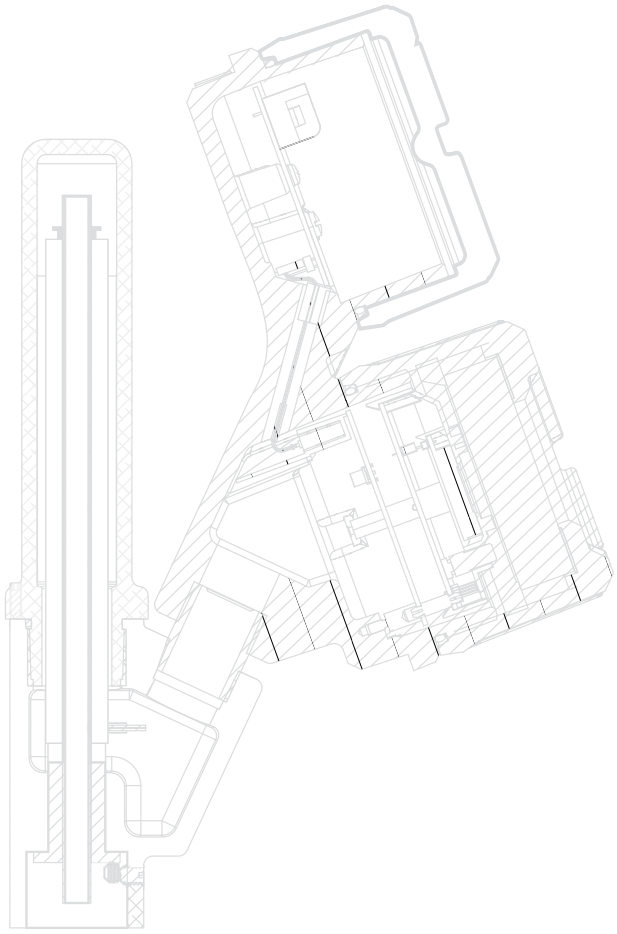
E4 MODULEVEL®

SIL Safety Manual for Model E4 Modulevel®

Liquid Level Displacer Transmitter



This manual complements and is intended to be used with the E4 Modulevel® Installation and Operating manual (Bulletin 48-636).

Application

The E4 Modulevel® Liquid Level Displacer Transmitter can be applied in most process or storage vessels, bridles, bypass chambers, interfaces, sumps, and pits up to the unit pressure and temperature ratings. The E4 Modulevel can be used in liquids, clean or dirty, light hydrocarbons to heavy acids (SG=0.23 to 2.20) to meet the safety system requirements of IEC 61508.

Benefits

The E4 Modulevel provides the following benefits to your operation:

- Certified for use up to SIL 2, based on FMEDA-evaluated SIL capability and independently assessed Proven In Use evidence, as evaluated by exida in accordance with IEC 61508.
- Capable of outputting total level, interface level, or specific gravity.
- Range Spring/LVDT design yields performance benefits over traditional torque tube displacer transmitters.
- Full range of hazardous location approvals with international certificates.

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E4 Modulevel® Displacer Level Transmitter
SIL Safety Manual

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1.0 Introduction

1.1 Product Description

The E4 Modulevel is a loop-powered, two-wire, 24 VDC level transmitter that uses simple buoyancy principles in combination with a precision range spring and a highly accurate LVDT (linear variable differential transformer) to detect and convert liquid level changes into a stable 4–20 mA output signal. The electronics are housed in an ergonomic, dual-compartment enclosure that is angled for ease of wiring and calibration.

The E4 Modulevel has microprocessor-based electronics with HART compatible output, in addition to the standard 4–20 mA output. The E4 Modulevel supports the FDT/DTM standard and a PACT*ware*™ PC software package allows for additional configuration and trending capabilities.

The linkage between the level sensing element and output electronics provides a simple mechanical design and construction. The vertical in-line design of the transmitter results in low instrument weight and simplified installation. The instrument comes in a variety of configurations and pressure ratings for varied applications.

1.2 Theory of Operation

The E4 Modulevel Displacer Level Transmitter relies on the principles of buoyancy to convert mechanical movement to an electronic output.

The movement of the range spring, as it compresses or elongates based on the volume of displacer submerged in the liquid, causes movement of a special LVDT core attached to the spring. The LVDT technology converts the movement of the LVDT core within the LVDT to a stable 4–20 mA output signal. The position of the core, with respect to a primary and two secondary windings, induces voltage in each winding. The comparison of the induced voltages within the microprocessor of the E4 Modulevel results in very accurate level or interface level output.

The E4 Modulevel can, alternatively, be set up to track the changing density of a liquid over a known density range and convert that into a stable 4–20 mA output signal. As the density of the liquid changes, so does the mass of the liquid displaced by the displacer. This resulting change in buoyancy force on the displacer causes movement of the LVDT core needed to convert the density change to the 4–20 mA signal.

1.3 Determining Safety Integrity Level (SIL)

Safety Instrumented System designers using the E4 Modulevel shall verify their design in accordance with applicable functional safety standards, including IEC 61508, for low-demand mode applications.

To achieve a specified Safety Integrity Level (SIL), the following conditions shall be met:

1. The average Probability of Failure on Demand (PFDavg) of the complete Safety Instrumented Function (SIF) shall meet the target SIL. Table 1 defines the relationship between SIL and PFDavg.
2. Architectural constraints shall be satisfied in accordance with IEC 61508. The E4 Modulevel is a Type B device and has been assessed for use in low-demand Safety Instrumented Functions. Compliance with applicable system-level requirements shall be verified by the system designer.
3. All devices used in the SIF shall be certified or otherwise qualified for the required SIL. The E4 Modulevel Liquid Level Displacer Transmitter is certified for use up to SIL 2 in a single (1oo1) architecture based on FMEDA analysis and independently assessed Proven In Use data.

   The exSILentia tool from exida is recommended for SIL verification.

Table 1
SIL vs. PFDavg

Safety Integrity Level (SIL)	Target Average Probability of Failure on Demand (PFDavg)
4	$\geq 10^{-5}$ to $<10^{-4}$
3	$\geq 10^{-4}$ to $<10^{-3}$
2	$\geq 10^{-3}$ to $<10^{-2}$
1	$\geq 10^{-2}$ to $<10^{-1}$

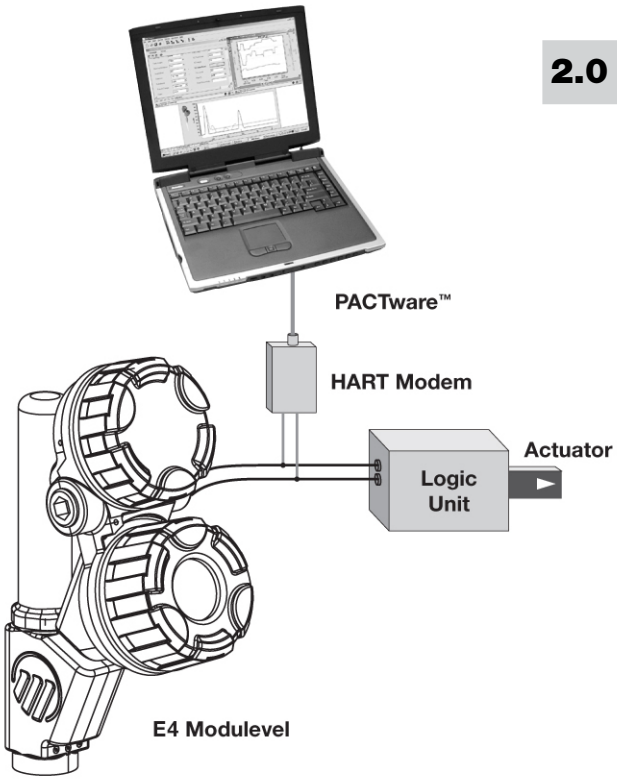


Figure 1
Typical System

2.0 Level Measuring System

Figure 1 shows the structure of a typical measuring system incorporating the E4 Modulevel.

This SIL 2 Certified device is available only with an analog signal with HART communications. The measurement signal used by the logic solver must be the analog 4-20 mA signal proportional to the level generated. The minimum configured level, interface level, or density corresponds to 4 mA and the maximum configured value corresponds to 20 mA, unless the output is driven to a fault condition in accordance with NAMUR NE 43.

For fault monitoring, the logic unit must recognize both high alarms (≥ 21.5 mA) and low alarms (≤ 3.6 mA). The SIF logic solver shall identify such conditions as faults, including but not limited to field wiring failures, loss of power, or internal device diagnostics, and shall take appropriate action as required to maintain the safety integrity of the overall Safety Instrumented System. If the logic solver loop uses intrinsic safety barriers, caution must be taken to ensure the loop continues to operate properly under the low alarm condition.

The only unsafe mode is when the unit is reading an incorrect level within the 4-20 mA range (> ±2% deviation). Magnetrol defines a safe failure as one in which the 4-20 mA current is driven out of range (i.e., less than 3.8 mA or greater than 20.5 mA).

Fault selection of the E4 Modulevel is 3.6 mA, 22.0 mA, or HOLD, and is selected by the user. HOLD should never be chosen as the Fault output in a safety application.

2.1 Applicable Models

This manual is applicable to the following models of the E4 Modulevel Liquid Level Displacer Transmitter:

E4M-51xx-xxx-xx-xxx

E4T-51xx-xxx

NOTE: The E4T retrofit model contains identical electronics and is intended for installation onto the same mechanical sensing assembly as the E4M. In this configuration, the safety-related behavior is equivalent to that of the E4M.

2.2 Miscellaneous Electrical Considerations

The E4 Modulevel is designed to meet the electromagnetic compatibility (EMC) requirements of EN 61326 and NAMUR NE 21 when installed in accordance with the Installation and Operating Manual.

2.2.1 Pollution Degree 2

The E4 Modulevel Level Displacer Transmitter is designed for use in Category II, Pollution Degree 2 installations.

A nonconductive pollution of the sort where occasionally a temporary conductivity caused by condensation must be expected. This is the usual pollution degree used for equipment being evaluated to IEC/EN 61010.

2.2.2 Overvoltage

The E4 Modulevel has overvoltage protection per CE requirements; this protection is to 1000 volts when considering Hi-pot, Fast Transients, and Surge. Therefore, there should be no unsafe failure modes up to 1 KV.

Overvoltage Category II is a local level, covering appliances, portable equipment, etc., with smaller transient overvoltages than those characteristic of Overvoltage Category III. This category applies from the wall plug to the power supply isolation barrier (transformer). The typical plant environment is Overvoltage Category II, so most equipment evaluated to the requirements of IEC/EN 61010 are considered to belong in that classification.

2.2.3 Loop Power and Load Requirements

The E4 Modulevel two-wire current loop output requires a minimum operating voltage of 16.25 VDC and is designed to operate with a maximum supply voltage of 36 VDC, measured at the transmitter terminals, when used in safety-related applications.

The current loop output is capable of properly controlling the output signal into loads ranging from 0 ohms up to the maximum loop impedance supported by the applied loop voltage, as defined in the E4 Modulevel Installation and Operating Manual.

2.3 Operating Modes and Timing Characteristics

The E4 Modulevel Liquid Level Displacer Transmitter operates in one of two defined modes during safety-related operation: Normal Mode or Faulted Mode. Faulted mode is defined as the condition in which the safety-related output current is driven to the user-selected alarm value (high or low) in accordance with NAMUR NE 43.

Upon application of power and completion of initialization, the E4 Modulevel will enter either Normal Mode or Faulted Mode depending on the results of internal diagnostics.

Normal Mode of operation is entered when all internal diagnostics complete successfully and no fault conditions are detected. Upon application of power and successful initialization, the E4 Modulevel will enter Normal Mode within 5 seconds.

Faulted Mode of operation is entered when one or more internal diagnostics detect a fault condition that may affect the safety function. If a fault is detected during initialization, the E4 Modulevel will enter Faulted Mode in less than 8 seconds after application of power.

While operating in Normal Mode, the E4 Modulevel continuously performs internal diagnostic testing. If a diagnostic event occurs, the device will transition from Normal Mode to Faulted Mode within the diagnostic test interval. The diagnostic test interval for safety-related diagnostics is less than 3 seconds.

The safety function output of the E4 Modulevel will respond to a change in the user's process within the safety function response time. The maximum safety function response time is 3 seconds, assuming the output damping parameter is configured to 0 seconds. The published safety function response time does not include the effect of user-configured output damping. Increased damping values will increase the overall response time and must be accounted for by the end user in the safety function design.

When a fault condition has cleared and all internal diagnostics return to a normal state, the E4 Modulevel may transition from Faulted Mode back to Normal Mode.

3.0 Mean Time To Repair (MTTR)

SIL determinations are based on a number of factors including the Mean Time To Repair (MTTR). The analysis for the E4 Modulevel is typically based on a MTTR of 24 hours.

4.0 Supplementary Documentation

The E4 Modulevel Installation and Operating Manual (Bulletin 48-636) must be available for installation of the measuring system.

The following Electronic Device Description File is required if HART is used:

E4 Modulevel HART Revision Table

HART Version	HCF Release Date	Compatible with Software
Dev Rev 1, DD Rev 1	2023	Version 1.0a and later

For device installations in a classified area, the relevant safety instructions and electrical codes must be followed.

5.0 Instructions

5.1 Systematic Limitations

The end user shall establish and maintain procedures to ensure safe operation of the device throughout its lifecycle, including installation, commissioning, operation, maintenance, proof testing, and decommissioning. These procedures shall be in accordance with applicable functional safety standards.

The following application and environmental limitations must be observed to avoid systematic failures.

5.1.1 Application

The E4 Modulevel transmitter should be located for easy access for service, configuration, and monitoring. There should be sufficient headroom to allow installation and removal of the transmitter head, and, in cases of tank top configuration, the displacer. Special precautions should be made to prevent exposure to corrosive atmosphere, excessive vibration, shock, or physical damage. The E4 Modulevel should only be used for applications in which buildup of solid materials on the spring or in the enclosing tube is not an issue.

The operating temperature range for the transmitter electronics is -40 to +80 °C (-40 to +176 °F). The operating temperature range for the digital display is -20 to +70 °C (-5 to +160 °F).

Caution: Operation of all buoyancy type level devices should be done in such a way as to minimize the action of dynamic forces on the float or displacer sensing element. Good practice for reducing the likelihood of damage to the control is to equalize pressure across the device very slowly.

5.1.2 Environmental

See E4 Modulevel Installation and Operating Manual (Bulletin 48-636) for environmental limitations.

5.2 Skill Level of Personnel

Personnel following the procedures of this safety manual should have technical expertise equal to or greater than that of a qualified instrument technician.

5.3 Necessary Tools

No special equipment or tools are required to install E4 Modulevel. The following items are recommended:

- Wrenches, flange gaskets, and flange bolting appropriate for process connection(s)
- Flat-blade screwdriver
- Level
- ⅛" Allen wrench
- 24 VDC power supply, 23 mA minimum
- Digital multimeter
- 250 to 450 ohm resistor for HART communication

5.4 Storage

The E4 Modulevel should be stored in its original shipping box and not be subjected to temperatures outside the storage temperature range -40 to +85 °C (-50 to +185 °F), as shown in the E4 Modulevel Installation and Operating Manual (Bulletin 48-636).

5.5 Installation

Refer to the E4 Modulevel Displacer Level Transmitter Installation and Operating Manual (Bulletin 48-636) for the proper installation instructions.

This SIL evaluation has assumed that the customer will be able to acknowledge an over or under current condition via the logic solver.

5.6 Configuration

5.6.1 General

The E4 Modulevel can be configured via the local display, the HART compatible handheld communicator, or a laptop computer with PACT*ware*. The local user interface and the HART communication interface are non-interfering with the safety function. Use of either interface for configuration, diagnostics, or proof testing does not affect the execution of the safety function, except when configuration changes are intentionally made in accordance with this Safety Manual.

All changes to user-configured parameters shall be independently verified by qualified personnel. Following any configuration change, the end user shall validate correct operation of the safety function through appropriate testing (site acceptance testing or proof testing) prior to relying on the device for safety protection.

5.6.2 Write Protecting / Locking

The E4 Modulevel transmitter is password protected. Refer to the Installation and Operating Manual (Bulletin 48-636) for information on password protection. The end user shall ensure that HART communication access is restricted to qualified and trained personnel only. Access to user password protected parameters is possible via HART communication, and inappropriate changes could impact the safety function.

5.6.3 Safety-Critical Parameter Setting

For safety-related applications, the following configuration requirements shall be implemented by the end user:

1. **Current Loop Alarm:** The device fault response shall be configured to drive the output current to a defined alarm value (3.6 mA or 22 mA). The HOLD setting shall not be used in safety applications.
2. **Current Loop Mode:** The analog output shall be configured in standard 4-20 mA mode representing the measure process variable. Fixed current mode or multidrop configurations shall not be used for safety-related functions.
3. **User Password Protection:** Access to configuration parameters shall be restricted through the use of the password protection mechanisms. Only authorized or trained personnel shall be permitted to modify safety-related parameters.

5.7 Site Acceptance Testing

Complete a site acceptance test to ensure proper operation after installation and configuration. This procedure is identical to the Proof Test Procedure described in Section 6.1.4 of this document.

5.8 Recording Results

Results of Site Acceptance Testing must be recorded for future reference.

5.9 Maintenance

The only maintenance required is the proof test.

- Report all failures to the factory.
- Firmware can only be upgraded by factory personnel.

5.9.1 Diagnostics

Internal diagnostic testing does a complete cycle about 16 times per second (every 60 ms). A message will appear and the output current will be driven to 3.6 or 22 mA (customer dependent) upon detection of a fault. Never specify HOLD as the fault signal in a safety application.

5.9.2 Troubleshooting

Refer to E4 Modulevel Installation and Operating Manual (Bulletin 48-636) for troubleshooting device errors.

6.0 Recurrent Function Tests

6.1 Proof Testing

6.1.1 Introduction

Following are the procedures used to detect Dangerous Undetected (DU) failures. The proof test coverage for the various product configurations is provided in the table below.

Device	λ_{DU}PT (FIT)	Proof Test Coverage
E4 Local	14	76%
E4 Remote	14	77%

6.1.2 Interval

To maintain the Safety Integrity Level of the Safety Instrumented Function (SIF), the E4 Modulevel shall be subjected to proof testing at regular intervals.

Based on the certified failure rates derived from FMEDA analysis and independently assessed Proven-In-Use evidence, the E4 Modulevel is capable of supporting proof test intervals of up to 5 years in a 1oo1 (simplex) architecture, while contributing less than 35% of the allowable PFDavg for a SIL 2 Safety Instrumented Function.

The actual proof test interval shall be selected by the owner/operator based on the required SIL, system architecture, diagnostic coverage, and maintenance practices. Shorter proof test intervals may be required to meet system-level safety requirements.

The proof test interval selected by the user shall not exceed the limits assumed in the SIL verification calculations for the Safety Instrumented System.

6.1.3 Recording results

Record the results of the Proof Test for future reference.

6.1.4 Proof Test Procedure

A suggested proof test is described below.

1. Bypass the safety function and take appropriate action to avoid a false trip.
2. Use HART communications to retrieve any diagnostics and take appropriate action.
3. Send a HART command to the transmitter to go to the high alarm current output and verify that the analog current reaches that value. ①
4. Send a HART command to the transmitter to go to the low alarm current output and verify that the analog current reaches that value. ②
5. Inspect the transmitter for any leaks, visible damage or contamination.
6. Perform a two-point calibration ③ of the transmitter over the full working range.
7. Remove the bypass and otherwise restore normal operation.

① This tests for compliance voltage problems such as a low loop power supply voltage or increased wiring resistance. This also tests for other possible failures.

② This tests for possible quiescent current related failures.

③ If the two-point calibration is performed with electrical instrumentation, this proof test will not detect any failures of the sensor.

7.0 Appendices

7.1 SIL Declaration of Conformity

Functional safety according to IEC 61508/IEC 61511.

AMETEK LMS, 705 Enterprise Street, Aurora,Illinois 60504, declares as the manufacturer that the level transmitter:

Displacer transmitters (4-20 mA) Model E4M-51xx-xxx-xx-xxx / E4T-51xx-xxx are suitable for the use in safety instrumented systems according to IEC 61511-1, provided that all safety instructions and requirements of this manual and I/O manual are observed.

Failure Modes, Effects and Diagnostic Analysis

Project:
E4 Modulevel® Liquid Level Displacer Transmitter

Company:
AMETEK Magnetrol USA, LLC
Aurora, IL
USA

Contract Number: Q25/06-143
Report No.: MAG 22/12-113 R001
Version V1, Revision R3, April 9, 2026
Rudolf Chalupa

Rudolf Chalupa

Management Summary

This report summarizes the results of the hardware assessment in the form of a Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the E4 Modulevel® Liquid Level Displacer Transmitter, hardware and software revision per Section 2.5.1 A Failure Modes, Effects, and Diagnostic Analysis is one of the steps to be taken to achieve functional safety certification per IEC 61508 of a device. From the FMEDA, failure rates are determined. The FMEDA that is described in this report concerns only the hardware of the E4. For full functional safety certification purposes, all requirements of IEC 61508 must be considered.

The E4 Modulevel® Liquid Level Displacer Transmitter is a loop-powered, two-wire, 24 VDC level transmitter which utilizes buoyancy in combination with a range spring and a linear variable differential transformer to detect and convert liquid level movement into a 4–20 mA output signal.

Table 1 lists the different versions that were considered in the FMEDA of the E4.

Table 1 Version Overview

E4 Local	The electronics and display are mounted at the displacer assembly
E4 Remote	The electronics and display are mounted remotely from the displacer assembly

The E4 is classified as a Type B[1] element according to IEC 61508, having a hardware fault tolerance of 0.

The failure rate data used for this analysis meet the *exida* criteria for Route 2_H (see Section 5.2).

Based on the assumptions listed in 4.3, the failure rates for the E4 are listed in section 4.5.

These failure rates are valid for the useful lifetime of the product, see Section 4.7.

The failure rates listed in this report are based on over 400 billion unit operating hours of industry field failure data. The failure rate predictions reflect realistic failures and include site specific failures due to random human events for Site Safety Index (SSI) = 2 [N10, N11].

A user of the E4 can utilize these failure rates in a probabilistic model of a safety instrumented function (SIF) to determine suitability in part for safety instrumented system (SIS) usage in a particular safety integrity level (SIL).

[1] Type B element: "Complex" element (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2, ed2, 2010.

7.3 Specific E4 Modulevel Values

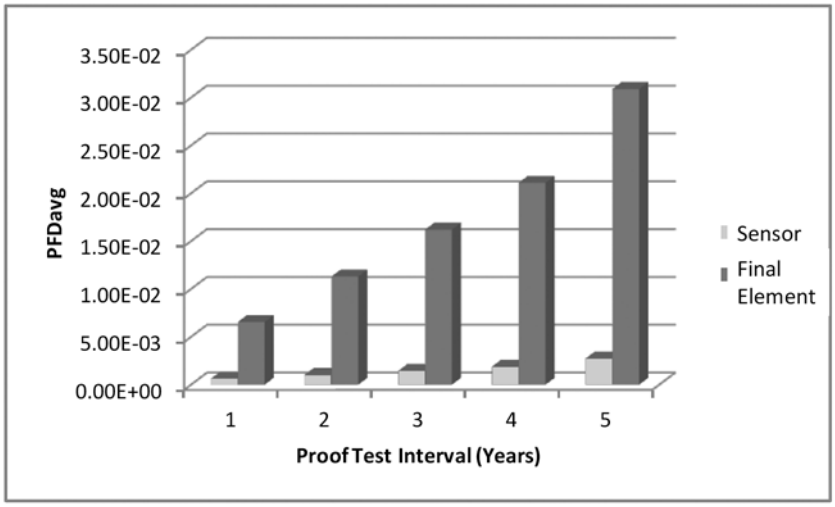
Failure rates for static applications with good maintenance assumptions in FIT @ SSI=2 according to IEC 61508.

Application/ Device/Configuration	λ_{DU}	λ_{SU}	λ_{DD}	λ_{DU}	#	E	DC
E4 Local	0	269	2194	309	242	28	87%
E4 Remote	0	270	2224	310	251	28	87%

Where:

λ_{SD} = Fail Safe Detected
λ_{SU} = Fail Safe Undetected
λ_{DD} = Fail Dangerous Detected
λ_{DU} = Fail Dangerous Undetected
# = No Effect Failures
E = External Leaks
DC = Diagnostic Coverage

7.4 PFD Graph



7.5 Report: Lifetime of Critical Components

The table below shows which components are contributing to the dangerous undetected failure rate and therefore to the PFDavg calculation and what their estimated useful lifetime is. The limiting factors with regard to the useful lifetime of the system are the tantalum electrolytic capacitors. Therefore, the useful lifetime is predicted to be 50 years. For full details, please review the E4 Modulevel FMEDA report.

Component	Useful Life
Capacitor (elecrolytic) – Tantalum electrolytic, solid electrolyte	Approx. 500,000 hours

References

IEC 61508: 2010 “Functional Safety of Electrical/ Electronic/Programmable Electronic Safety Related Systems”

IEC 60654-1: 1993-02, second edition, “Industrial-process Measurement and Control Equipment – Operating Conditions – Part 1: Climatic Condition”

Disclaimer

The SIL values in this document are based on an FMEDA analysis using exida’s SILVER Tool. AMETEK LMS accepts no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

ASSURED QUALITY & SERVICE COST LESS

Service Policy

Owners of AMETEK LMS controls may request the return of a control or any part of a control for complete rebuilding or replacement. They will be rebuilt or replaced promptly. Controls returned under our service policy must be returned by Prepaid transportation. Magnetrol will repair or replace the control at no cost to the purchaser (or owner) other than transportation if:

1. Returned within the warranty period; and
2. The factory inspection finds the cause of the claim to be covered under the warranty.

If the trouble is the result of conditions beyond our control; or, is NOT covered by the warranty, there will be charges for labor and the parts required to rebuild or replace the equipment.

In some cases it may be expedient to ship replacement parts; or, in extreme cases a complete new control, to replace the original equipment before it is returned. If this is desired, notify the factory of both the model and serial numbers of the control to be replaced. In such cases, credit for the materials returned will be determined on the basis of the applicability of our warranty.

No claims for misapplication, labor, direct or consequential damage will be allowed.

Return Material Procedure

So that we may efficiently process any materials that are returned, it is essential that a “Return Material Authorization” (RMA) number be obtained from the factory, prior to the material’s return. This is available through a Magnetrol local representative or by contacting the factory. Please provide the following information:

1. Company Name
2. Description of Material
3. Serial Number
4. Reason for Return
5. Application

Any unit that was used in a process must be properly cleaned in accordance with OSHA standards, before it is returned to the factory.

A Material Safety Data Sheet (MSDS) must accompany material that was used in any media.

All shipments returned to the factory must be by prepaid transportation.

All replacements will be shipped F.O.B. factory.

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705 Enterprise Street • Aurora, Illinois 60504-8149 USA
630.969.4000 • info.magnetrol@ametek.com • ametek-measurement.com

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