

**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.

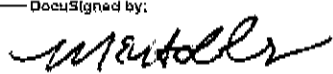
Due to the rigorous functional testing and the historical reliability of the coil in the field, Flowserve does not believe this incident is indicative of an issue with the manufacturing or testing of the coil and concludes that this issue does not affect other coils currently in service.

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.

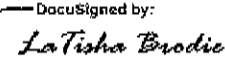
Respectfully Submitted,

Sincerely,

DocuSigned by:  
  
0BDBEB0375aC4E1...

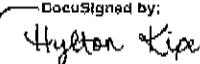
Matt Hobbs, PE  
Engineering Manager  
Office: (919) 334-7127  
[mhobbs@flowserve.com](mailto:mhobbs@flowserve.com)

Sincerely,

DocuSigned by:  
  
61ED11ABE1EA422...

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

Sincerely,

DocuSigned by:  
  
896BE52703D547B...

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

## **Attachment 1 – As-Found Inspection Report**

**Flow Control Division***Anchor/Darling Valves**BW/IP 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.

Flowserve U S Inc  
Flow Control DivisionRaleigh Operations  
PO Box 1961  
1900 South Saunders Street  
Raleigh, NC 27603Toll Free: 1-800-225-6989  
Phone: 1-919-832-0525  
Facsimile: 1-919-831-3369  
[www.flowserve.com](http://www.flowserve.com)

## Conclusion

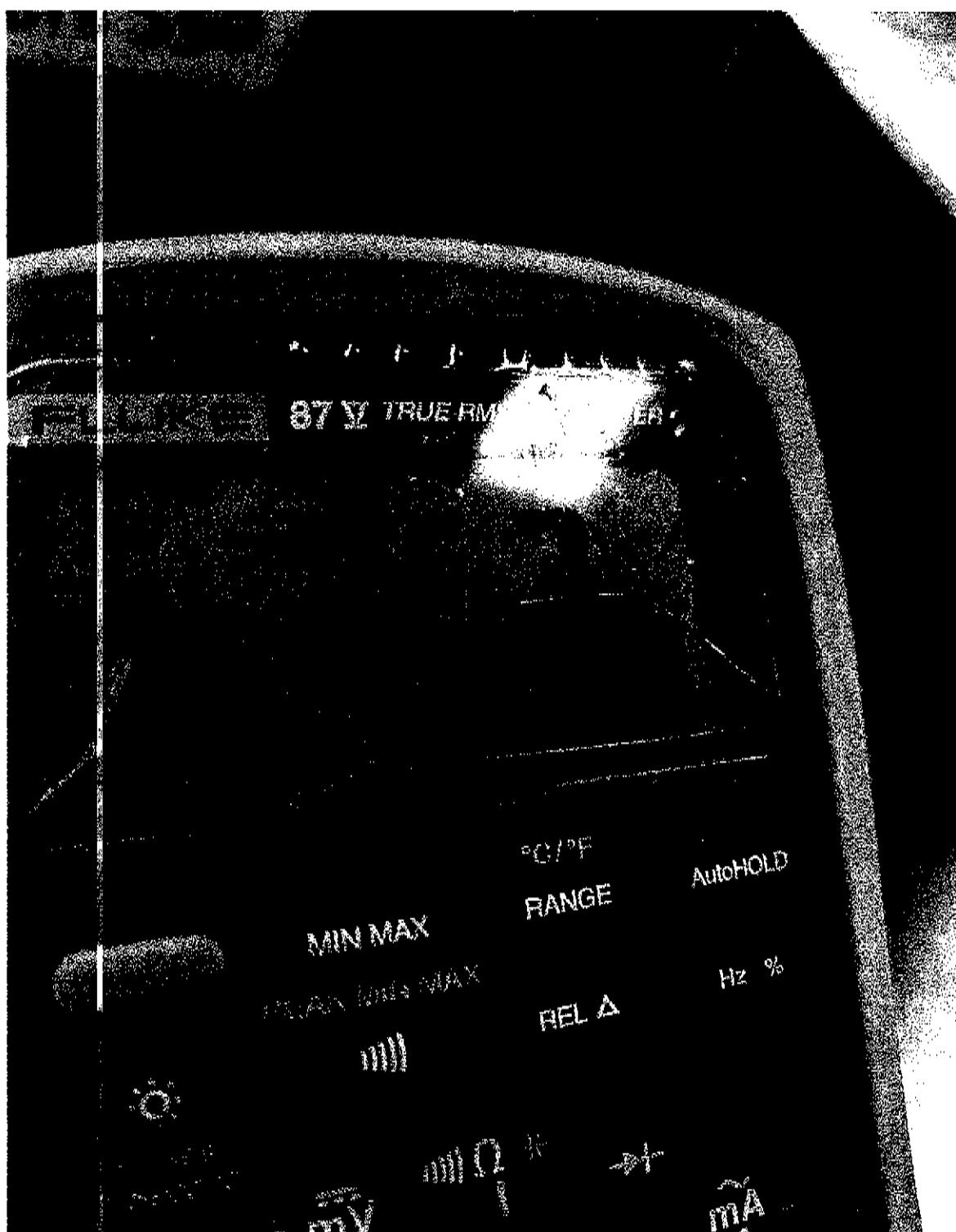
Flowserve recommends disassembly of the solenoid valve to further investigate the cause of coil failure.

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

Image 2 – Tamper-Indicating Fastener Paint (2)

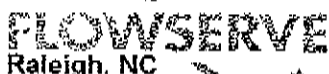


Image 3 – Multimeter Reading





**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: -

Flowserve Corporation		Test Summary Sheet				Rev 0
Customer: D&K				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		Date:
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



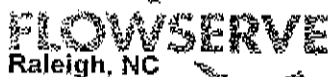
## METHOD SPECIFICATION

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: <u>DUKE</u>				Shop Order: <u>124353</u> <u>WO 565338</u>		
Tested By: <u>3887</u>		Ass'y S/N: <u>B2332</u>		Part No. 38878-8		
Date: <u>2-7-19</u>		Limits		Record Value		By:
Para.	Description	U/M	Min	Max		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>NA</u>	
	<u>Limits</u> (Ref. Para. 6.3.2.6) Leakage: 1 Drop/1 Minute @ 90 +/- 1 VDC	Drop/10 Minutes		1	<u>NA</u>	
	<u>Limits</u> (Ref. Para. 6.3.2.8) Steady-State current: .37 to .45 amperes.	AMPS	0.37	0.45	<u>NA</u>	
6.3.4	For -3 Assemblies <u>Limits</u> (Ref. Para. 6.3.4.5) Leakage: 1CC/10 minutes	CC/Min.			<u>NA</u>	
	<u>Limits</u> (Ref. Para. 6.3.4.6) Steady-State current: .37 to .45 amperes.	AMPS	0.37	0.45	<u>NA</u>	
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	<u>NA</u>	

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			.0025	
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: 50/27353 A55X5/N 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	✓	

15 JAN 18 10:01AM

Receiving Document

Page 1

PURR4001 RMASSENGILL R.Massengill

Avante 9.7.5c Flowserve Raleigh NC Production

Company -->Flowserve US Inc.

PO Nbr 256959 Po Revision 1  
Receiver Nbr 347101 Date Rcvd 01/15/18  
Rcvd Facility 1  
Shipped Via Conway Prt or Fed Ex  
Buyer 23 Scott Heil  
Requester

Packslip Nbr 157968 Supplier  
Nbr of Boxes OHMEGA SOLENOID CO. INC.  
SANTA FE SPRING CA

Drop Ship

Advice Note

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

General Location: Large Cast  
Revision 01 Reg 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.

KGA  
01/13/18  
LEVEL II

KGA  
01/15/18  
LEVEL II

KGA  
01/15/18  
LEVEL II

Receiver

Inspector

Stock Clerk

ATTACHMENT 1

Flowserve Raleigh10CFR21 DEDICATION OF COMMERCIAL GRADE ITEMSPart Name: SOLENOID COIL OHMEGAPart Number: 04103969DEDCATDRevision: 2 By: Sizemore, Andy Date: 6/20/2014 Code Number(s): CMT941RMC Number: 55555 Drawing Number(s): 38903Technical Evaluation Number: RTE-0015 PDF00020Flowserve P.O./F.O./R.R. Number: 256959-001/ Recv.# 347101 Vendor: Ohmega Solenoid Co.Quantity Received: 9 pcs. Date: 01-17-2018 Method: 1Verification 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:

**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  
01-15-18  
LEVEL II

Measuring and Test Equipment Serial #s: Q1B-369, Q1B-188, QT2-AD/V-108, Tape Measure 33882341 9331302Verify that Counterfeit and Fraudulent Part/Material Checks Have Been Performed: KON 2-15-18Inspector: Karen J. Hays Date: 02-13-18QA Signature: 77 QA 580 LEVEL II Date: 2-15-18

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

By: M. O'Hara 4/25/05 Appd By: [Signature] 4/25/05  
[Signature]

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  $140 \pm 5$  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

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 Oliver*  
 QUALITY CONTROL CERTIFICATIONS

Customer	
Flowserve Valve S.O. No.	<u>04103969DEDCATD</u>
Component	<u>Solenoid Coils</u>
Traceability Code	<u>CMT 941</u>
Flowserve Q.A. Rep.	<u>8046</u> Date <u>1-26-18</u>
Authorized Inspector	<u>100211</u> 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  $\Omega$  @ 68°FIs: 26.7 $\Omega$ **Failure Analysis:**Verify reject – low resistance 26.65 $\Omega$  @ 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**

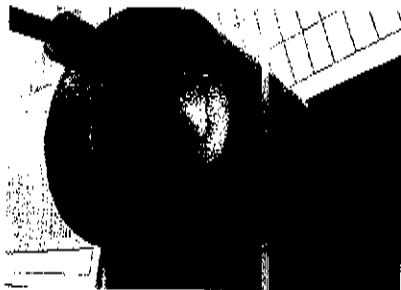
**OHMEGA SOLENOID CO., INC.****Failure Analysis Report**

**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**

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