspection (See Attachment 1). Flowserve found there to be no apparent external damage and noted that the tamper-indicating fastener paint was not broken indicating that the solenoid valve had not been disassembled. Flowserve tested the resistance across the coil and confirmed the condition as described by the customer. The coil resistance measured 26.7 Ohms. The required resistance is 290-320 Ohms per Flowserve's internal specification and 175-500 Ohms per Duke Energy's internal procedure. As no root cause of failure was evident after initial inspection and testing of the solenoid valve assembly and coil, Flowserve returned the coil to the original equipment manufacturer, Ohmega Coil, for inspection to determine if a manufacturing defect is potentially the reason for failure.

Upon receipt of the coil, Ohmega verified the condition and found the low resistance condition to be as described at 26.65 Ohms at 68 degrees F. Ohmega noted that there were no defects on the outer molded surface. The coil was machined back to expose the magnet wire. The lead wire solder joints were inspected and found to be properly attached and insulated. Due to the unit being molded in epoxy, it was not possible for Ohmega to inspect the coil in stages to fully evaluate the magnet wire.

Following the investigation by the coil manufacturer, Ohmega, it was determined that the lead wires and solder joints were not the cause of failure. Per the manufacturer's failure analysis report, the exact cause of failure could not be determined. Ohmega states that a possible cause for the failure is a small nick in the magnet wire insulation that over time caused the coil to short out (See Attachment 2 for Ohmega Failure Analysis Report).

Flowserve notes that an overvoltage condition could also cause a similar failure but no obvious evidence of an overvoltage condition (discoloration, damage to housing, obvious fused conducting material, etc.) was found during inspection.

The subject Coil (Part number 04103969DEDCATD) has been shipped from Flowserve at least 273 times with the subject issue being the only known failure recorded to date (See Attachment 3). Before shipping, each coil is tested at Flowserve for both operability and resistance. During this process, each coil is cycled approximately 150 times for a total duration of approximately 750 seconds to verify the coil is satisfactory before delivery to the customer.

Extent of Condition:

Because the coil windings are self-contained and can move very little within the housing, the probability of a coil enduring 150 cycles, passing all electrical and functional tests, and subsequently failing in service is very low. In this case, this low probability outcome occurred, based on the findings of the investigation. However, Flowserve does not believe that this isolated incident is indicative of an issue with the manufacturing or testing methods of the coil and does not believe that this issue affects other coils in service based on historical reliability and the failure mode.

Corrective Actions:

Though the exact cause of the failure could not be determined within the magnet wire, Ohmega suggests a possible manufacturing improvement of winding the coil with a varnish to provide extra insulation of the magnet wire.

Additionally, Flowserve suggests that plant operators using these solenoid coils measure the resistance of the coil periodically, especially after the coil has been energized for testing or service.

Summation:

In summary, the Model 38878-8 solenoid valve failed a routine coil resistance test at Catawba Nuclear Station while installed on a feed water isolation valve actuator. The solenoid valve was returned to Flowserve where the low resistance was confirmed. The solenoid coil was then sent to the OEM for further evaluation.

The OEM (Ohmega) completed their analysis and found the reason for failure to be associated with the magnet wire, but the exact point of failure could not be located due to the construction of the coil.

Additionally, Flowserve compiled shipment data for the subject coil and found there to be at least 273 instances where the part was shipped to customers. Of those 273+, this case is the only known instance of a failure associated with the coil.


Due to the rigorous functional testing and the historical reliability of the coil in the field, Flowserve does not believe this incident is indicative of an issue with the manufacturing or testing of the coil and concludes that this issue does not affect other coils currently in service.

Ohmega suggests a possible manufacturing improvement of winding the coil with a varnish to provide extra insulation of the magnet wire.

Flowserve suggests that plant operators using these solenoid coils measure the resistance of the coil periodically, especially after the coil has been energized for testing or service.

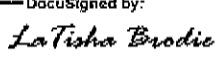
Respectfully Submitted,

Sincerely,

DocuSigned by:

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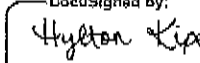
Matt Hobbs, PE
 Engineering Manager
 Office: (919) 334-7127
mhobbs@flowserve.com

Sincerely,

DocuSigned by:

 61E011ABE1EA422...

LaTisha Brodie
 QA Supervisor
 Office: (919) 334-7113
latwilliams@flowserve.com

Sincerely,

DocuSigned by:

 8968E52703D547B...

Hylton Kipe
 Director, Plant Manager
 Raleigh Operations
 Office: (931) 432-4021
hkipe@flowserve.com

Attachment 1 – As-Found Inspection Report

**Flow Control Division***Anchor/Darling Valves**BWIP Valves**Edward Valves**Valtek Control Products**Worcester Valves***March 3, 2022****As Found Inspection Report for Returned Valve****Order Information:**

Sales Order Number: 135833 (RMA #11477)

Customer: Duke Energy Carolinas, LLC

Purchase Order Number: N/A

Scope:

The order consists of QTY 1 Solenoid Valve, Model 38878-8, Serial Number BR-332.

The subject valve was returned on Flowserve Sales Order 135833 for a failure mode analysis to be performed on the solenoid coil originally supplied on 124353, Line Item 001. The valves were returned to Flowserve for evaluation due to low resistance readings across the solenoid coil. Below are the results of the as-found condition.

Inspection Results

The solenoid was received with no apparent external damage. The tamper-indicating fastener paint was not broken indicating that coil housing had never been removed and the internal components had not been manipulated (See Attachment 1, Images 1 and 2). Resistance measurements across the solenoid coil leads resulted in a value of 26.7 Ohms (See Attachment 1, Image 3). This is consistent with the measurements obtained by Duke Energy. After the initial value was recorded, the wire was manipulated with the multimeter leads still connected. The resistance did not fluctuate, indicating that issue most is most likely in the coil itself.

Research revealed that the subject valve was sent for refurbishment/repair in 2018 during an outage under normal process for QA-1 Borg Warner Solenoid Valves. Refurbishment was performed under Flowserve Sales Order 124353 in early 2019. During refurbishment, the solenoid coil was replaced and tested. Post-refurbishment testing results show that coil resistance was measured to be 296 Ohms during functional testing before shipment (See Attachment 2, Step 6.6.1) and was within specification. Flowserve also confirmed that the original dedication of the solenoid coil itself was satisfactory. The heat number for the solenoid coil on the failed unit is CMT941. See Attachment 3 for dedication results of solenoid coils under this heat number. Note that all were satisfactory.

Conclusion

Flowserve recommends disassembly of the solenoid valve to further investigate the cause of coil failure.

Jake Buske
Product Engineer
Flowserve Corp, Flow Control Division
1900 S. Saunders St.
Raleigh, NC 27603

Image 2 – Tamper-Indicating Fastener Paint (2)



Image 3 – Multimeter Reading



Attachment 2 - Functional Test Results for BR332
As-supplied condition on RMA 10958 (Flowserve Sales Order 124353-001)



METHOD SPECIFICATION

Exhibit III	TITLE: FUNCTIONAL TEST PROCEDURE FOR 38878 SOLENOID VALVES
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MS : 9792	Original Date: 5/04/2016	Revision Date: -
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Flowserve Corporation	Test Summary Sheet		Rev 0			
Customer: D&K C	Shop Order: 124353 w/o 565338					
Tested By: 3883	Ass'y S/N: BR332	Part No. 38878-8				
Date: 2-7-19	Limits	Record Value	By:			
Para.	Description	U/M	Min	Max	Record Value	By:
6.1.5	PROOF TEST <u>Limits:</u> No external leakage or deformation			Zero	ZERO	
6.2.4.3	STROKE ADJUSTMENT <u>Limits:</u> Gap setting on -1, -2, -4, -5, and -6, -7, -8 assemblies	Inches	0.0025	0.0035	0.0025	
6.2.4.6	STROKE ADJUSTMENT <u>Limits:</u> Gap setting on -3 assemblies	Inches	0.018	0.02	NA	
	PULL-IN VOLTAGE ADJUSTMENT On -1, -5, -7, -8 Assemblies <u>Limits:</u> (Ref. Para. 6.3.2.5) Leakage: 1 Drop/10 Minutes	Drop/10 Minutes		1	1	
	<u>Limits:</u> (Ref. Para. 6.3.2.6) Leakage: 1 Drop/1 Minute @ 90 +/- 1 VDC	Drop/10 Minutes		1	1	
	<u>Limits:</u> (Ref. Para. 6.3.2.8) Steady-State current: .37 to .45 amperes	AMPS	0.37	0.45	0.40	

Form #36-Q-1365



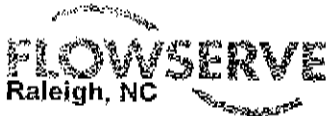
METHOD SPECIFICATION

Exhibit III	TITLE: FUNCTIONAL TEST PROCEDURE FOR 38878 SOLENOID VALVES
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MS : 9792	Original Date: 5/04/2016	Revision Date: -
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Flowserve Corporation	Test Summary Sheet	Rev 0				
Customer: <i>DUKE</i>	Shop Order: <i>124353</i> <i>WO 565338</i>					
Tested By: <i>3887</i>	Ass'y S/N: <i>B2332</i>	Part No. 38878-8				
Date: <i>2-7-19</i>	Limits	Record Value				
Para.	Description	U/M	Min	Max	By:	Date:
6.3.3.5	For -2 & -8 Assemblies <u>Limits</u> (Ref. Para. 6.3.2.5) 1 drop/10 minutes	Drop/10 Minutes		1		
	<u>Limits</u> (Ref. Para. 6.3.2.6) Leakage: 1 Drop/1 Minute @ 90 +/- 1 VDC	Drop/10 Minutes		1		
	<u>Limits</u> (Ref. Para. 6.3.2.8) Steady-State current: .37 to .45 amperes.	AMPS	0.37	0.45		
6.3.4	For -3 Assemblies <u>Limits</u> (Ref. Para. 6.3.4.5) Leakage: 1CC/10 minutes	CC/Min.				
	<u>Limits</u> (Ref. Para. 6.3.4.6) Steady-State current: .37 to .45 amperes.	AMPS	0.37	0.45		
6.3.5	For -4 Assemblies <u>Limits</u> (Ref. Para. 6.3.5.4) Leakage: 1CC/10 Minutes @ 90 +/- 1 VDC	AMPS	0.37	0.45		

Form #36-Q-1365



METHOD SPECIFICATION

Exhibit III	TITLE: FUNCTIONAL TEST PROCEDURE FOR 38878 SOLENOID VALVES
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MS : 9792	Original Date: 5/04/2016	Revision Date: -
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Flowserve Corporation	Test Summary Sheet			Rev. 0	
Customer: Duke	Shop Order: 124353 W/O 565358				
Tested By: 3883	Ass'y S/N: BR332		Part No. 38878-8		
Date: 2-7-19	Limits		Record Value	By:	
Para.	Description	U/M	Min	Max	Date:
6.3.5	(Continued) <u>Limits</u> (Ref. Para. 6.3.2.8) Steady-State current: .37 to .45 Amperes	AMPS	0.37	0.45	NA
6.4	External Leakage Test <u>Limits:</u> No external leakage allowed			ZERO	ZERO
6.5	Swab Fluid From Valve Cavity & Coil Housing		CHECK	OFF	✓
6.5.1	Apply Loctite TL 290		CHECK	OFF	✓
6.5.2	Set Screw Tolerances <u>Limits:</u> -3: .018 to .020 in Others: .0025 to .0035 in	Inches			10025
6.5.3	Tamper Proof Paint		CHECK	OFF	✓
6.5.4	All Assemblies Torque End Cap	FT- LBS	20	25	20
6.6.1	<u>Coil Resistance Test</u> <u>Limits:</u> 290 to 320 OHMS.	OHMS	290	320	296
6.7.1	<u>Insulation Resistance Test</u> <u>Limits:</u> There shall be no breakdown or arcing.				✓

Form #36-Q-1365



METHOD SPECIFICATION

Exhibit III	TITLE: FUNCTIONAL TEST PROCEDURE FOR 38878 SOLENOID VALVES
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MS : 9792	Original Date: 5/04/2016	Revision Date: - 50/27355 A55 X5/W B832 - W/056533P
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Para.	Tested By:					By:
	3887					Date:
7.0	<u>Marking:</u> (For New Assemblies) Vibro-Etch: 1) Flowserve P/N 38878- on valve body 2) S/N on valve body flange		Check	Off	✓	
8.0	<u>Cleaning and Packaging</u>		Check	Off	✓	

PURR4001 RMASSENGILL R.Massengill

Avante 9.7.5c Flowserve Raleigh NC Production

Company -->Flowserve US Inc.

PAGE 13

PO Nbr	256959	Po Revision	1	Supplier		Drop Ship	
Receiver Nbr	347101	Date Rcvd	01/15/18	Packslip Nbr	157968		
Rcvd Facility	1			Nbr of Boxes			
Shipped Via	Conway Prt or Fed Ex				OHMEGA SOLENOID CO. INC.		
Buyer	23 Scott Heil				SANTA FE SPRING CA		
Requester							

Advice Note

THE UPS STORE 4378

Lin	Item/GL/WO	Seq	Job	Task	Suppl	Item Nbr	Certs Req?	Insp Req?	Qty Rec	Recv Qty to Date	Qty Acc	Qty Rej	Qty Test
0001	04103969DEDCATD COIL SOLENOID						N	Y	9	19	9	0	9
									Bal Due	0			

General Location: Large Cast
Revision 01 Req Nbr
Bin Nbr Insp Req Lot Number(s)
Supplier Lot Number:

Product Class Code: 8010

Rejection Reason:

DMR Number(s):

Drawing No: D-38903 REV-L

RMC: 55555

CMT941

*Qty.
9 pcs.*

*KGH
01/15/18
LEVEL II*

*KGH
01/15/18
LEVEL II*

*KGH 01/15/18
LEVEL II*

Receiver

Inspector

Stock Clerk

ATTACHMENT 1

9196627742

01/14/2018 05:01

Flowserve Raleigh

10CFR21 DEDICATION OF COMMERCIAL GRADE ITEMS

Part Name: SOLENOID COIL OHMEGA

Part Number: 04103969DEDCA1D

Revision: 2

By: Sizemore, Andy

Date: 6/20/2014

Code Number(s): CMT941

RMC Number: 55555

Drawing Number(s): 38903

Technical Evaluation Number: RTE-0015

PDF00020

Flowserve P.O./F.O./R.R. Number: 256959-001/ Recv.# 347101

Vendor: Ohmega Solenoid Co.

Quantity Received: 9 pcs.

Date: 01-17-2018

Method: 1

Verification Attributes (Quantity Sampled: 9 pcs.)

Attribute	Required	Actual Measurement	Inspector
OHMEGA # 38903			
PER DRAWING			

Comments: SEE COMMENTS UNDER DIMENSIONAL CRITERIA FOR MATERIAL VERIFICATION IF APPLICABLE

VERIFY LEADWIRE IS 14 GAGE WIRE

FUNCTIONAL TEST PER PDF00020

Special Order Requirements:

Q.C. Cmts 2-15-18

Dimensions:

OD- 2.255/2.315	2.308, 2.305, 2.302, 2.307, 2.307, 2.307, 2.307, 2.307, 2.307
Overall Length- 4.00/4.06	4.05, 4.06, 4.05, 4.06, 4.06, 4.04, 4.06, 4.05, 4.05
Height- .380/.420	.395, .403, .401, .411, .409, .407, .411, .409, .407
Dia.- .440/.480	.466, .465, .465, .465, .464, .466, .468, .464, .465
ID- .750/.810	.778, .781, .779, .776, .782, .777, .776, .771, .774
Center to Center- .75/1.00	.88, .89, .89, .88, .89, .90, .89, .89, .89
Wire Length- 36"	37", 37", 36 1/2", 37", 37", 37", 37", 37", 37"

KGN
01-17-18
LEVEL II

Measuring and Test Equipment Serial #s: Q1B-369, Q1B-188, QT2-AD/V-108, Tape Measure *33882341 9891302*

Verify that Counterfeit and Fraudulent Part/Material Checks Have Been Performed: KON 2-15-18

Inspector: Karen J. Hays

Date: 02-13-18

QA Signature: [Signature]

QA 580
LEVEL II

Date: 2-15-18

- Methods:
- 1. Special tests and inspections
 - 2. Commercial grade survey of supplier
 - 3. Source verification of the material
 - 4. Acceptable supplier/item performance record

By: M. O'Hara *M. O'Hara* 4/23/05 Appd By: *[Signature]* 4/23/05

PDF00020

INITIAL

DATE

SEE DRAWING 38903, NOTE 15

RESISTANCE TEST

- 1) VERIFY DC RESISTANCE TO BE 290-320 OHMS AT AN AMBIENT TEMPERATURE OF $70^{\circ} \pm 10^{\circ}\text{F}$.

RAC2-15-18**DIELECTRIC TEST**

- 2) USING A HYPOT TESTER, APPLY 1450-1500 VAC, 60 HZ, SINGLE PHASE, BETWEEN BOTH LEAD WIRES AND BODY OF SOLENOID FOR (1) ONE MINUTE.

RAC2-15-18

LIMITS: THERE SHALL BE NO BREAKDOWN OR ARCING.

VOLTAGE EXCITATION (CURRENT LIMIT) TEST

- 3) APPLY A VOLTAGE OF 140 ± 5 VDC FOR 20 CYCLES, (A COUPLE OF SECONDS PER CYCLE)

RAC2-15-18

LIMITS: CURRENT SHALL NOT EXCEED 0.5 AMPERES.

RESISTANCE TEST

- 4) REVERIFICATION OF RESISTANCE AFTER COIL COOL OFF, ABOVE.

RAC2-15-18

LIMITS: OHMS SHALL BE WITHIN 1% OF VALUE OF 1), AT 290-320 OHMS.



OHMEGA SOLENOID CO., INC.
SOLENOIDS • TRANSFORMERS • MOLDED COILS

10912 So. Painter Ave. • P.O. Box 2747
 Santa Fe Springs, California 90670
 (562) 944-7948 • FAX: (562) 941-1981

INVOICE NO.

PACKING LIST **PL-45641**

BILL TO:

SHIP TO:

Flowserve Flow Control Division - Raleigh Operations 1900 S. Saunders Street Raleigh, NC 27603	Flowserve Flow Control Division - Raleigh 1900 S. Saunders Street Raleigh, NC 27603
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DATE	SHIP VIA	F.O.B.	TERMS	
1/12/18	FedEx Collect	Origin	Net 30	
PURCHASE ORDER NUMBER	BUYER	WORK ORDER NUMBER		
256959 ✓		13525		
QUANTITY	PART NUMBER/DESCRIPTION		UNIT PRICE	EXTENDED PRICE

9 / 38903 REV L COIL
 ITEM #0001 P/N 04103969DEDCATD ✓

COUNTRY OF ORIGIN: USA ✓

WE HEREBY CERTIFY THE MATERIAL MENTIONED ON THIS SHIPPER CONFORMS TO ALL PURPOSES TO APPLICABLE SPECIFICATIONS AND/OR STANDARDS. COMPLETE PHYSICAL AND CHEMICAL TEST REPORTS AS REQUIRED ARE ON FILE AND AVAILABLE FOR REVIEW. PROCESSING, PRODUCT TESTING, INSPECTION & CONTROL OF RAW MATERIAL SHALL BE IN CONFORMANCE WITH ALL APPLICABLE SPECIFICATIONS DRAWINGS AND/OR STANDARDS OF ALL COPIES ON THIS PURCHASE ORDER.

OHMEGA SOLENOID CO., INC.

BY *Patricia Oberg*
 QUALITY CONTROL CERTIFICATIONS

Customer	
Flowserve Valve S.O. No.	<i>04103969DEDCATD</i>
Component	<i>Solenoid Coils</i>
Traceability Code	<i>CMT 941</i>
Flowserve Q.A. Rep.	<i>8016</i> Date <i>1-26-18</i>
Authorized Inspector	<i>[Signature]</i> Date

Attachment 2 – Ohmega Failure Analysis Report

OHMEGA SOLENOID CO., INC.**Failure Analysis Report**

Customer: Flowserve
Date: 4-11-22

NCR Number: 1539
Part Number: 3890

Information:

PN 38903 1 pc Shipped PL-45641 PO 256959 1-12-18 (9 pc lot)

Requirement/Defect Description:

Resistance 290-300 Ω @ 68°F
Is: 26.7 Ω

Failure Analysis:

Verify reject – low resistance 26.65 Ω @ 68°F
Visual inspection – no defects found to outer molded surface

Tear down unit to inspect magnet wire/leadwire solder joint.

Note: because the unit is molded with epoxy it is not possible to inspect the coil in stages to find failure

Steps taken:

Machine back end of unit to remove outer bobbin flange, exposing magnet wire.
Remove coil wire to inspect solder joint

Findings:

Coil is covered by 2 layers of Kapton Tape prior to installing leadwire, solder joint is covered by sleeving and then glass tape held in place with yarn.

Unable to determine cause of failure.

Possible cause:

Small nick in the magnet wire insulation that over time caused the coil to short out
Unable to determine due to nature of coil/molded

Comments:**Suggested improvement:**

We wind coil with RSN-00997 varnish to provide extra insulation of magnet wire

Completed By: Tina Miller Ives

Date: 6-29-22

OHMEGA SOLENOID CO., INC.

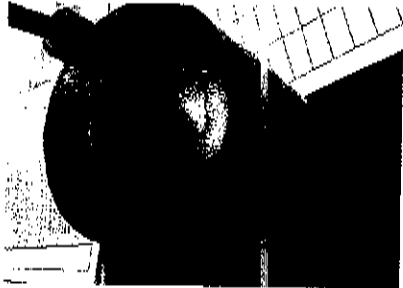
Failure Analysis Report

Customer: Flowserve
Date: 4-11-22

NCR Number: 1539
Part Number: 3890

Reference:

1) Unit as Received



2) Remove Epoxy front end
Magnet Wire – 2 layers of Kapton Tape – Glass Tape visible



3) Inside Coil
Magnet wire removed up to Kapton Tape



4) Solder Joints, sleeving opened to inspect solder joint



Attachment 3 – 04103969DEDCATD Shipment Data**QUANTITY BY CUSTOMER**

Customer, Site	Quantity
Comanche Peak Power Company	12
Comanche Peak	12
Duke Energy	89
Catawba	89
EFH CORPORATE SERVICES	46
Comanche Peak	46
Exelon	62
Braidwood	30
Byron	32
First Energy	8
Beaver Valley	6
Long term storage	2
FPL Energy	4
Seabrook	4
Luminant	4
Comanche Peak	4
Nextera Energy Seabrook LLC	22
Seabrook	22
Texas Utilities Electric Co.	8
Comanche Peak	8
TXU GENERATION COMPANY LP	18
Comanche Peak	18
Grand Total	273