



Standards

Certification

Education & Training

Publishing

Conferences & Exhibits

Setting the Standard for Automation™

TECHNICAL REPORT

ISA-TR96.05.02-2022

In-Situ Proof Testing of Automated Valves

Approved 18 February 2022

NOTICE OF COPYRIGHT

This is a copyright document and may not be copied or distributed in any form or manner without the permission of ISA. This copy of the document was made for the sole use of the person to whom ISA provided it and is subject to the restrictions stated in the *Copyright of ISA Standards* policy. It may not be provided to any other person in print, electronic, or any other form. Violations of ISA's copyright will be prosecuted to the fullest extent of the law and may result in substantial civil and criminal penalties.

ISA-TR96.05.02-2022
In-Situ Proof Testing of Automated Valves

ISBN: 978-1-64331-220-0

Copyright © 2022 by the International Society for Automation (ISA). All rights reserved. Not for resale. Printed in the United States of America. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic mechanical, photocopying, recording, or otherwise), without the prior written permission of the Publisher.

ISA
3252 S. Miami Blvd., Suite 102
Durham, NC 27703 USA

Preface

This preface is included for information purposes and is not part of ISA-TR96.05.02-2022.

This document has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; P. O. Box 12277; Research Triangle Park, NC 27709; Telephone (919) 549-8411; Fax (919) 549-8288; E-mail: standards@isa.org.

International System of Units (SI) are the preferred units of measurement in ISA standards.

It is the policy of ISA to encourage and welcome the participation of all concerned individuals and interests in the development of ISA standards, recommended practices, and technical reports. Participation in the ISA standards-making process by an individual in no way constitutes endorsement by the employer of that individual, of ISA, or of any of the standards, recommended practices, and technical reports that ISA develops.

CAUTION — ISA ADHERES TO THE POLICY OF THE AMERICAN NATIONAL STANDARDS INSTITUTE WITH REGARD TO PATENTS. IF ISA IS INFORMED OF AN EXISTING PATENT THAT IS REQUIRED FOR USE OF THE DOCUMENT, IT WILL REQUIRE THE OWNER OF THE PATENT TO EITHER GRANT A ROYALTY-FREE LICENSE FOR USE OF THE PATENT BY USERS COMPLYING WITH THE DOCUMENT OR A LICENSE ON REASONABLE TERMS AND CONDITIONS THAT ARE FREE FROM UNFAIR DISCRIMINATION.

EVEN IF ISA IS UNAWARE OF ANY PATENT COVERING THIS DOCUMENT, THE USER IS CAUTIONED THAT IMPLEMENTATION OF THE DOCUMENT MAY REQUIRE USE OF TECHNIQUES, PROCESSES, OR MATERIALS COVERED BY PATENT RIGHTS. ISA TAKES NO POSITION ON THE EXISTENCE OR VALIDITY OF ANY PATENT RIGHTS THAT MAY BE INVOLVED IN IMPLEMENTING THE DOCUMENT. ISA IS NOT RESPONSIBLE FOR IDENTIFYING ALL PATENTS THAT MAY REQUIRE A LICENSE BEFORE IMPLEMENTATION OF THE DOCUMENT OR FOR INVESTIGATING THE VALIDITY OR SCOPE OF ANY PATENTS BROUGHT TO ITS ATTENTION. THE USER SHOULD CAREFULLY INVESTIGATE RELEVANT PATENTS BEFORE USING THE DOCUMENT FOR THE USER'S INTENDED APPLICATION.

HOWEVER, ISA ASKS THAT ANYONE REVIEWING THIS DOCUMENT WHO IS AWARE OF ANY PATENTS THAT MAY IMPACT IMPLEMENTATION OF THE DOCUMENT NOTIFY THE ISA STANDARDS AND PRACTICES DEPARTMENT OF THE PATENT AND ITS OWNER.

ADDITIONALLY, THE USE OF THIS DOCUMENT MAY INVOLVE HAZARDOUS MATERIALS, OPERATIONS OR EQUIPMENT. THE DOCUMENT CANNOT ANTICIPATE ALL POSSIBLE APPLICATIONS OR ADDRESS ALL POSSIBLE SAFETY ISSUES ASSOCIATED WITH USE IN HAZARDOUS CONDITIONS. THE USER OF THIS DOCUMENT MUST EXERCISE SOUND PROFESSIONAL JUDGMENT CONCERNING ITS USE AND APPLICABILITY UNDER THE USER'S PARTICULAR CIRCUMSTANCES. THE USER MUST ALSO CONSIDER THE APPLICABILITY OF ANY GOVERNMENTAL REGULATORY LIMITATIONS AND ESTABLISHED SAFETY AND HEALTH PRACTICES BEFORE IMPLEMENTING THIS DOCUMENT.

THE USER OF THIS DOCUMENT SHOULD BE AWARE THAT THIS DOCUMENT MAY BE IMPACTED BY ELECTRONIC SECURITY ISSUES. THE COMMITTEE HAS NOT YET ADDRESSED THE POTENTIAL ISSUES IN THIS VERSION.

ISA (www.isa.org) is an international professional association that sets the standard for those who apply engineering and technology to improve the management, safety, and cybersecurity of modern automation and control systems used across industry and critical infrastructure. Founded in 1945, ISA develops widely used international standards for industrial automation, safety, and cybersecurity; certifies industry professionals; provides education and training; publishes books and technical articles; hosts conferences and events; and provides networking and career development programs for its members and customers around the world.

ISA owns Automation.com, a leading online publisher of automation-related content. In addition, through a wholly owned subsidiary, ISA bridges the gap between standards and their implementation with the ISA Security Compliance Institute (www.isasecure.org) and the ISA Wireless Compliance Institute (www.isa100wci.org).

The following people served as leaders and voting members of ISA96 in the development of this document.

NAME	COMPANY
V. Mezzano, Chair	Fluor
W. Weidman, Managing Director	Consultant
S. Hale, Working Group Leader	MRC Global
D. Anderson	Score Diagnostics, Ltd.
M. Bober	Celeros Flow Technology
S. Boyle	Consultant
K. Enos	Rexa, Inc.
P. Flanders	PSF Consultants LLC
L. Hilliard	Puffer Sweiven LP
E. Holtgraver	QTRCO, Inc.
A. Izzeldin	Petronas
D. Leese	FloWorks International
I. Leufgen	Neles Germany GmbH
G. Liu	Consultant
S. Samy	CCI
C. Schaffer	Burns & McDonnell
W. Tatum	Westlock Controls
L. Winkel	Flowserve
Y. Yermanos	Ecopetrol S.A.
J. Young	The Dow Chemical Company
W. Zmudzinski	bp America Inc.

This document was approved for publication by the ISA Standards and Practices Board on 18 February 2022.

NAME	COMPANY
D. Zetterberg, Vice President	Consultant
D. Bartusiak	Collaborative Systems Integration, LLC
D. Brandl	BR&L Consulting, Inc.
P. Brett	Honeywell Inc.
D. Dunn	WS Nelson
J. Federlein	Consultant
B. Fitzpatrick	Wood
S. Fluchs	admeritia GmbH
J.-P. Hauet	KB Intelligence
D. Lee	Emerson
G. Lehmann	AECOM
T. McAviney	Consultant

V. Mezzano
C. Monchinski
G. Nasby
D. Reed
N. Sands
H. Sasajima
I. Verhappen
D. Visnich
W. Weidman
J. Weiss
M. Wilkins

Fluor Corp.
Automated Control Concepts Inc.
City of Guelph Water Services
Rockwell Automation
DuPont
FieldComm Asia LLC
Willowglen Systems
Burns & McDonnell
Consultant
Applied Control Solutions LLC
Yokogawa UK Ltd.

This page intentionally left blank.

Contents

Foreword.....	9
Introduction	11
1 Scope	13
2 References	13
3 Abbreviations	14
4 Definitions.....	14
5 The critical link between automated valve engineering and in-situ proof testing	16
5.1 Valve considerations.....	17
5.2 Actuator considerations.....	21
5.3 Establishing acceptance criteria for in-situ proof testing.....	23
5.4 Stroke time considerations	24
6 Automated valve in-situ proof testing	26
6.1 Qualitative versus quantitative proof testing and data analysis	26
6.2 In-situ proof test levels.....	27
7 Automated valve degradations and causes of failure	30
8 Estimating proof test coverage of each test level.....	33
9 Summary	35
Annex A (informative) Example of a failure mode and effects analysis – automated valve degradations (adapted from ISA-TR96.05.01-2017).....	37
Annex B (informative) Proof testing frequently asked questions	41

This page intentionally left blank.

Foreword

The information contained in ISA-TR96.05.02-2022 is intended for information purposes only. The users of ISA-TR96.05.02-2022 may include:

- owner/operators that use automated valves in operating environments requiring in-situ proof testing to support the valve's mechanical integrity;
- designers that identify automated valve applications whose potential failure rate in the operating environment indicates the need for more frequent testing than supported by the operability and maintainability requirements; and
- operations and maintenance personnel who need to understand how in-situ proof testing is performed and what it indicates about the mechanical integrity of an automated valve.

Comments on the content of this document should be sent to standards@isa.org.

This page intentionally left blank.

Introduction

An important element of process safety is assurance that safety-related devices, including automated valves, remain capable of performing intended safety functions at all times during plant operation. Government regulations, operating licenses and permits, technical specifications, and various industry standards specify requirements for testing automated valves used in process safety applications. To meet these requirements, automated valves are routinely subjected to in-situ proof testing at intervals determined by the importance of each valve, valve and actuator manufacturer's recommendations, in-service performance experience, and other factors.

The purpose of periodic in-situ proof testing of automated valves is to ensure degraded performance and increased probability of failure on demand can be identified and corrected before plant or system operating conditions require the valve(s) to perform intended safety functions. In many cases, valves in certified safety instrumented systems (SIS) must be proof tested consistent with the proof test coverage and test frequency assumptions used in the safety analysis. In certain cases, the proof test approach and frequency for SIS devices may be included in the plant technical specifications.

The proof testing approach must be designed, and test frequency implemented such that degraded conditions and increased risk of failure can be detected before failure of the automated valve occurs during a process upset or accident. Test approaches that only detect existing failures or "failure modes" and have no predictive capability provide limited benefit and are inherently "run-until-failure" strategies. In certain process safety applications, detection of failure during the proof testing process indicates that safety-related equipment was unable to perform intended safety functions for some unknown period while the plant was operating. Failures found during operation or during the periodic proof testing process should be evaluated similar to a near-miss analysis to understand the potential consequences if a process upset or accident occurred while the failure was present, and consideration should be given to whether the same degradations or root causes may reoccur and whether other automated valves in similar safety-related applications may also be affected.

A wide range of testing and analysis strategies have been developed and adopted by industry to satisfy in-situ proof testing requirements. "Proof test coverage" is a measure of how effectively each testing process can identify failures, degradations, and other precursors to failure. Recent experience suggests that some proof testing approaches for automated valves provide higher levels of assurance than others and are an important factor in judging the coverage provided by each in-situ proof testing method. ISA-TR96.05.01-2017, *Partial Stroke Testing of Automated Valves*, provides example analytical techniques necessary to determine the effectiveness of various proof testing approaches used during partial stroke testing of automated valves. This technical report (TR) expands certain guidance of ISA-TR96.05.01-2017 to full stroke in-situ proof testing of automated valves.

This TR discusses the relationship between automated valve design engineering and the various approaches currently used for in-situ proof testing and analysis of automated valve performance. The purpose of this TR is to help engineers and operators develop and deploy periodic proof testing strategies and analysis methods that ensure safety-related automated valves remain capable of performing intended functions at all times during plant and safety system operation. Advantages and disadvantages of the various approaches are also discussed. Periodic in-situ proof testing must provide early detection of degradations associated with the entire automated valve system, including controls, automation components, and the valve.

Regardless of the test and analysis approach used, all performance measurements obtained during periodic in-situ proof testing should be compared to established acceptance criteria for the

specified operating conditions of each valve and judged to be within limits, or corrective action should be taken to return performance to acceptable levels. In addition to accounting for the accuracy and repeatability of the test method, sensors, and equipment used during the proof testing process, test engineers and analysts must fully understand and apply uncertainties and limitations of the analytical techniques employed to quantify automated valve performance margin. For example, a torque value that is calculated from an actuator pressure measurement is subject to additional uncertainty associated with converting the pressure measurement to torque or force and is not limited to the sensor uncertainty alone. Further, any software used to record sensor values and perform calculations that provide the basis for decisions related to automated valve performance must be validated using appropriate software quality control systems and processes required for safety-related equipment.

Further, it is recommended that valve test personnel and analysts receive training and complete operating company-specified certification requirements which may include, but are not limited to:

- automated valve operating principles
- automated valve testing or monitoring instrumentation
- test acceptance criteria
- procedures
- automated valve assembly maintenance
- changes in automated valve performance due to process conditions

This TR uses several equations and valve performance models to help illustrate the link between automated valve engineering and in-situ proof testing. These equations and models are provided for reference only and are not intended to replace equations used as part of valve and actuator original equipment manufacturer (OEM) sizing procedures.

1 Scope

This ISA technical report:

- a) is informative and does not contain any mandatory requirements;
- b) is limited to on/off automated valves normally operated to a fully open or fully closed position (excludes control valves);
- c) introduces the concept of in-situ proof testing and analysis of automated valves; and
- d) relates loss of functional margin with failure causes and failure modes and discusses the effectiveness of different in-situ proof testing approaches.

The automated valve assembly includes the following:

- a) valve, actuator, control and ancillary components, and monitoring devices;
- b) actuation media regulation and filtration system;
- c) actuated valves whose safe position is specified; and
- d) automated valves that employ only pneumatic or hydraulic actuators.

Guidance is provided for the following:

- a) various criteria to consider when selecting the in-situ proof testing method -- for example, automated versus manual test execution, spurious trip potential, actuator force or torque output, and on-line maintainability;
- b) the capability and limitations of the various measurement, analysis, and acceptance criteria approaches used to assess in-situ proof testing results;
- c) assessing the accuracy of measurement and analysis methods employed by the various proof testing systems, sensors, and analysis techniques; and
- d) guidance related to testing electric valve actuators is provided in ANSI/ISA-96.02.01 and is excluded from the scope of this technical report.

2 References

ISA-TR84.00.02-2022, *Safety Integrity Level (SIL) Verification of Safety Instrumented Functions*, ISA, Durham NC; www.isa.org.

IEC 61508-1:2010, Ed. 2, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*, IEC, Geneva, Switzerland; www.iec.ch.

IEC 61511-1:2016/AMD1:2017, Ed. 2, *Amendment 1 – Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and application programming requirements*, IEC, Geneva, Switzerland; www.iec.ch.

ISA-TR96.05.01-2017, *Partial Stroke Testing of Automated Valves*, ISA, Durham NC; www.isa.org.

3 Abbreviations

BPCS	basic process control system
BSDV	boarding shutdown valve
BSEE	US Bureau of Safety and Environmental Enforcement
CF	correction factors
FMEA	failure mode and effects analysis
MAST	maximum allowable stem torque or thrust
OEM	original equipment manufacturer
PST	partial stroke testing
SIS	safety instrumented system
SPPE	safety and pollution prevention equipment
SSV	surface safety valve

4 Definitions

4.1

actuator output

the torque, thrust, or force capacity of the actuator

4.2

availability

the degree to which an automated valve is in a specified operable and committable state when in service and called on to operate at an unknown, i.e., random, time

4.3

closure member

the moveable part of the valve that is positioned in the flow path to modulate the rate of flow through the valve

4.4

dangerous failure

failure affecting equipment in a system that has the potential to put the system in a fail-to-function state or to cause the process to be put in a hazardous state

4.5

design margin

a theoretical value that is a result of the various safety factors applied during the design and sizing process. Safety factors may be applied by valve manufacturers or actuator manufacturers or be specified by the user to increase the expected valve and actuator operating requirements to