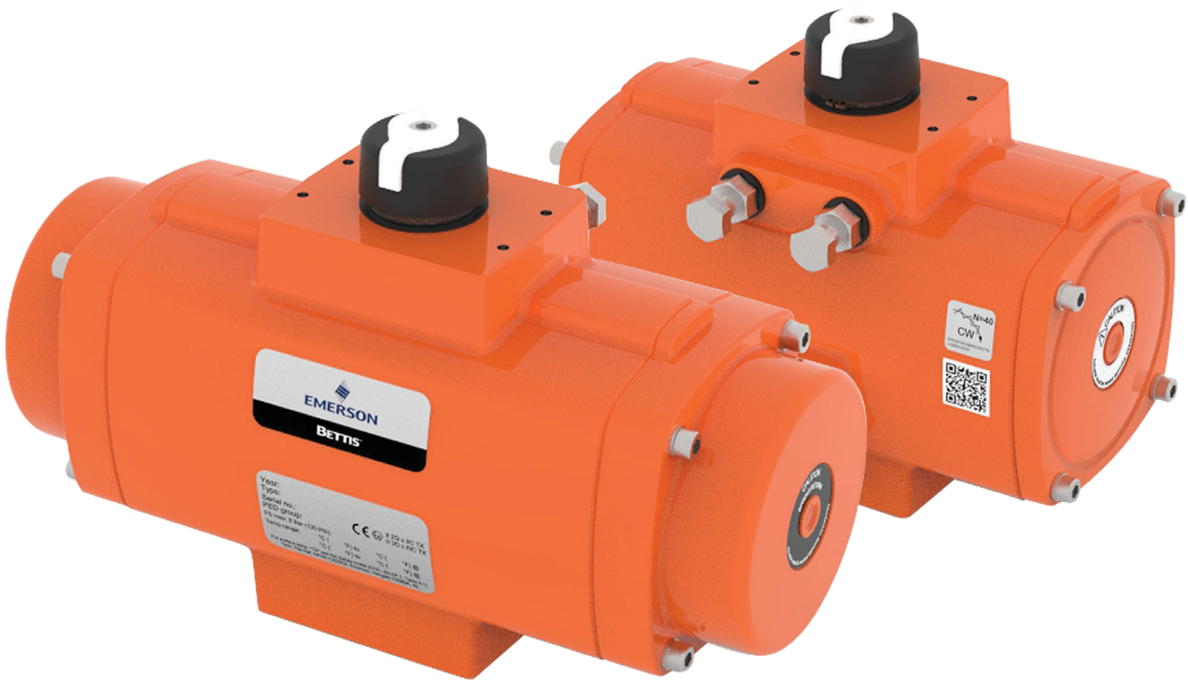
SIL Safety Manual
DOC.SILM.BE.EN Rev. 3
March 2023

Bettis RPE-Series

Rack and Pinion Pneumatic Actuator



BETTIS™

EMERSON™

This page intentionally left blank.

Table of Contents

This page intentionally left blank.

Section 1: Introduction

Purpose of this Safety Manual, written in compliance with IEC 61508-2, Annex D, is to give all the necessary information to the system integrator for a correct use of the product in Safety Instrumented Systems for SIL classified applications.

Section 2: Functional Specification

The safety function for Bettis RPE-Series pneumatic actuator is defined as follows:

Double-Acting Scenario:

a. When an unsafe condition is detected in a plant by a process sensor, the controller, via actuator control system, drives the Actuator to **close** the shut-down valve, depressurizing (if under pressure) the Opening side of the actuator and pressurizing the Closing side of the actuator.

b. When an unsafe condition is detected in a plant by a process sensor, the controller, via actuator control system, drives the Actuator to **open** the blow-down valve, depressurizing (if under pressure) the Closing side of the pneumatic actuator and pressurizing the Opening side of the pneumatic actuator.

Single-Acting Scenario:

When an unsafe condition is detected in a plant by a process sensor, the controller, via actuator control system, drives the Actuator to rotate with sufficient torque to move a valve to its fail-safe state when hold-position air pressure is released.

The Bettis brand Actuator Selection Procedure provides functional definition with specifics on input variables and performance.

In any case, the choice of the safety function to be implemented is responsibility of the system integrator.

Section 3: Configuration of the Product

The Bettis RPE-Series are pneumatically operated actuators designed to operate Ball/Plug/Butterfly valves, automation of louvers and dampers and automation of any quarter-turn mechanism. Both the double-acting and single-acting (spring-return) versions of the Bettis RPE-Series pneumatic actuators are designed in such a way that there are no moving parts on the outside (with the exception of the position indicator). This makes them safe, easy to install and virtually maintenance free.

For further details about actuator configurations, please refer to the Bettis RPE-Series Product Data Sheets, Safety Guide, and Installation, Operation and Maintenance Manual.

Section 4: Service Condition Limitations (Limitation of Use)

The operating capabilities are listed below:

- Maximum Operating Pressure:
  - Pneumatic Service
  - Up to 120 psig / 8.3 barg

- Ambient Temperature:
  Temperature extremes require different solutions to maintain actuator operational integrity and reliability. For each Bettis RPE-Series actuator is available in three different temperature executions.
  - -20 to +80 °C / -4 to +176 °F Standard temperature
  - -10 to +120 °C / +14 to +250 °F High Temperature
  - -40 to +80 °C / -40 to +176 °F Low Temperature

- Torque Output Range:
  - Double-Acting Bettis RPE-Series actuators, requiring pressure to rotate in either direction, are available with a torque range between 4.8 N·m / 44 lbf-in. and 6,490 N·m / 59,000 lbf-in.
  - The Bettis RPE-Series spring-return models require pressure in only one direction of travel and are suitable for air-fail close and air-fail to open applications without modification. These models are available with a spring end torque between 2 N·m / 20 lbf-in. and 2,394 N·m / 21,000 lbf-in.

- Safety Function:
  For spring-return models, the safety function is self-evident performed by the springs. The safety function of double-acting models should be performed by the A-chamber for safety related systems.

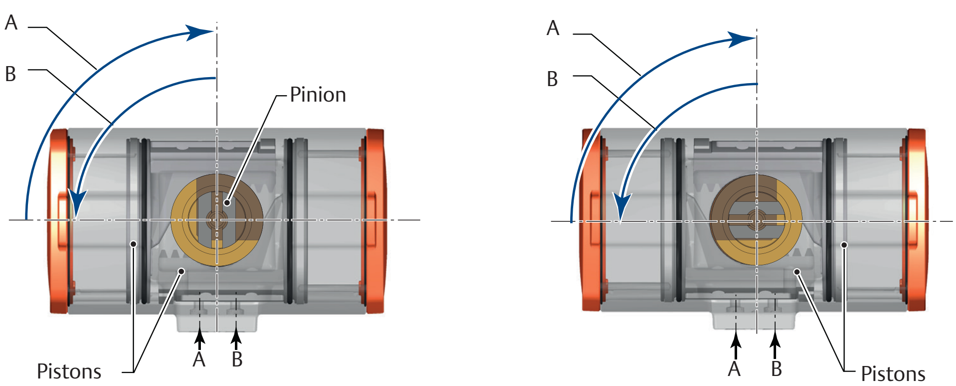
Figure 1 Use the A-Chamber for Safety Related Systems on Double-Acting Actuators

Assembly Code: CW

= Safety Function is Counterclockwise Rotation

Assembly Code: CC

= Safety Function is Clockwise Rotation



- Use of Manual Override:
  The use of a Manual Override is not recommended in a SIL classified application as it results in a bypass of the safety function. In case the manual override is used, the following requirements must be fulfilled or the Functional Safety Certification will become invalid:
  - The Manual Override shall be protected to prevent unauthorized use (e.g. by key locks in conjunction with effective management controls).
  - The users authorized to operate on the actuator shall be skilled personnel.
  - The maximum duration of the manual override shall be defined.
  - If necessary, compensatory measures to allow the safe operation of the process shall be defined (responsibility of the final user).
- When test or bypass facilities are included in the SIS (Safety Integrated System), they shall conform with the following:
  - The SIS shall be designed in accordance with the maintenance and testing requirements defined in the SRS (Safety Requirement Specification).
  - The operator shall be alerted to the bypass of any portion of the SIS via an alarm or operating procedure.

Before selecting remote operating mode control of actuator, the manual override must be disengaged according to the relevant Installation, Operation and Maintenance Manual.

The position selected (remote/automatic control or local/manual control) can be achieved with a specific technical solution that does not allow to reach an intermediate position lever's and avoids unintentional activation.

The engagement of the manual override shall be signaled, at least locally, according to IOM. As optional request from final user, to determine if the manual override is engaged, an electrical signal using contact switching can be provided to communicate the status to the control room.

- Loss of utility:
  For double-acting configurations that on loss of utility (e.g. electrical power or pneumatic supply) does not fail to the safe state a system for detecting and alarming of loss of utility and SIS circuit integrity shall be implemented (e.g. end-of-line monitoring, supply pressure measurement), and action taken according to Section 11.3 of IEC. 61511-1.

Section 5: Expected Lifetime

Actuator lifetime (for which failure rates indicated in Section 6 are ensured) strongly depends on operating conditions.

For normal service conditions, Bettis RPE-Series actuators can be in good conditions also after more than 10 years with planned minimum maintenance. Normal working life is 500,000 cycles. Bettis RPE-Series carry a warranty period of:

- 18 months after delivery if properly stored in conditions that we declare; or
- 12 months after installation on site

Section 6: Failure Modes and Estimated Failure Rates

Please refer to the values included in the latest valid version of SIL certificate(s) (available upon request sent to Emerson).

NOTE:

- No internal diagnostics is included in the product.
- The failure rates are guaranteed:
  - For the service conditions listed in Section 4
  - For the expected lifetime declared in Section 5
  - Considering the periodic test and maintenance included in Section 8

The failure rates are determined performing a FMEDA based on the failure rates of components taken from industrial databases (NPRD-2016/FMD97/2016, EXIDA E&MCRH and NSWC-2011), integrated with field feedback using the Bayesian statistical approach mentioned in IEC 61508-2 Section 7.4.4.3.3.

The system for reporting failures is based on field feedback from end users, with:

- Identification of the claim/failure
- Root cause analysis to identify cause and responsibility of the failure
- Identification of the possible effect of the failure on the Safety Function
- Classification of the failure considering the failure categories of IEC 61508-2 (Safe, Dangerous, No Effect) Customer Service, Quality and Technical Department are responsible for the procedure, according to the respective role

---

Section 7: Installation and Site Acceptance Procedure

Any necessary installation and site acceptance procedures are discussed in the Bettis RPE-Series actuators Installation, Operation and Maintenance Manual. The IOM defines exercising of the actuator after installation and defines testing after maintenance.

Section 8: Periodic Test and Maintenance Requirements

8.1 General

NOTE:
Please consider that the information in this paragraph are relevant only in regards of Reliability Tests; please refer to the IOM for detailed information about product maintenance, handling and storage.

Diagnostic tests may be made to increase the system reliability (Full Stroke or Partial Stroke Test). "On site" tests depend on Project/Plant facilities requirements; however, a functional test must be executed on site, prior actuator operation.

8.2 Full Stroke Test

The "Full Stroke Test" ("On-line") must be performed to satisfy the PFD_{AVG} (average probability of failure on demand) value.

The full test frequencies will be defined by the final integrator in relation to the defined PFD_{AVG} to be achieved.

- Procedure:
  - Operate the Actuator/Valve assembly for 2 complete open/close cycles with complete closing of the valve
  - Verify the Correct performing of open - close manoeuvre and within the required operating times (eg. check locally, or automatically via Logic solver, the correct movement of the actuator/valve)
  - Compare the results with the ones stored during SAT (Site Acceptance Test) activities
  - Record the test results in your company's SIF (Safety Instrumented Function) database
  - Restore normal operation

Considering the application of the above described Full Stroke Test procedure, the "Test Coverage", in case of automatic procedure, can be considered > 99%.

In case of manual procedure the "Test Coverage" shall take into account also the test imperfection and the reliability/competence of the operator.

NOTE:

- If the test is automatic, then the Test Coverage is PTC (Proof Test Coverage), but can also considered as DC (Diagnostic Coverage).
- If the test is manual, then the Test Coverage is PTC, but cannot be considered as DC.

The procedure can be performed manually or automatically. For both cases, the following points are listed:

- Parameters to be measured
- Instruments to be used
- Failure modes detected
- Diagnostic Coverage/Proof Test Coverage

The following parameters have to be measured for an effective Full Stroke Test:

- Angular position of the shaft
- Time necessary to reach to final position
- Output torque (as indirect measure, by means of the of pressure measurement in the cylinder chamber)

NOTE:

Not all parameters are needed, but the following combinations can be used:

1. Measurement of angular position as function of time (pressure measurement is optional)
2. Measurement of cylinder chamber pressure as function of time
3. Verification of final position achievement in the established maximum time

Table 1. Instruments/equipment to be used for the test

<table>
<tr><th rowspan="2">Quantity</th><th colspan="2">Instruments/Equipment</th></tr>
<tr><th>Automatic Procedure</th><th>Manual Procedure</th></tr>
<tr><td>Angular position of the shaft</td><td>Case A
Use of a Logic Solver:
1. Limit switches box, or 4 to 20 mA position transmitter
2. Digital Input Module/Analog Input Module included in the Logic Solver
3. Application Software function (to compare the actual trend with the one stored during SAT)
Case B
Use of a Partial stroke testing device:
1. Limit switches box, or 4 to 20 mA position transmitter
2. Partial stroke testing device with integrated software function</td><td>1. Limit switches box, and/or visual indication
2. Skilled and trained personnel</td></tr>
<tr><td>Time necessary to reach the final position</td><td>As above</td><td>1. Limit switches box, and/or visual indication
2. Chronometer
3. Skilled and trained personnel</td></tr>
<tr><td>Output torque (Pressure in the cylinder)</td><td>Case A
Use of a Logic Solver:
1. Pressure transmitter connected to the cylinder chamber
2. Analog Input Module included in the Logic Solver
3. Application Software function (to compare the actual trend with the one stored during SAT)
Case B
Use of a Partial stroke testing device:
1. Pressure transmitter connected to the cylinder chamber
2. Partial stroke testing device with integrate Software function</td><td>Skilled and trained personnel
(to check audible partial sticking)</td></tr>
</table>

Table 2. Failure mode detectable by the test

<table>
<tr><th rowspan="2">Component</th><th colspan="2">Detectable Failure Modes</th></tr>
<tr><th>Automatic Procedure</th><th>Manual Procedure</th></tr>
<tr><td>Housing</td><td>Breakage</td><td rowspan="7">As per automatic procedure</td></tr>
<tr><td>End cap</td><td>Breakage</td></tr>
<tr><td>Piston</td><td>Breakage
Sticking</td></tr>
<tr><td>Rack</td><td>Breakage
Binding</td></tr>
<tr><td>Pinion</td><td>Breakage
Binding</td></tr>
<tr><td>Spring</td><td>Breakage
Weakened</td></tr>
<tr><td>Stroke adjustment</td><td>Breakage
Bended</td></tr>
</table>

NOTE:

- The ones listed above are the major failure modes of the main components.
- In case of manual procedure, the detectable failure modes are the same as per automatic procedure. The test coverage is lower than the one for automatic mode, due to the human factor.
- The manual procedure cannot be considered as diagnostic.

8.3 Partial Stroke Test

The “Partial Stroke Test” (“On-line”) can be performed to improve the PFD_{AVG} value.

For the execution of a partial stoke test the actuator performs a partial open-close cycle operation, typically a 15 to 25 degrees rotation of the valve, in order to check the correct functioning of the actuator and the correct movement of the valve (not sticking and able to move).

The “Partial Stroke Test” (“On line”) can be performed to satisfy PFD_{AVG} (average probability of failure on demand) value.

- Recommended Test Interval = 1 to 3 months.
- Procedure:
  - Operate the actuator to perform N°2 partial open/close cycles, to verify the correct functioning of the actuator/valve assembly;
  - Verify that the partial stroke manoeuvre was performed correctly and within the expected time;
  - Verify the correct performing of partial stroke operation and within the expected time; (e.g. check locally, or automatically via Logic solver, or via the partial stroke testing system the correct movement of the actuator/valve assembly);
  - Inspect the actuator components for any leakages (internal and external).
- The procedure can be performed manually or automatically. For both cases, the following points are listed:
  - Parameters to be measured
  - Instruments to be used
  - Failure modes detected
  - Diagnostic Coverage/Proof Test Coverage

The above parameters to check will depend from the partial stroke test system available. Considering the application of the above described Partial Stroke Test procedure, the “Diagnostic Coverage” is > 90%.

In case of manual procedure the “Test Coverage” shall take into account also the test imperfection and the reliability/competence of the operator.

NOTE:

- If the test is automatic, then the Test Coverage can also considered as DC.
- If the test is manual, then the Test Coverage cannot be considered as DC.

The following parameters have to be measured for an effective Partial Stroke Test:

- Angular position of the shaft;
- Time necessary to reach to final position;
- Output torque (as indirect measure, by means of the of pressure measurement in the cylinder chamber).

NOTE:

Not all parameters are needed but the following combinations can be used:

1. Measurement of angular position as function of time (pressure measurement is optional)
2. Measurement of cylinder chamber pressure as function of time
3. Verification of final position achievement in the established maximum time

The parameters to be measured depend upon the partial stroke test system available. Instruments/equipment to be used for the test:

The Partial Stroke Test can be executed in the following way:

1. Using commercial Partial stroke testing device, measuring/verifying:
    a. Measurement of angular position as function of time
    b. Measurement of cylinder chamber pressure as function of time (optional)
    c. Verification of final position achievement in the established maximum time
2. By means of Logic Solver, measuring/verifying:
    a. Measurement of angular position as function of time
    b. Measurement of cylinder chamber pressure as function of time (optional)
    c. Verification of final position achievement in the established maximum time

Table 3. Instruments/equipment to be used for the test

Quantity	Instruments/Equipment	
	Automatic Procedure	Manual Procedure
Angular position of the shaft	**Case A** Use of a Logic Solver: 1. Limit switches box, or 4 to 20 mA position transmitter 2. Digital Input Module/Analog Input Module included in the Logic Solver 3. Application software function (to compare the actual trend with the one stored during SAT) **Case B** Use of a Partial stroke testing device: 1. Limit switches box, or 4 to 20 mA position transmitter 2. Partial stroke testing device with integrated Software function	1. Limit switches box, and/or visual indication 2. Skilled and trained personnel
Time necessary to reach the final position	As above	1. Limit switches box, and/or visual indication 2. Chronometer 3. Skilled and trained personnel
Output torque (Pressure in the cylinder)	**Case A** Use of a Logic Solver: 1. Pressure transmitter connected to the cylinder chamber 2. Analog Input Module included in the Logic Solver 3. Application software function (to compare the actual trend with the one stored during SAT) **Case B** Use of a Partial stroke testing device: 1. Pressure transmitter connected to the cylinder chamber 2. Partial stroke testing device with integrate Software function	Skilled and trained personnel (to check audible partial sticking)

Table 4. Failure mode detectable by the test

Component	Detectable Failure Modes	
	Automatic Procedure	Manual Procedure
Housing	Breakage	As per automatic procedure
End cap	Breakage	
Piston	Breakage Sticking	
Rack	Breakage Binding	
Pinion	Breakage Binding	
Spring	Breakage Weakened	
Stroke adjustment	Breakage Bended	

NOTE:

- The ones listed above are the major failure modes of the main components.
- In case of manual procedure, the detectable failure modes are the same as per automatic procedure. The test coverage is lower than the one for automatic mode, due to the human factor.
- The manual procedure cannot be considered as diagnostic. The test can be considered as “non-perfect Proof Test”, and can be considered in the estimation of PFD_{AVG}, while it is not considered for the estimation of the SFF (Safe Failure Fraction).

8.4 Proof Test and Periodic Maintenance

We advise to perform the following checks upon each proof test interval complying with the rules and regulations of the country of final installation:

- Visually check the entire valve operating system.
- Ensure there are no leaks on the pressurized parts.
- Check pneumatic connections for leaks. Tighten tube fittings as required.
- Check if manual override (where foreseen) is regular.
- Check if pneumatic filter cartridge (where foreseen) is sound and filter bowl (where foreseen) has been cleaned properly.
- Check the setting of the relief valves (where foreseen).
- Verify that the power fluid supply pressure value is within the required range.
- Remove built-up dust and dirt from all actuator surfaces.
- Inspect actuator paint work for damages to ensure continued corrosion protection. Touch-up as required in accordance with the applicable paint specification.
- Operate the actuator/valve assembly for 2 open/close complete cycles with complete closing of the valve.
- Verify the correct performing of open-close operations (for example, check locally, or automatically via Logic solver, the correct movement of the actuator).

The IOM defines a minimum maintenance interval after 500,000 cycles for the Bettis RPE-series actuators. This addresses components that may have age related degradation. When the maintenance interval has elapsed a complete overhaul of the actuator is required.

Section 9: Architectural Constraints

For the evaluation of the conformity to the requirement of hardware safety integrity architectural constraints of the standard IEC 61508, both Route 1_H and Route 2_H are used.

Route 1_H

- The product has a single channel configuration, HFT (Hardware Fault Tolerance) = 0
- Safe Failure rate λ_S:
  - Single-Acting Actuators: According to IEC 65108 definitions (in particular definitions 3.6.8 and 3.6.13 of IEC 61508-4), no Safe Failures are possible in a Single-Acting actuator. Each failure mode of the actuator itself shall be classified as "Dangerous" or "No Effect" (failures which can generate the spurious operation of the safety function are only external to the actuator itself, or are related to components that "plays no part in implementing the safety function", e.g. components of the pneumatic cylinder. Therefore, according to definition 3.6.13 of IEC 61508- 4, they cannot be used for the calculation of the SFF.
    Hence $\lambda_S = 0$ for each type of Single-Acting actuator.
  - Double-Acting Actuators: According to IEC 65108 definitions (in particular definitions 3.6.8 and 3.6.13 of IEC 61508-4), no Safe Failures are possible in a Double-Acting actuator. Each failure mode of the actuator itself shall be classified as "Dangerous" or "No Effect" (failures which can generate the spurious operation of the safety function are only external to the actuator itself, and in the case of loss of power supply the actuator "stays put"). Therefore, according to definition 3.6.13 of IEC 61508- 4, they cannot be used for the calculation of the SFF.
    Hence $\lambda_S = 0$ for each type of Double-Acting actuator.

For this reason, according to definition 3.6.15 of IEC 61508-4, we have:

- SFF = 0 without external diagnostic tests;
- SFF > 0 with external diagnostic tests, carried out according to definition 3.8.7 of IEC 61508-4, and according to what written in Section 6 above (see the same paragraph for the SFF/DC reachable).

Route 2_H

- The application of Route 2_H ("field feedback") is assessed.
- As the product is classified as "Type A", no requirements for SFF are given for Route 2_H.

In conclusion:

The product can be used in single channel configuration up to:

- SIL 2 without external diagnostic tests
- SIL 3 considering external diagnostic tests

Section 10: Common Cause Factors

The product has a single channel configuration, HFT = 0.

The β factors can be used when performing PFD_{AVG} calculations for redundant architectures.

The Common Cause factors, relevant when the product is used in redundant configuration, are: $\beta = \beta_D = 0.05$.

NOTE:

- The above value is the value for 1oo2 architecture. The values for other architectures shall be calculated according to IEC 61508 Part 6, Table D.5.
- The above value is calculated in the hypothesis of redundancy without diversity.

Section 11: Mean Repair Time

The mean repair time of the device is 1 hour.

NOTICE

The mean repair time is estimated considering availability of skilled personnel for maintenance, spare parts and adequate tools and materials on site (that is, it encompasses the effective time to repair and the time before the component is put back into operation).

Procedures to repair or replace the Bettis RPE-Series actuators are provided in the respective IOM. Please refer to the IOM for any tools required for repair and replacement and required competency of technicians. Maintenance and subsequent test procedures are also covered in the IOM. Any failures, identified by the end-user during maintenance, repair, or proof testing, that potentially impact the functional safety of the Bettis RPE-Series actuators, should be reported back to Actuation Technologies Customer Service Coordinator.

Section 12: Systematic Capability

The systematic capability of the device is 3.

This systematic capability is guaranteed only if the user:

1. Use the device according to the instructions for use and to the present Manual.
2. Use the device in the appropriate environment (limitation of use).

World Area Configuration Centers (WACC) offer sales support, service, inventory and commissioning to our global customers.
Choose the WACC or sales office nearest you:

NORTH & SOUTH AMERICA

19200 Northwest Freeway
Houston TX 77065
USA
T +1 281 477 4100

Av. Hollingsworth
325 Iporanga Sorocaba
SP 18087-105
Brazil
T +55 15 3413 8888

ASIA PACIFIC

No. 9 Gul Road
#01-02 Singapore 629361
T +65 6777 8211

No. 1 Lai Yuan Road
Wuqing Development Area
Tianjin 301700
P. R. China
T +86 22 8212 3300

MIDDLE EAST & AFRICA

P. O. Box 17033
Jebel Ali Free Zone
Dubai
T +971 4 811 8100

P. O. Box 10305
Jubail 31961
Saudi Arabia
T +966 3 340 8650

24 Angus Crescent
Longmeadow Business Estate East
P.O. Box 6908 Greenstone
1616 Modderfontein Extension 5
South Africa
T +27 11 451 3700

EUROPE

Holland Fasor 6
Székesfehérvár 8000
Hungary
T +36 22 53 09 50

Strada Biffi 165
29017 Fiorenzuola d'Arda (PC)
Italy
T +39 0523 944 411

For complete list of sales and manufacturing sites, please visit
www.emerson.com/actuationtechnologieslocations or contact us at
info.actuationtechnologies@emerson.com

www.emerson.com/bettis

BETTIS™

EMERSON™