Motor-Operated Valve Training Course

Thomas G. Scarbrough
Michael F. Farnan
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Day 1 of 3

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  2. MOV Training Objectives
  3. MOV Design
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  5. MOV Performance and Design Analysis

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  7. MOV Diagnostics
  8. MOV Design-Basis Capability
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  11. Operating Experience and Notices

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- Day 3
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  17. Roundtable and Q/A Session

Acronyms

AC	Alternating Current
AF	Application Factor
AFW	Auxiliary Feedwater
AIT	Augmented Inspection Team
AOV	Air-Operated Valve
ASME	American Society of Mechanical Engineers
B&W	Babcock & Wilcox
BWR	Boiling Water Reactor
BWROG	BWR Owners Group
CCW	Component Cooling Water
CDF	Core Damage Frequency
COF	Coefficient of Friction
COL	Combined License
ComEd	Commonwealth Edison
CP	Construction Permit
CS	Containment Spray
CST	Control Switch Trip
CV	Check Valve
DC	Direct Current
DDGV	Double Disc Gate Valve
DP	Differential Pressure
DV	Degraded Voltage
ECW	Essential Chilled Water
Eff	Efficiency
EFW	Emergency Feedwater
EGM	Enforcement Guidance Memorandum

Acronyms

EPRI	Electric Power Research Institute
EQ	Environmental Qualification
FRG	Federal Republic of Germany
FRN	Federal Register Notice
FSAR	Final Safety Analysis Report
FT-LB	Foot-pounds force
FWG	Flexible Wedge Gate
GDC	General Design Criterion
GE	General Electric
GL	Generic Letter
GSI	Generic Safety Issue
HOV	Hydraulic-Operated Valve
HPCI	High Pressure Coolant Injection
HPCS	High Pressure Core Spray
HQ	Headquarters
HSSC	High Safety Significant Component
ICES	INPO Consolidated Event System
IDP	Integrated Decision-making Panel
IE	Inspection and Enforcement
IEEE	Institute of Electrical and Electronics Engineers
IMC	Inspection Manual Chapter

Acronyms

IN	Information Notice
INL	Idaho National Laboratory
INPO	Institute of Nuclear Power Operations
IP	Inspection Procedure
IR	Inspection Report
ISI	Inservice Inspection
IST	Inservice Testing
ITAAC	Inspections, Tests, Analyses, and Acceptance Criteria
JOG	Joint Owners Group
LER	Licensee Event Report
LERF	Large Early Release Frequency
LPCI	Low Pressure Coolant Injection
LRA	Locked Rotor Amps
LRC	Locked Rotor Current
LS	Limit Switch
LSB	Load Sensitive Behavior
LSSC	Low Safety Significant Component
MCC	Motor Control Center
MO	Month
MOV	Motor-Operated Valve
MOVATS	MOV Analysis and Test System
M&TE	Measurement and Test Equipment
MTR	Material Test Report
MUG	MOV Users Group

Acronyms

NEI	Nuclear Energy Institute
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
NUGEQ	Nuclear Utility Group on Equipment Qualification
OAR	Overall Actuator Ratio
OD	Operability Determination
OE	Operating Experience
OM	Operation and Maintenance
OpESS	Operating Experience Smart Sample
P	System Pressure
PAT	Performance Assessment Testing
PI&R	Problem Identification & Resolution
PM	Preventive Maintenance
PMT	Post-Maintenance Testing
PPM	Performance Prediction Methodology
PL	Pressure Locking
PORV	Power-Operated Relief Valve
POV	Power-Operated Valve
PRA	Probabilistic Risk Assessment
PSI	Pounds per square inch
PSID	PSI differential

Acronyms

PWR	Pressurized Water Reactor
PWROG	PWR Owners Group
QA	Quality Assurance
QC	Quality Control
QME	Qualification of Mechanical Equipment
RCIC	Reactor Core Isolation Cooling
RCS	Reactor Coolant System
RFO	Refueling Outage
RG	Regulatory Guide
RHR	Residual Heat Removal
RIS	Regulatory Issue Summary
RM	Radiation Monitoring
ROL	Rate of Loading
RPM	Revolutions Per Minute
RTD	Resistance Temperature Detector
RTNSS	Regulatory Treatment of Non-Safety Systems
RWCU	Reactor Water Clean-Up
SDC	Shutdown Cooling
SE	Safety Evaluation
SER	Safety Evaluation Report
SF	Stem Factor
SFC	Stem Friction Coefficient
SIL	Service Information Letter
SONGS	San Onofre Nuclear Generating Station
SR	Surveillance Requirement
SRP	Standard Review Plan
SSC	Structure, System, and Component
STR	Special Treatment Requirement
TB	Thermal Binding

Acronyms

TOL	Thermal Overload Relay
TI	Temporary Instruction
TOL	Thermal Overload
TOR	Thermal Overload Relay
TPI	Threads Per Inch
TRF	Torque Reaction Factor
TS	Torque Switch
TSR	Torque Switch Repeatability
TST	Torque Switch Trip
TTC	Torque Thrust Cell
TU	Technical Update
TVA	Tennessee Valley Authority
UFSAR	Updated Final Safety Analysis Report
VAM	Valve Actuator Motor
VOTES	Valve Operating and Test System
VF	Valve Factor
YR	Year

1. MOV Training Basis

- In 1980s, significant MOV failures occurred that caused concerns for their capability to perform safety functions.
- Bulletin 85-03 requested specific MOV testing and Generic Letter 89-10 for all safety-related MOVs.
- NUREG-1352 provided an MOV action plan.
- Based on MOV testing and research, numerous problems found with MOV performance and qualification.
- Licensees expended significant resources to correct MOV issues.
- NRC expended significant resources for MOV testing, evaluation, and inspections.
- This training is intended to transfer historical and technical information on MOV design, operation, testing, and issues to NRC engineers and inspectors.

2. MOV Training Objectives

- Describe design and operation of motor-operated valves (MOVs) used in nuclear power plants.
- Describe regulatory requirements and guidance to provide reasonable assurance of capability of safety-related MOVs to perform safety functions.
- Discuss specific MOV performance issues and lessons learned.

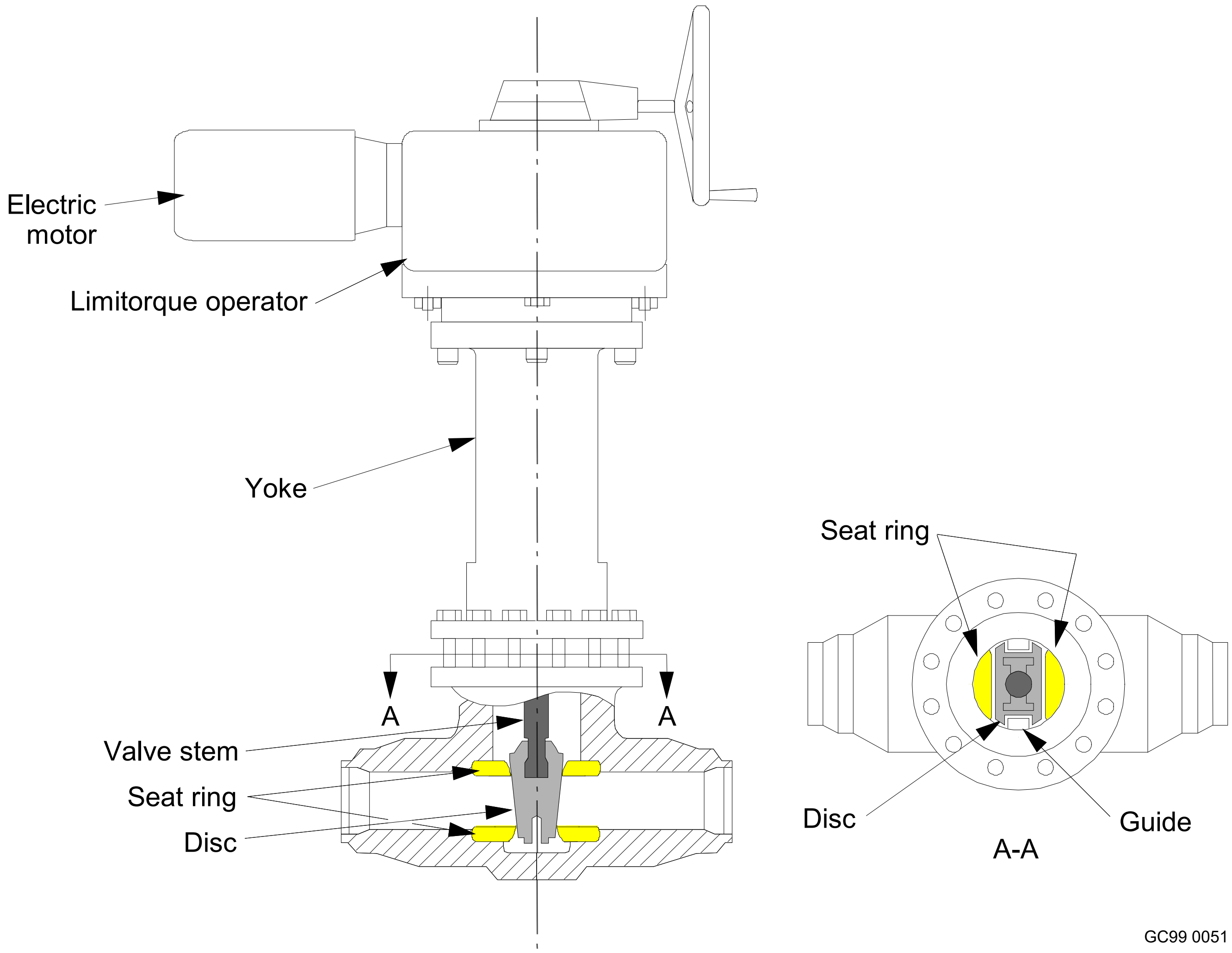
- Discuss MOV inspection procedures.
- Provide recommendations for MOV inspections.
- Present tools for use by MOV engineers and inspectors.
- Discuss 10 CFR 50.69 as special topic.
- Conduct roundtable discussion and Q/A session.

3. MOV Design

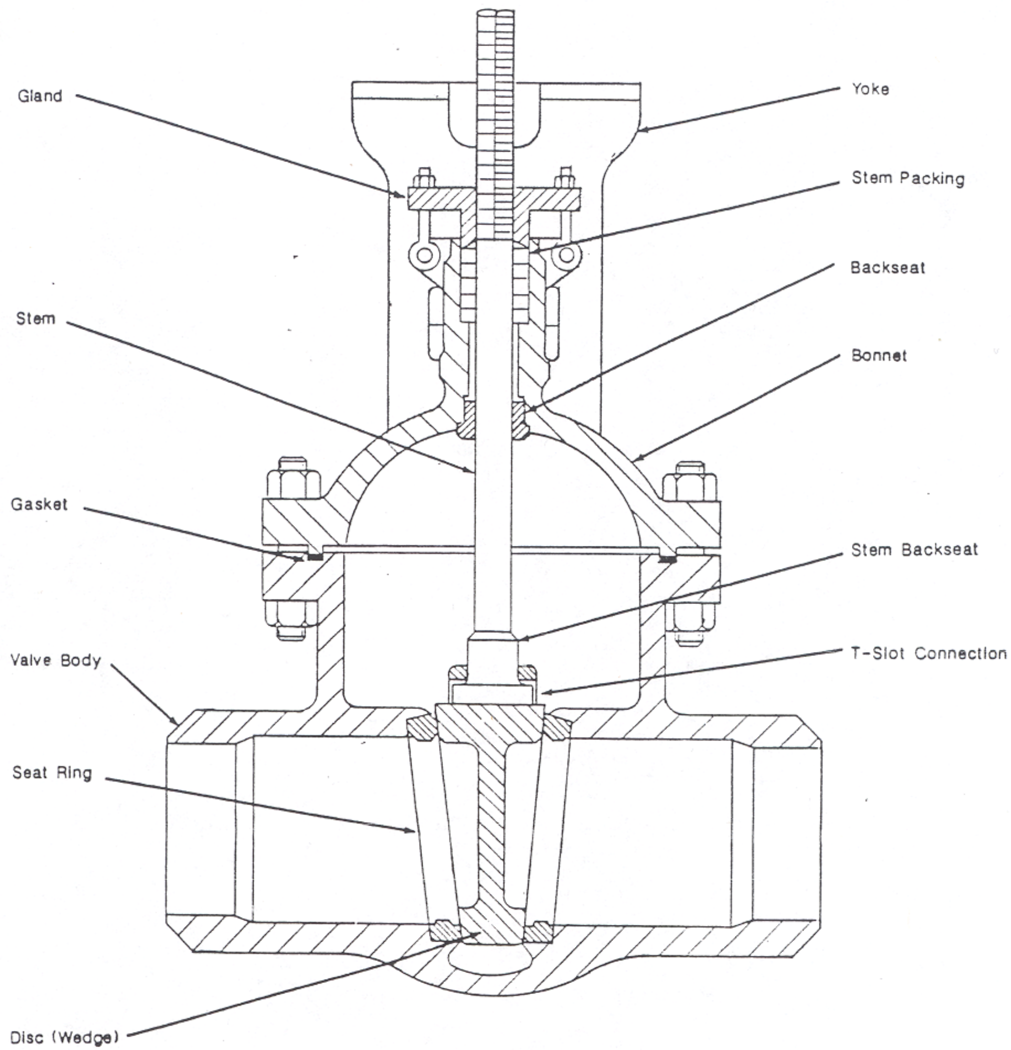
3.a Valve types and function

Anchor/Darling FWG Valve

MOV Gate Valve



Flexible Wedge Gate Valve



Anchor/Darling Flexwedge Gate Valve

FIGURE REDACTED

Wedge Gate Valve Tilting

FIGURE REDACTED

Valve damage from tipping

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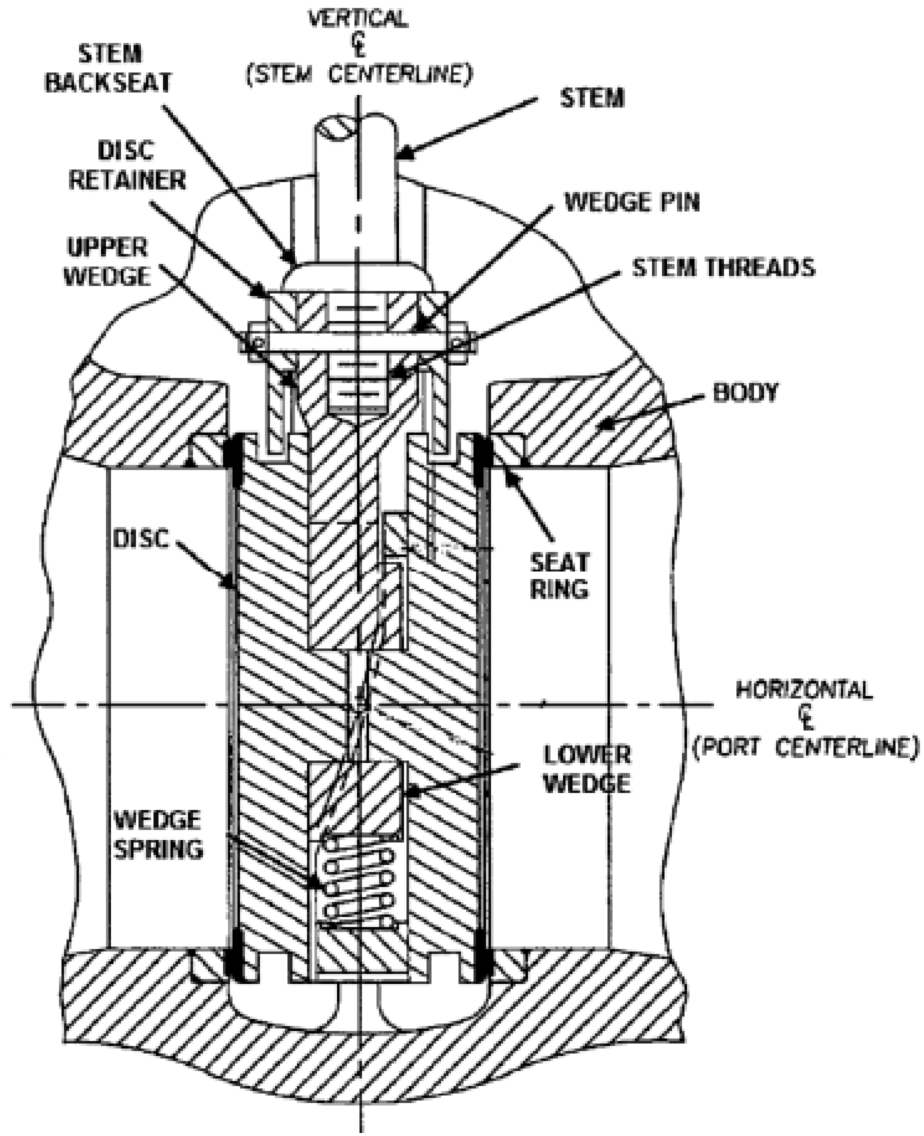
Anchor/Darling Parallel Slide Gate Valve

Anchor/Darling Double Disc Gate Valve

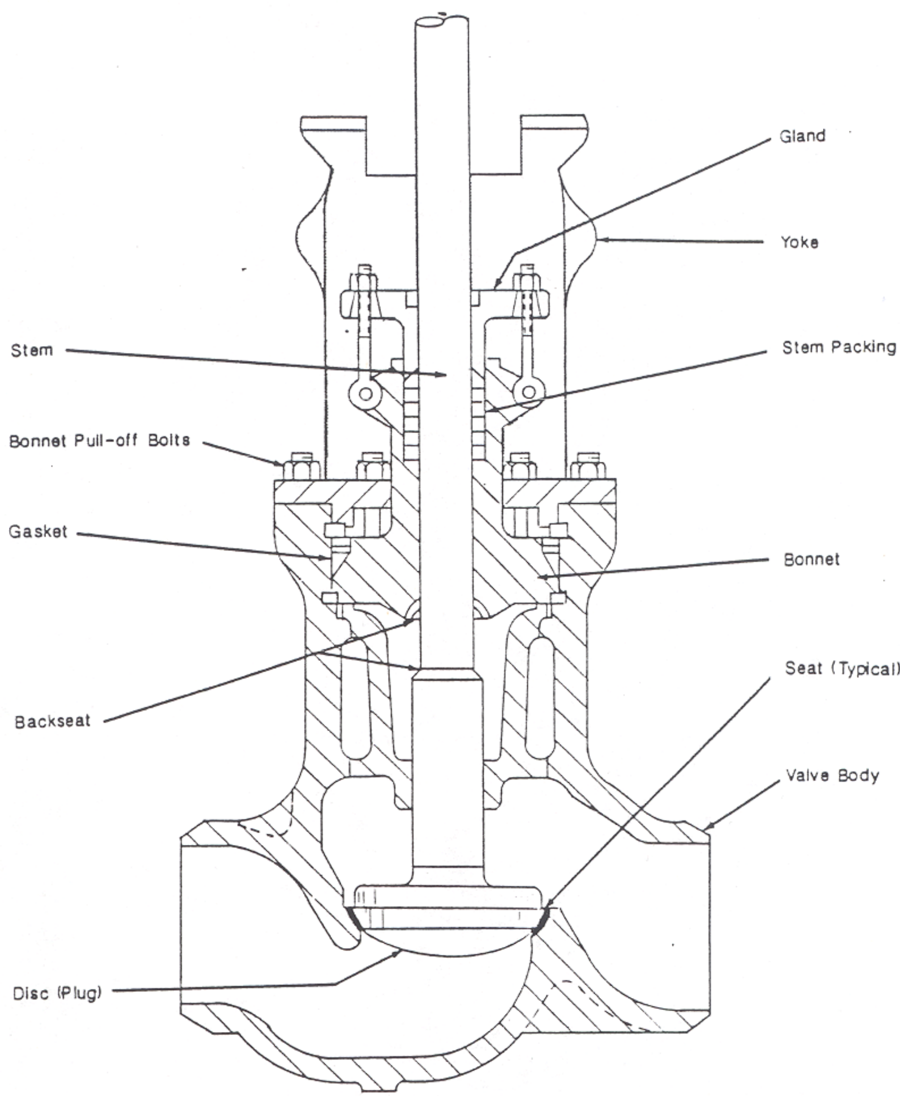


Anchor/Darling Double Disc Gate Valve

FIGURE REDACTED

Anchor/Darling T-Pattern Globe Valve

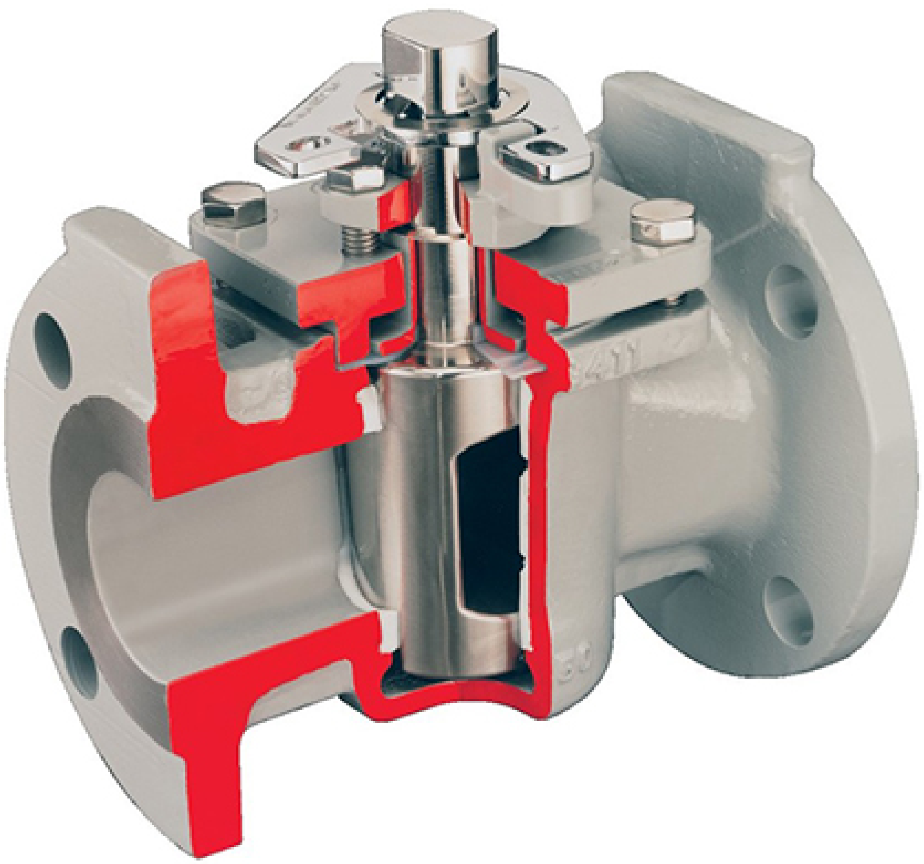
Globe Valve


Gland
Yoke
Stem
Stem Packing
Bonnet Pull-off Bolts
Gasket
Bonnet
Seat (Typical)
Backseat
Valve Body
Disc (Plug)

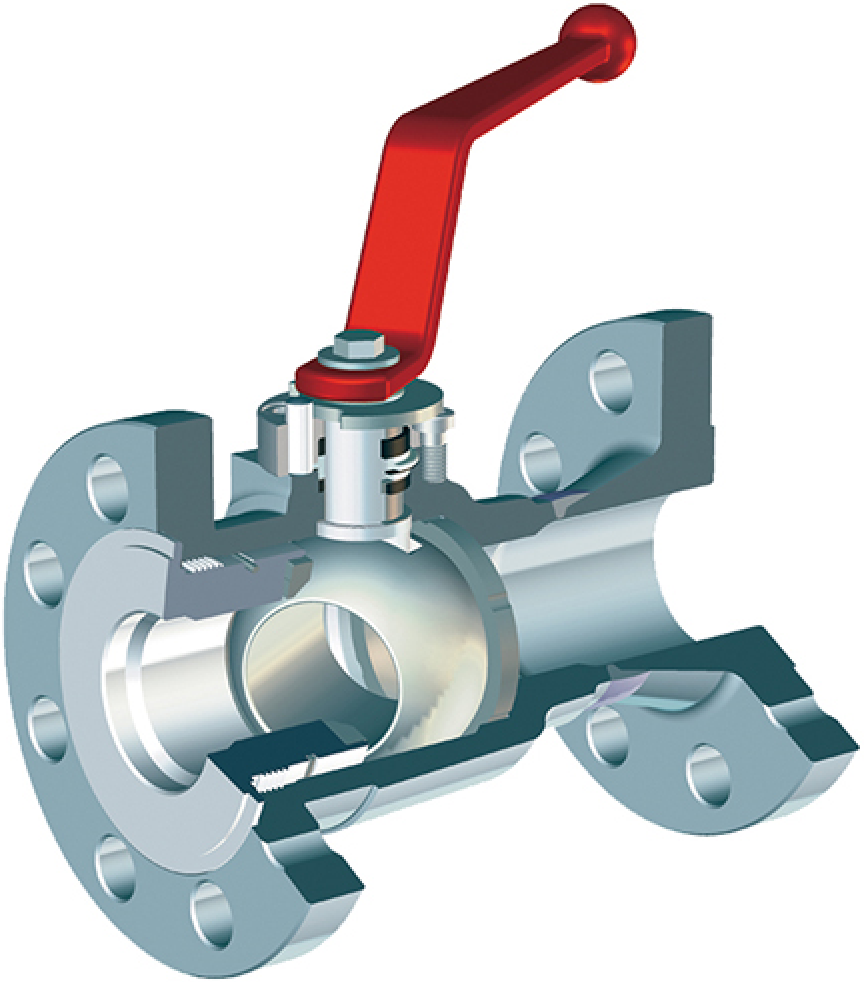
Anchor/Darling Y-Pattern Globe Valve

Valtek Ball Valve

Durco Plug Valve

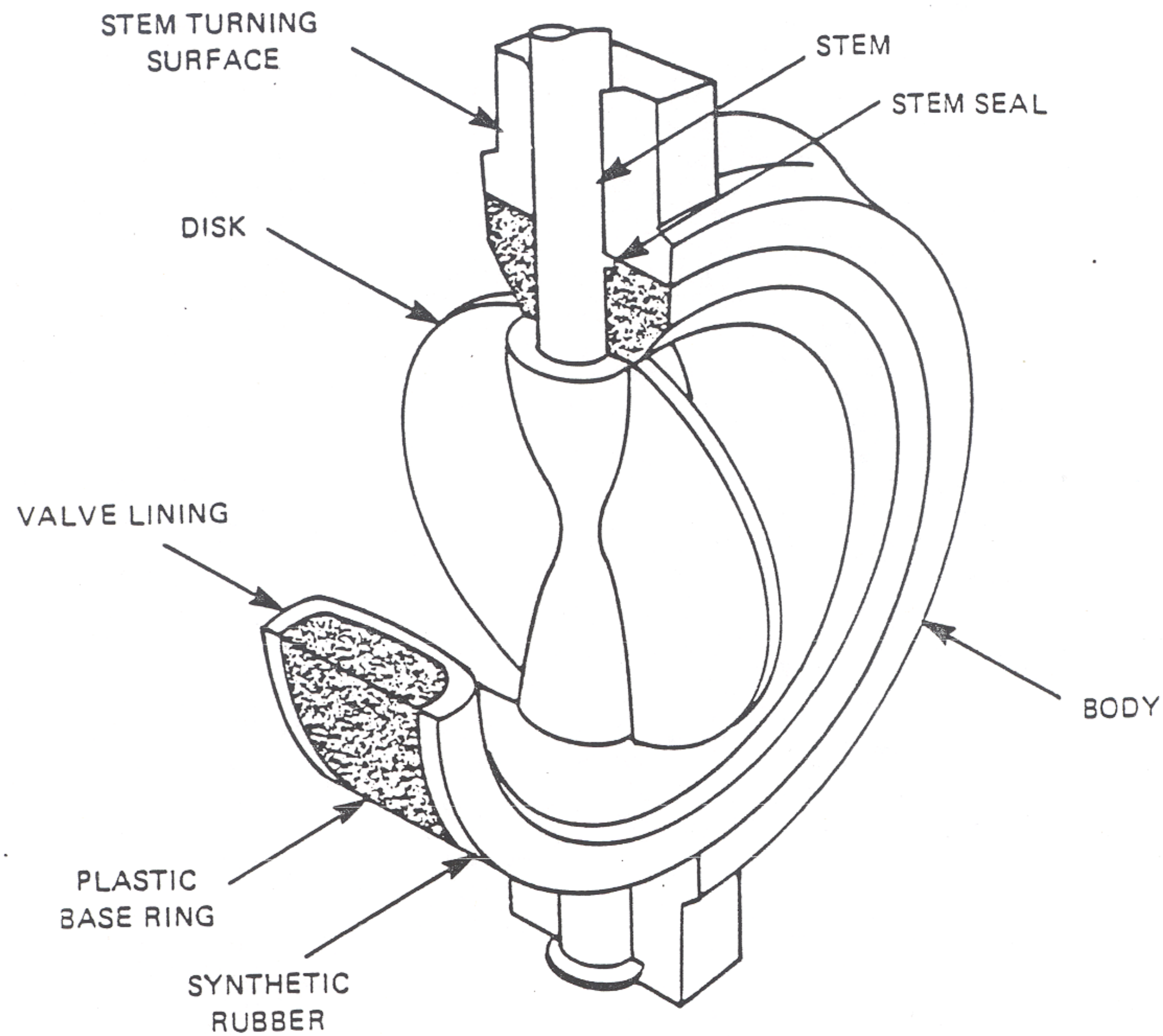


Flowserve Ball Valve

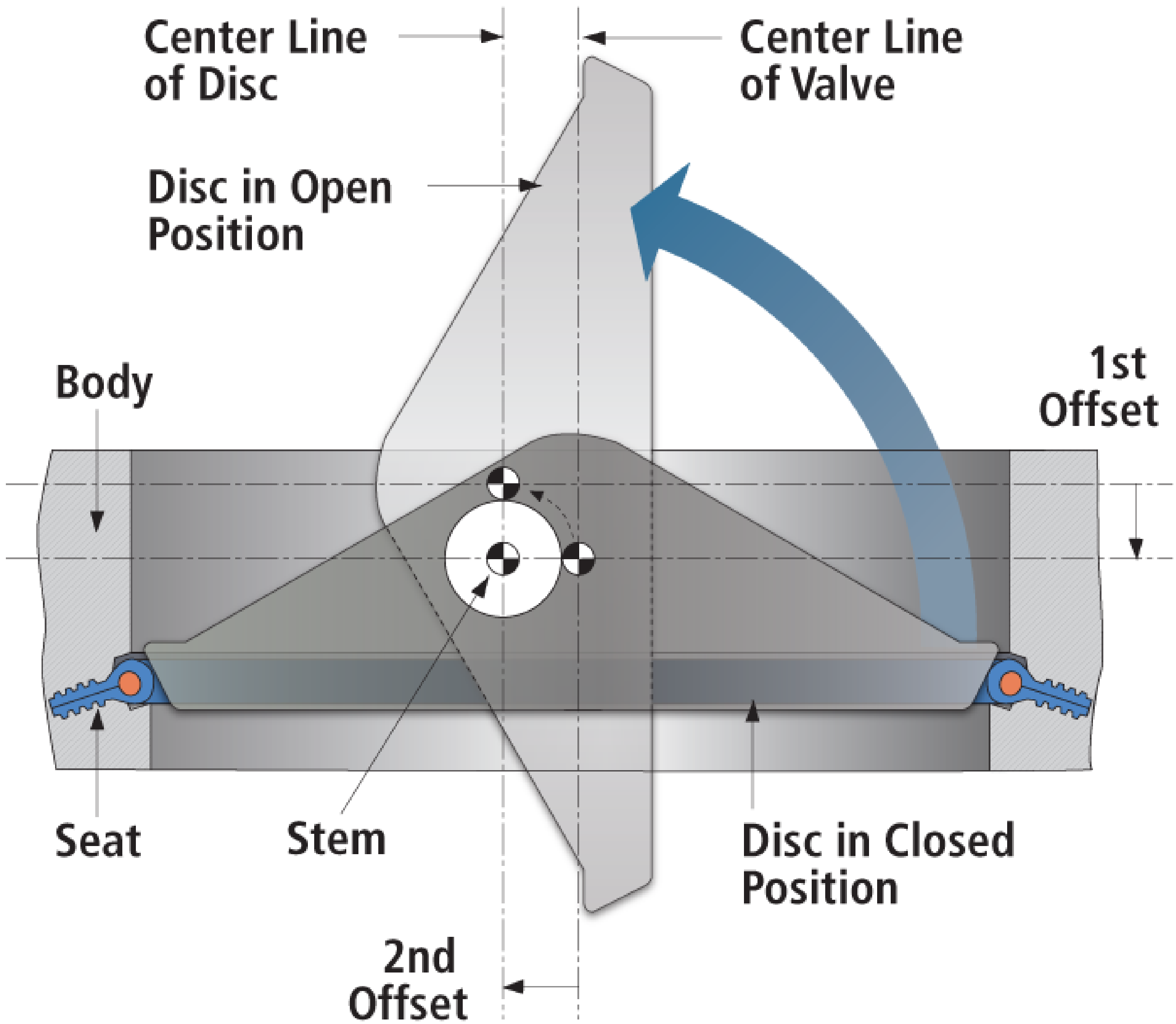


NAF Butterfly Valve

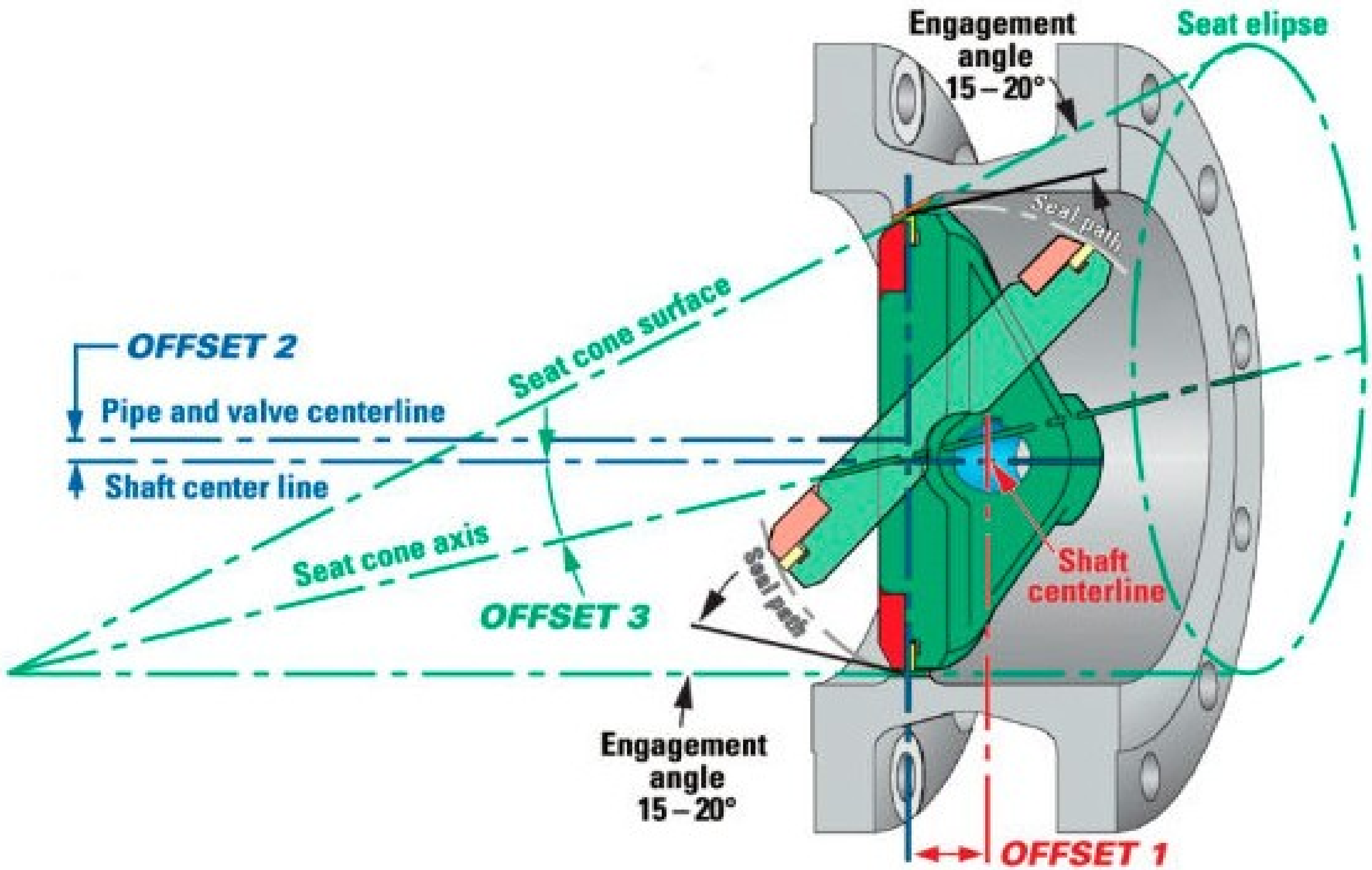
Symmetric Disc Butterfly Valve



Double Offset Butterfly Valve

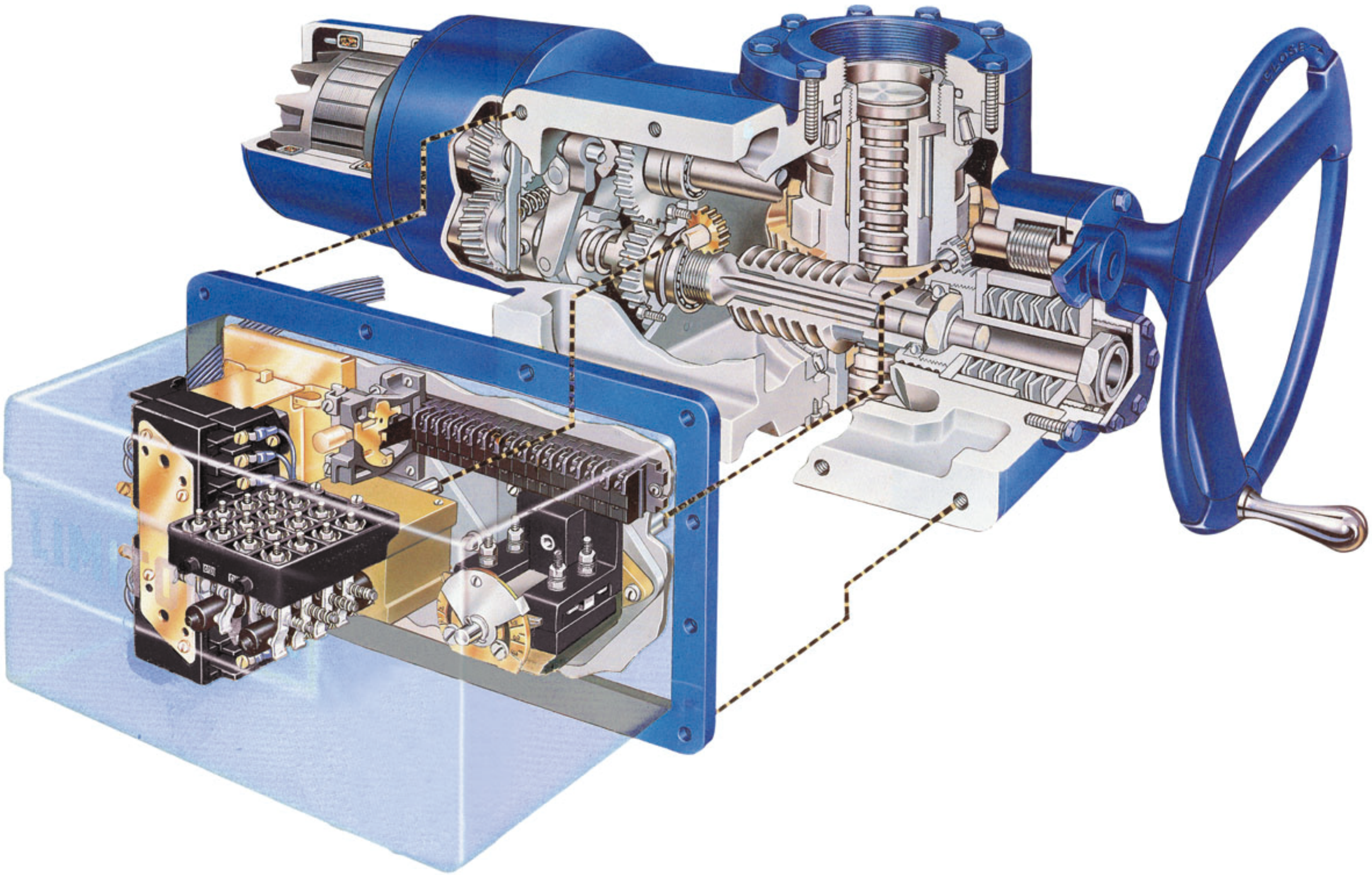


Triple Offset Butterfly Valve



3.b Motor actuator types and function

Limitorque SMB-0



Limitorque Nameplate

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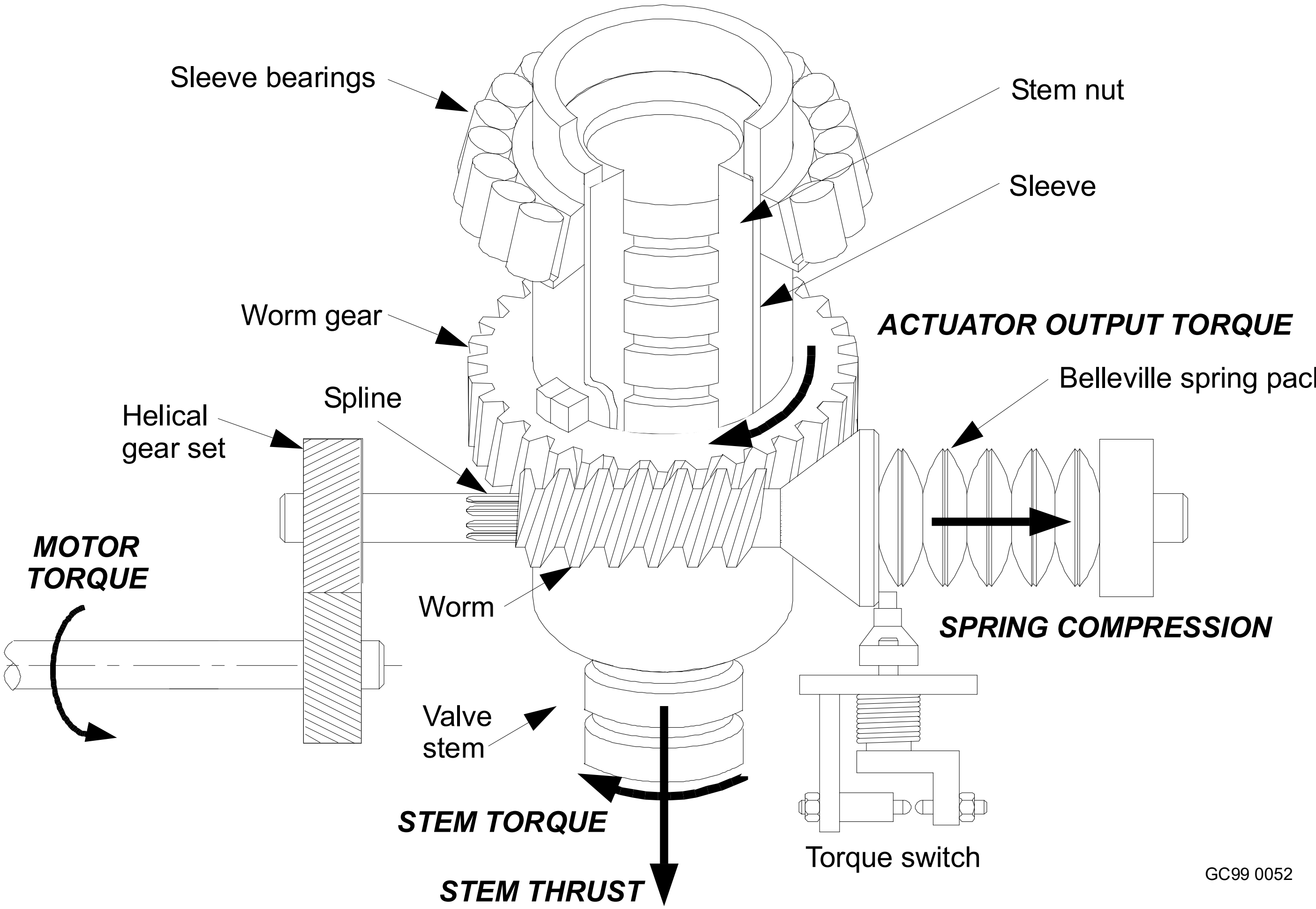
SMB-0 thru SMB-4 Exploded View

FIGURE REDACTED

Limitorque Motor Operation



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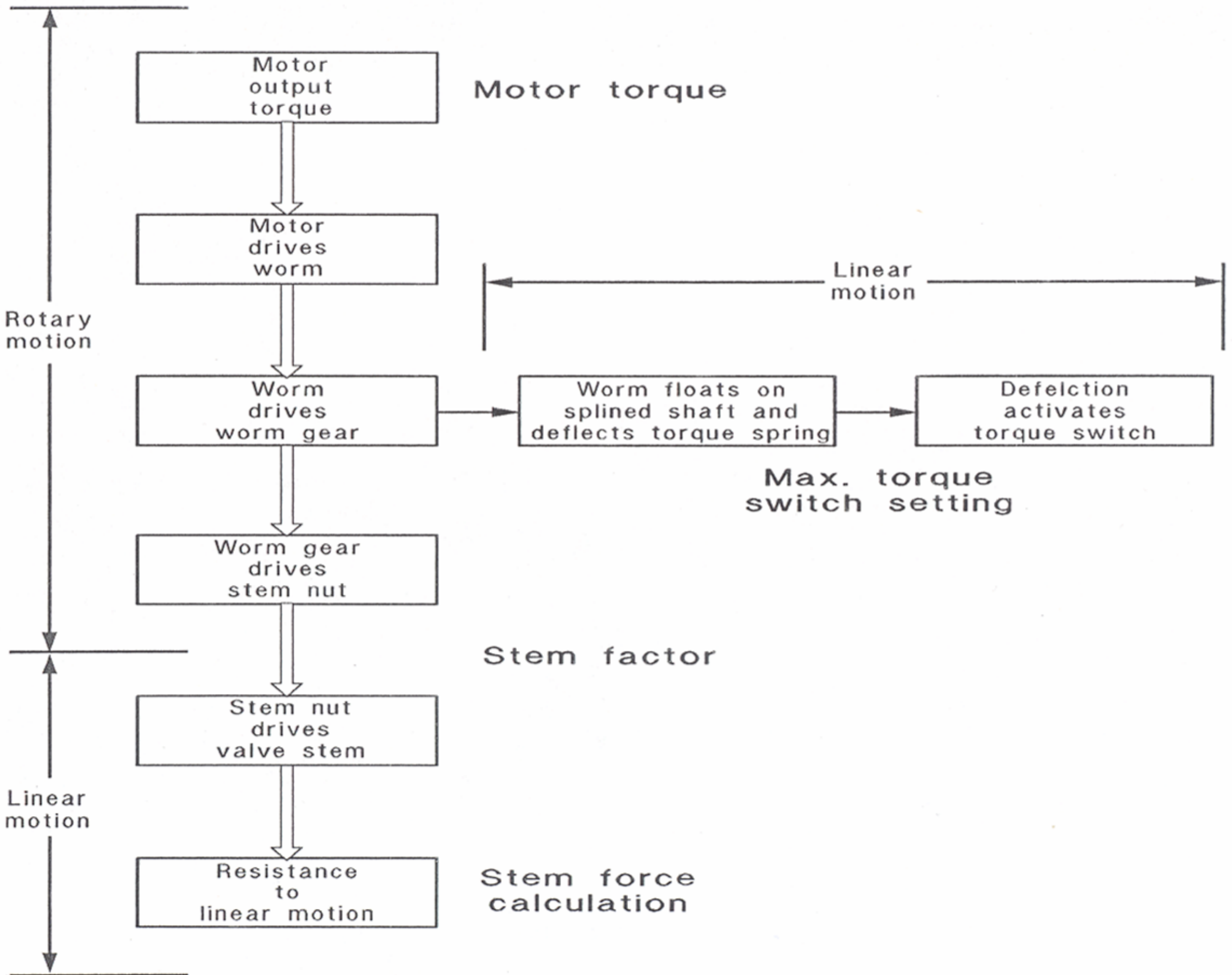
SMB-0 thru SMB-4 Power Train

Worm Gear

Framatome website

Motor Operator Process Diagram



Actuator Tripper Fingers

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SMB-0 thru SMB-4 Tripper Finger

FIGURE REDACTED

FIGURE REDACTED

SMB-0 thru SMB-4

FIGURE REDACTED

SMB-0 thru SMB-4 Declutch Mechanism

SMB-0 thru SMB-4 Worm Shaft

FIGURE REDACTED

Limitorque Torque Switch

FIGURE REDACTED

Limitorque Torque Switch Photograph

PHOTO REDACTED

Limitorque

Torque

Switch

FIGURE REDACTED

New Limitorque SMB/SB-000 Torque Switch

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Limitorque 2-Train Limit Switch

FIGURE REDACTED

Limitorque
4-Train
Limit Switch

FIGURE REDACTED

Limitorque Limit Switch

eBay

Limit Switch Contacts

FIGURE REDACTED

Limit Switch Control Functions

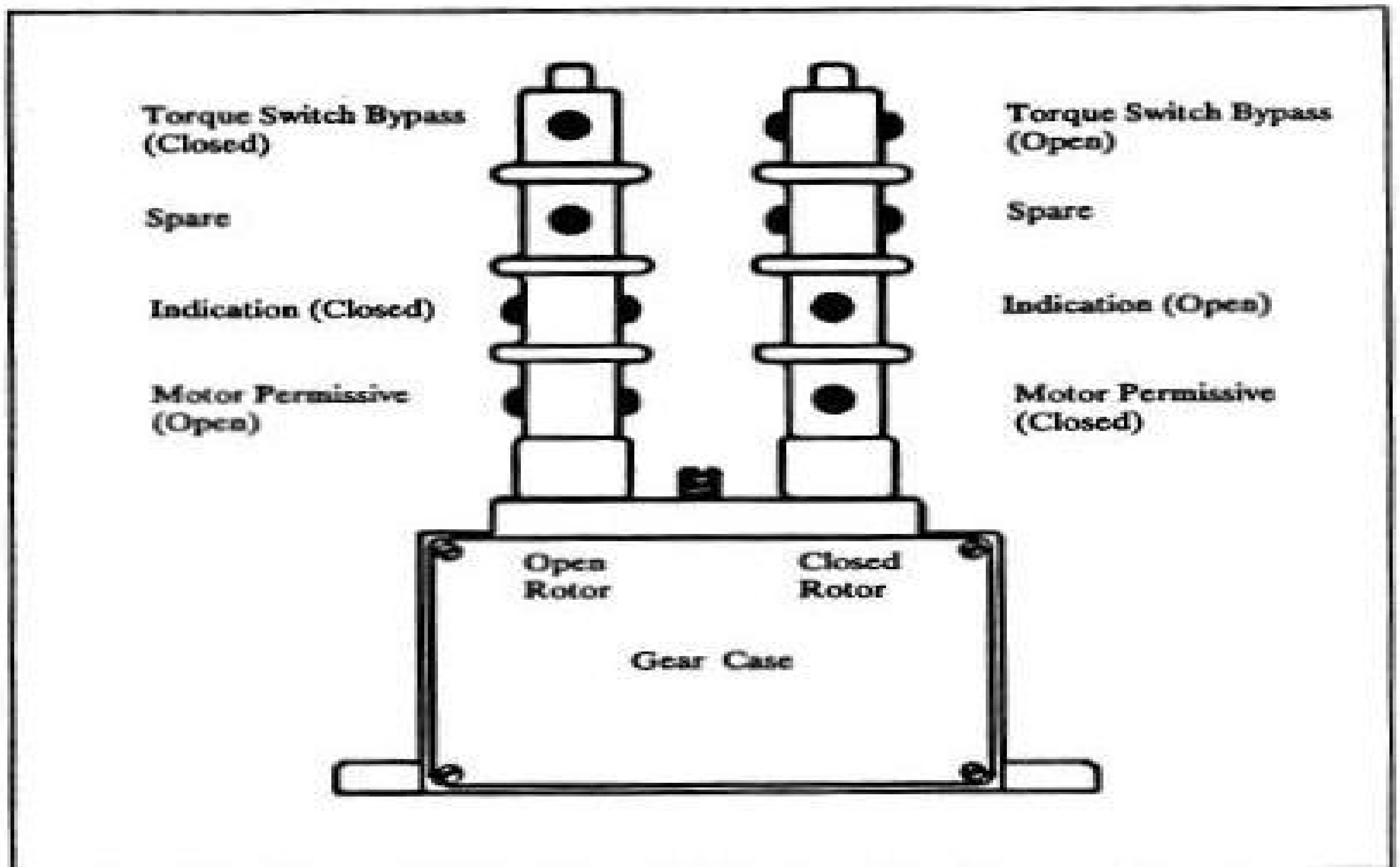
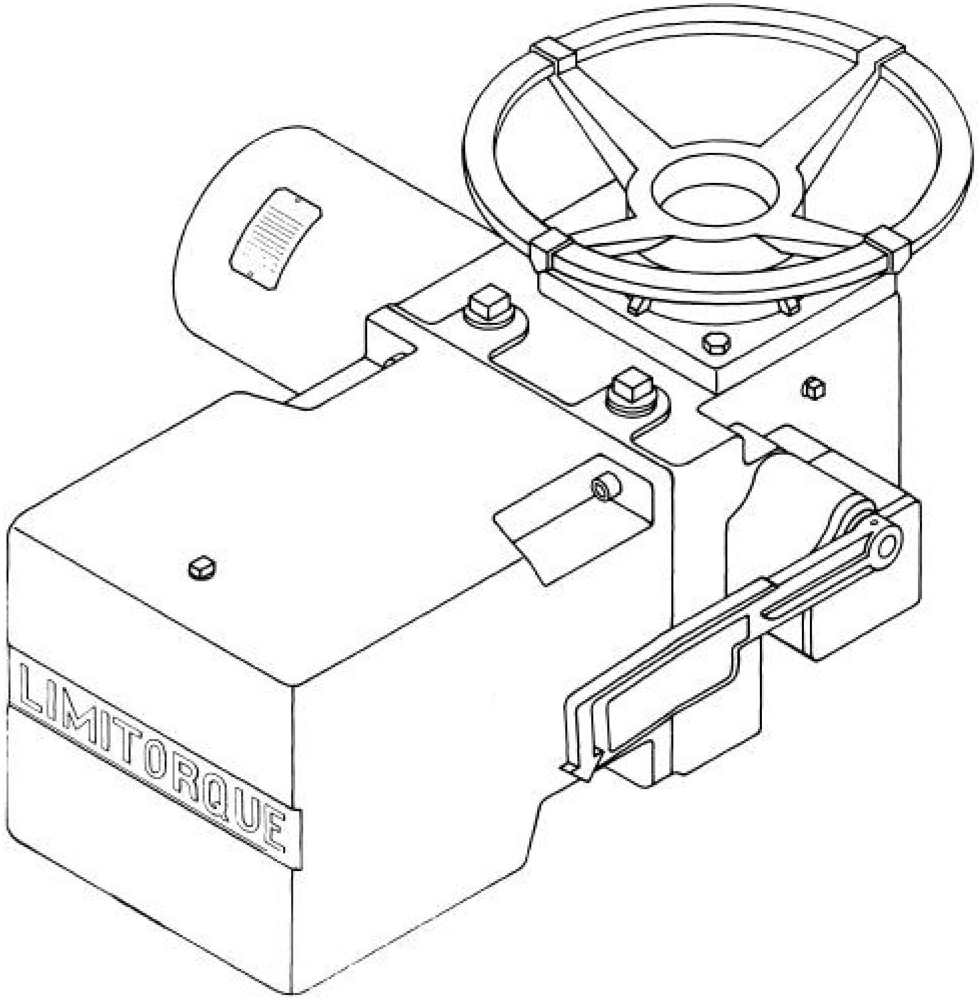


Figure 10-4 Limit Switch Control Functions

SMB-00 & SMB-000



SMB-00 & SMB-000
Exploded View

FIGURE REDACTED

FIGURE REDACTED

FIGURE REDACTED

SMB-00 & SMB-000 Tripper Finger Motor Mode

FIGURE REDACTED

FIGURE REDACTED

FIGURE REDACTED

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SMB-00 & SMB-000
Drive Sleeve

FIGURE REDACTED

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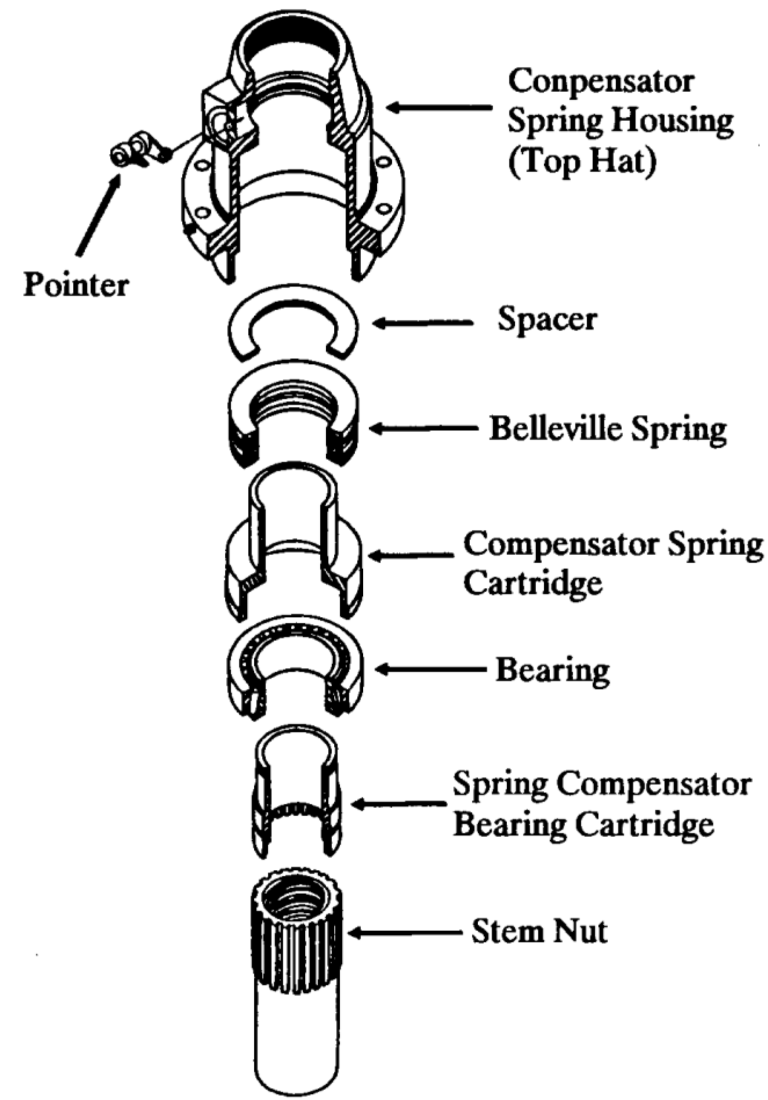
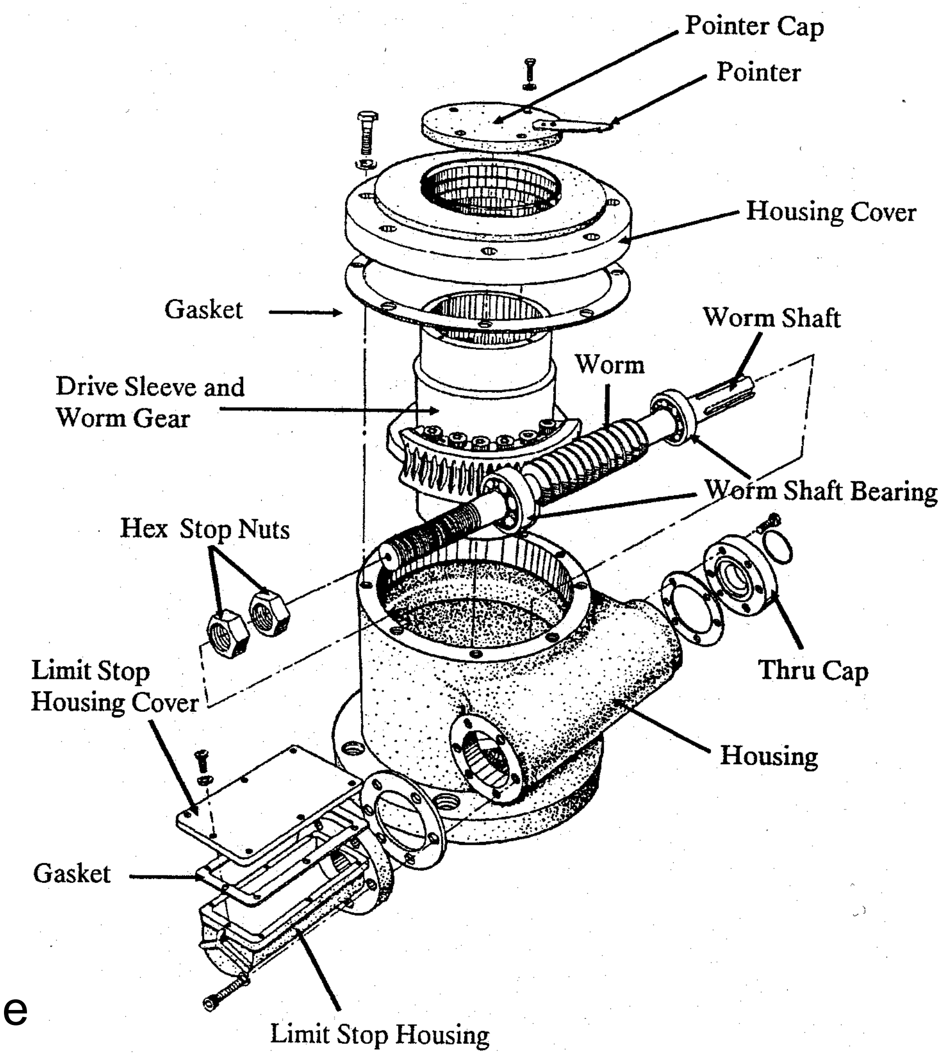
Typical Blank Stem Nut & Stem Nut Lock Nut

SB Belleville Spring Compensator



NRC Training E112

HBC-0 to 3 Operator



ISU Training Slide
internet site

SMB-000/HBC
Actuator

Can-Am
Machinery

Limitorque Critical Parts List

- Limitorque provides a list of critical parts for its actuators.
- Critical parts should be treated as safety-related components under the QA Program established to satisfy 10 CFR Part 50, Appendix B.
- Stem nut is an example of a critical part in the Limitorque actuator.
- Limitorque critical parts list is located on NRC Sharepoint site.

AC Motors

- 3-phase 230/460/550/575 VAC Reliance squirrel-cage induction motors
- Speeds: 900, 1800, 3600 rpm
- Frame sizes: 48, 56, 180, 210, 256, 326
- Factory lubricated sealed bearings
- Output torque approximately proportional to square of per unit voltage.
- Locked rotor torque is approximately 1.1 times starting torque.
- For motor voltage less than 70% of rated voltage, actuator vendor should be consulted for motor performance.

DC Motors

- 125/250 VDC Peerless compound-wound motors
  - Compound-wound motors are compromise between shunt-wound (good speed regulation) and series-wound (high starting torque)
- Output torque approximately linearly proportional to voltage.
- Locked rotor torque is approximately 1.6 times starting torque.
- For motor voltage less than 70% of rated voltage, actuator vendor should be consulted for motor performance.

Motor Insulation

- Class B: 85 °C rise over 40 °C [mild 125 °C]
- Class H: 135 °C rise over 40 °C [harsh 175 °C]
- Class RH: 135 °C rise over 40 °C plus radiation [very harsh 250 °C]

Motor Torque Output

<u>AC Motor</u>

$Tq_{motor} = Tq_{rated} (V_{act} / V_{rat})^2 F_{temp} F_{app}$

Tq_{motor} = motor output torque
Tq_{rated} = rated torque
V_{act} = actual voltage
V_{rat} = rated voltage
F_{temp} = factor due to motor heating
F_{app} = application factor

<u>DC motor</u>

$Tq_{motor} = Tq_{rated} (V_{act} / V_{rat}) F_{temp} F_{app}$

Motor Definitions

- **<u>Duty</u>**

  Time during which a motor can carry its nameplate rating safely (Typically, 15 minutes for ac and 5 minutes for dc motors.)
- **<u>Duty Cycle</u>**

  Number of strokes needed for intended service.
- **<u>Available Duty Cycles</u>**

  Duty rating time divided by stroke time to determine number of strokes before exceeding duty rating.
- **<u>Stroke Time</u>**

  Time to stroke valve in one direction (e.g., open to close).
- **<u>Torque Control</u>**

  Control relies on torque switch trip (typically close direction).
- **<u>Limit Control</u>**

  Control relies on limit switch trip (typically open direction).

Motor Definitions- Cont'd

- **Motor RPM**

  RPM listed on nameplate of motor is RPM of motor at running torque.
- **Running Torque**

  Typically run rated at 20% of starting torque.
- **Starting Torque**

  Motor torque at beginning of zero speed condition.
- **Locked Rotor Torque/Stall Torque**

  Torque output of motor at zero speed and rated voltage and frequency noted on motor curve data sheet. If motor curve data sheet is unavailable, locked rotor torque is estimated to be 110% of start torque due to manufacturer designing motor with 10% margin to cover undervoltage conditions.
- **Motor temperature**

  Motor temperature rise plus ambient temperature.

Limitorque Wiring Diagram

FIGURE REDACTED

FIGURE REDACTED

AC Motor Curve

FIGURE REDACTED

DC Motor Curve

Motor Actuator Environmental Qualification

- Motor actuators undergo environmental qualification in accordance with IEEE standards, such as IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," accepted in RG 1.89 (Revision 1), and IEEE 382-2006, "Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations," accepted in RG 1.73 (Revision 1).
- Limitorque and EPRI have issued guidance for the environmental qualification of motor actuators.
- As discussed later, ASME Standard QME-1-2007 references the IEEE standards as part of the equipment qualification requirements.

IEEE 1290-2015

- REDACTED

FIGURE REDACTED

IEEE 1290-2015

FIGURE REDACTED

IEEE 1290-2015

FIGURE REDACTED

IEEE 1290-2015

IEEE 741-2007

- REDACTED

Thermal Overload Relay (TOR) Heater Selection

- REDACTED

TOR Tripping Criteria

- REDACTED

FIGURE REDACTED

IEEE 741-2007

FIGURE REDACTED

IEEE 741-2007

Limitorque Actuator Motor vs. Manual Mode

- Actuators typically are not qualified for performing safety functions in the manual mode.
- Actuators might not undergo qualification testing to demonstrate changes from manual to motor mode.
- Some actuators have experienced problems with changing from manual to motor mode.
- Licensees should ensure that actuators are returned to motor mode prior to declaring operable.

Limitorque Actuator Orientation

- Limitorque actuators should be installed in preferred orientation to avoid performance issues.
- Preferred orientation is motor, spring pack, and limit switch compartment in the same horizontal plane.
- Other orientations might result in grease interfering with performance of motor, spring pack, or electrical components in limit switch compartment.
- Licensees need to justify qualification of Limitorque actuators where installation will be inconsistent with preferred orientation.
- If MOV cannot be installed in preferred orientation, licensee should conduct periodic inspections to identify any adverse impacts.

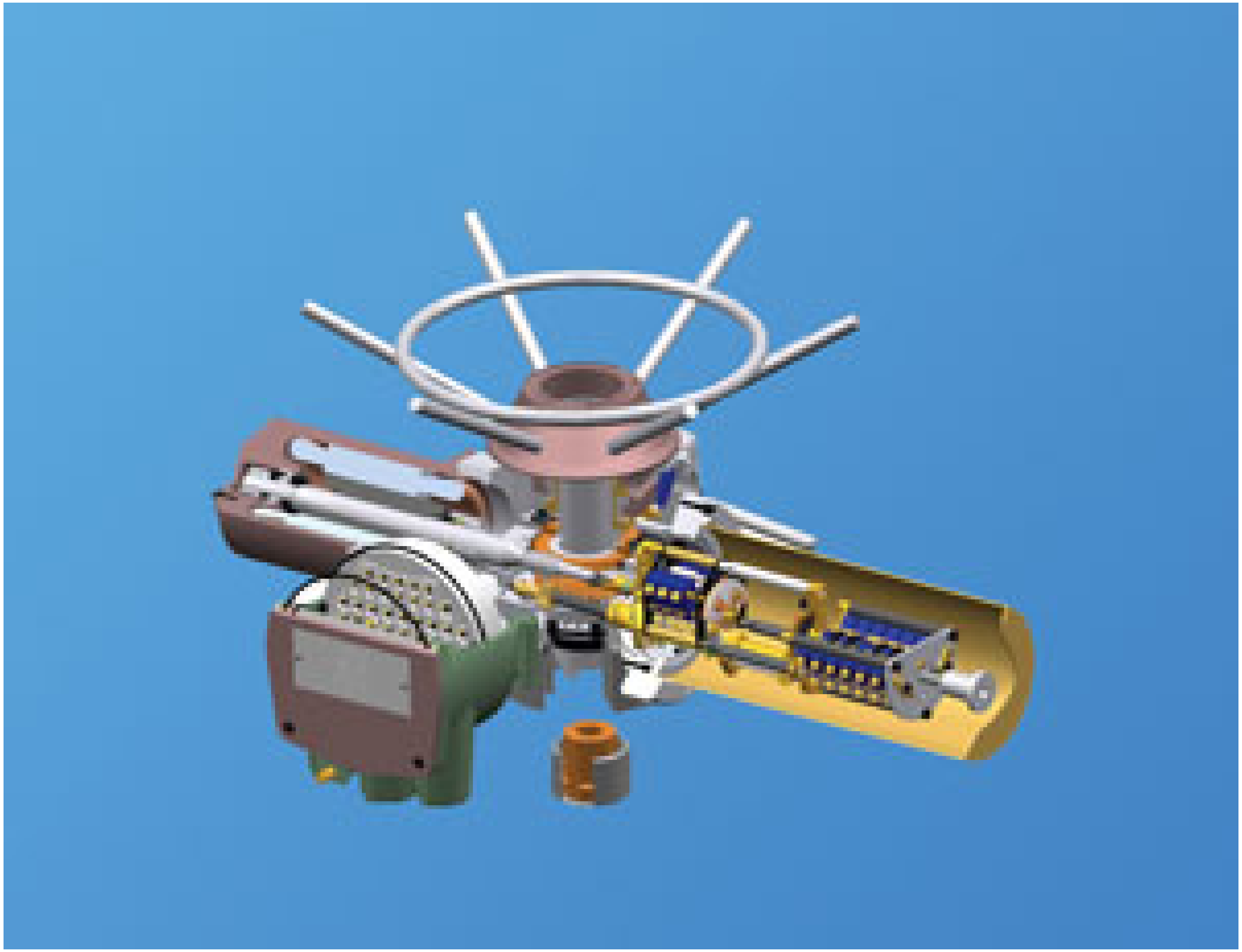
Rotork Actuator

- 3-phase 220 VAC squirrel-cage induction motor
- Electric motor-driven gear box similar to Limitorque
- Oil gear lubrication
- Open and close spring packs and switches
- Motor shaft also acts as worm shaft
- Nuclear Actuator Sizes 7NA, 11NA, 14NA, 16NA, 30NA, 40NA, 90NA
- Syncroset watertight/explosion-proof actuators for containment
- On September 6, 2018, Rotork announced that it is obsoleting its nuclear safety-related NA actuator with production ceasing by December 20, 2019.

Rotork Terminology

- Syncroset (Nuclear): most electrical components remote
- Syncropak (Non-nuclear): all electrical components on actuator
- Insulation Sizes: Class B (125 °C), Class F (155 °C), and Class H (175 °C)
- Nuclear Actuator Output Range:
  - 7NA range: low rpm (25 ft lb) to high rpm (16 ft lb)
  - 90 NA range: low rpm (1500 ft lb) to high rpm (540 ft lb)

Rotork NA Nuclear Electric Actuator



Valve Magazine.com 10-21-2011

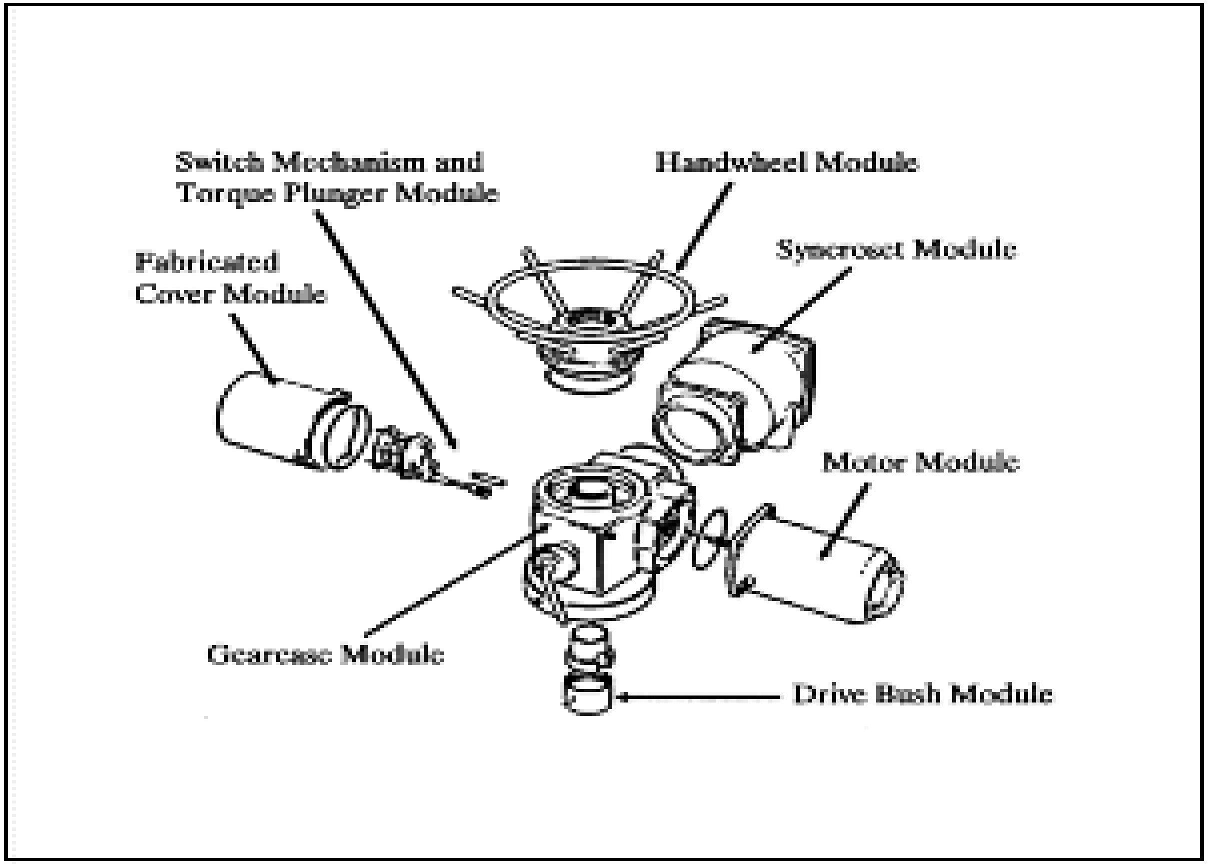


Figure 2-54 Rotork Syncroset

Rotork Operation

1. Motor operation initiated
2. Motor shaft (Wormshaft) rotates and turns Wormwheel
3. Wormwheel rotates Center Column
4. Center Column drives Drive Bush which turns to open and close valve
5. At full stroke, switch de-energizes motor control circuit
6. At high torque, Wormshaft overcomes Belleville spring and walks Wormwheel and actuates torque switch
7. In open direction, actuator has hammerblow before Center Column engaged

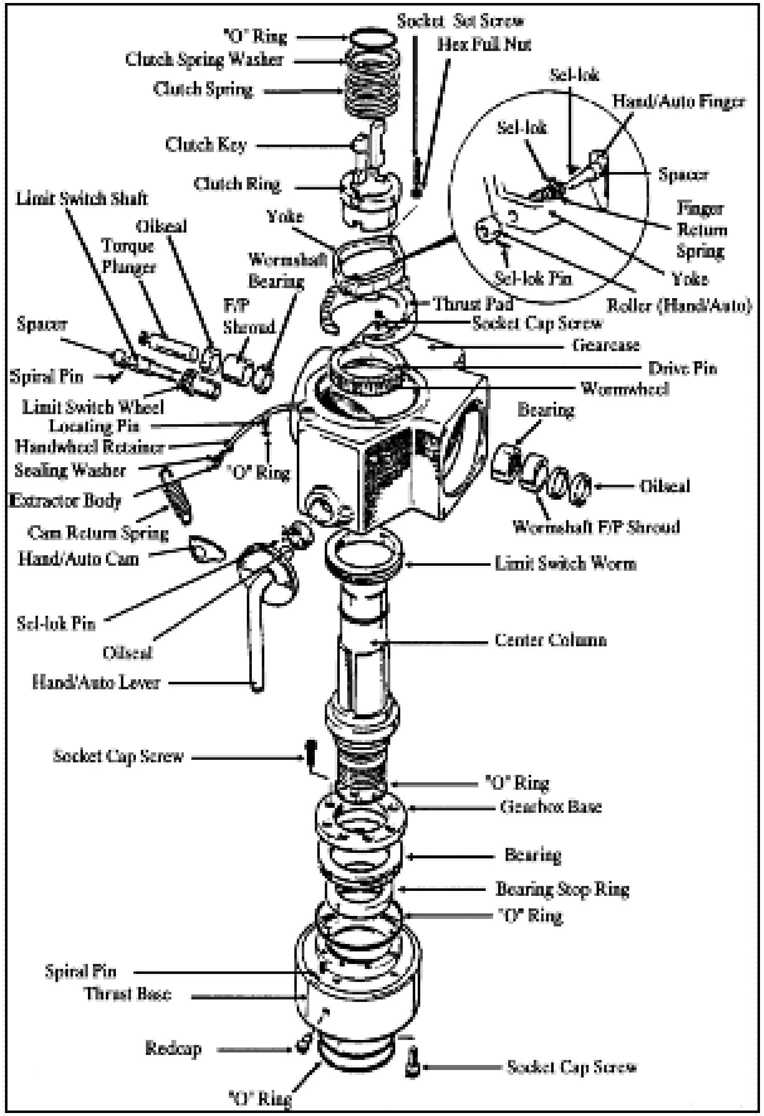


Figure 2-55 Rotork Assembly

Rotork Actuator

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Rotork vs. Limitorque Actuators

1. Rotork uses modules instead of parts
2. Rotork Belleville washers installed behind motor
3. Rotork has only 1 gear arrangement (worm/wormwheel)
4. Rotork has a yoke for manual operation
5. Different bearing designs
6. Rotork NA actuators are watertight and explosion-proof
7. Rotork has 1 switch mechanism for torque and limit switches while Limitorque uses separate torque and limit switches

Rotork Operating Experience

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4. MOV Lessons Learned

4.a Operating experience

MOV Operating Experience

- NUREG-0660 included TMI-2 Accident Action Items II.E.4.2 (Containment) and II.E.6.1 (Valve Testing)
- In 1980s, operating experience revealed weaknesses in design, qualification, maintenance, personnel training, and inservice testing (IST) for MOVs:
  - Davis Besse Feedwater Failure (IN 85-50)
  - Catawba Auxiliary Feedwater Failure (IN 89-61)
  - Palisades PORV Block Valve Failure (AIT Nov. 1989)
- Research programs by industry and NRC confirmed MOV design and qualification weaknesses.
- NRC initiated regulatory action to address these weaknesses.

Past MOV Issues

- Underestimation of required valve thrust or torque from assumptions for differential pressure (DP), valve factors, butterfly valve torque coefficients, and unwedging.
- Overestimation of motor actuator thrust or torque output from assumptions for actuator efficiency, degraded voltage effects, ambient temperature effects, stem friction, and load sensitive behavior.
- Potential unpredictability of valve performance under high flow conditions.
- Significant variation in MOV performance.

Past MOV Issues
(continued)

- Deficiencies in MOV parts (e.g., torque and limit switches, motor shafts, pinion keys, valve yokes, and stem-disc connections).
- Improper low voltage operation of motor brakes.
- Inadequacies in some MOV diagnostic equipment in accurately measuring thrust and torque.
- Gearbox and spring pack grease hardening.
- Maintenance and training weaknesses.
- Inadequate corrective action.
- MOV magnesium rotor degradation.
- Motor thermal overload issues.

Regulatory Action

- NRC Office of Nuclear Regulatory Research sponsored valve testing program by Idaho National Laboratory (INL).
- NRR prepared NUREG-1352 for MOV Action Plan
- Revised 10 CFR 50.55a to supplement ASME OM Code.
- Issued Bulletin 85-03 and Generic Letter (GL) 89-10, GL 95-07, and GL 96-05.
- Issued several Regulatory Issue Summaries and numerous Information Notices.
- Updated RG 1.73, RG 1.100, and RG 1.106
- Performed reviews and inspections of MOV programs at nuclear power plants.
- Updated Standard Review Plan and Inspection Procedures.

MOV Information Notices

- IN 1981-31, Failure of Safety Injection Valves to Operate Against DP
- IN 1985-20 and S1, Motor-Operated Valve Failures due to Hammering Effect
- IN 1985-22, Incorrect Installation of MOV Pinion Gear
- IN 1985-50, Complete Loss of Main and Auxiliary Feedwater at PWR Designed by B&W
- IN 1985-67, Valve Shaft to Actuator Key Failure
- IN 1986-02, Failure of Valve Operator Motor During Environmental Qualification Testing
- IN 1988-84, Defective MOV Motor Shaft Keys
- IN 1989-61, Failure of Borg-Warner Gate Valves to Close Against Differential Pressure
- IN 1990-21, Potential Failure of Motor-Operated Butterfly Valves
- IN 1990-37, Sheared MOV Pinion Keys
- IN 1990-40, Results of NRC-Sponsored MOV Testing

- IN 1990-72, Testing of Parallel Disc Gate Valves in Europe
- IN 1992-17, NRC Inspections of MOV Programs
- IN 1992-23, Results of Validation Testing of MOV Diagnostic Equipment
- IN 1992-26, Pressure Locking of Motor-Operated Flexible Wedge Gate Valves
- IN 1992-27, Thermally Induced Accelerated Aging and Failure of ITE/Gould AC Relays
- IN 1992-59 (R1), Horizontally Installed Motor-Operated Gate Valves
- IN 1992-83, Thrust Limits for Limitorque Actuators
- IN 1993-74, High Temperatures Reduce AC Motor Output
- IN 1993-98, Motor Brakes on Actuator Motors
- IN 1994-10, MOV Motor Pinion Key Failure
- IN 1994-41, Problems with GE Type CR124 Overload Relay
- IN 1994-50, Failure of GE Contactors to Pull In at Required Voltage
- IN 1994-67, Pratt Butterfly Valve MOVs
- IN 1994-69, Potential Inadequacies in Torque Requirements and Output for Motor-Operated Butterfly Valves

- IN 1995-14, Susceptibility of Containment Sump Valves to Pressure Locking
- IN 1995-18, Potential Pressure Locking of Gate Valves
- IN 1995-30, Low Pressure Coolant Injection and Core Spray Valve Pressure Locking
- IN 1996-08, Thermally Induced Pressure Locking of HPCI Valve
- IN 1996-30, Inaccuracy of Diagnostic Equipment for Motor-Operated Butterfly Valves
- IN 1996-48 and Supplement 1, MOV Performance Issues
- IN 1997-07, GL 89-10 Close-out Inspection Issues
- IN 1997-16, Preconditioning of Plant SSCs before ASME Code Inservice Testing or TS Surveillance Testing
- IN 2002-26 S2, Additional Flow-Induced Vibration Failures after a Recent Power Uprate
- IN 2003-15, Importance of Maintenance Follow-up Issues

- IN 2005-23, Vibration-Induced Degradation of Butterfly Valves
- IN 2006-03, Motor Starter Failures due to Mechanical-Interlock Binding
- IN 2006-15, Vibration-Induced Degradation and Failure of Safety-Related Valves
- IN 2006-26, Failure of Magnesium Rotors in MOV Actuators
- IN 2006-29, Potential Common Cause Failure of MOVs as a result of Stem Nut Wear
- IN 2008-20, Failures of MOV Actuator Motors with Magnesium Alloy Rotors
- IN 2010-03, Failures of MOVs due to Degraded Stem Lubricant
- IN 2012-14, MOV Inoperable due to Stem-Disc Separation
- IN 2013-14, Potential Design Deficiency in MOV Control Circuitry
- IN 2017-03, Anchor/Darling Double Disc Gate Valve Wedge Pin and Stem-Disc Separation Failures

IN 1992-59, Revision 1 Horizontally Installed Motor-Operated Gate Valves

- In March 1992, SONGS Unit 3 reported two 4-inch HPCI MOVs failed to close during GL 89-10 DP testing.
- In October 1991, Crystal River determined that three EFW MOVs would not close during GL 89-10 DP testing.
- In April 1992, FitzPatrick notified NRC that two double-disc MOVs might not fully seat during closure.
- Horizontal installation can cause increased operating requirements and maintenance problems with spring pack, motor, and limit switch compartment at lowest actuator location.

Motor Hammering Effects

- IN 1985-20 and Supplement 1 discussed MOV motor hammering effects, including mechanical overloading, motor overheating, starter contactor failure, circuit breaker trips, and valve seat jamming.
- Hammering caused by spring pack energy reclosing torque switch contacts if worm gear is not self-locking.
- IN 1993-98 reported that some motor brakes were not adequately sized to prevent hammering.
- IN 2013-14 reported that MOV control circuitry modification used to avoid hammering might result in a dead zone if power interrupted during valve stroke.
- Locking gear sets are recommended to prevent MOV motor hammering.

Related Information Notices

- IN 2008-02, Findings Identified During Component Design Bases Inspections
- IN 2008-04, Counterfeit Parts Supplied to NPPs
- IN 2011-01, Commercial-Grade Dedication Issues
- IN 2012-06, Ineffective Use of Vendor Technical Recommendations
- IN 2014-11, Recent Issues of Qualification and Commercial Grade Dedication of Safety-Related Components
- IN 2015-13, Main Steam Isolation Valve Failure Events
- IN 2016-09, Recent Issues when using Reverse Engineering Techniques in Procurement
- IN 2018-04, Operating Experience Regarding Failure of Operators to Trip Plant When Experiencing Unstable Conditions

Regulatory Issue Summaries

- RIS 2000-03, Resolution of GSI 158: Performance of Safety-Related POVs Under Design Basis Conditions
- RIS 2000-17, Managing Regulatory Commitments Made by Power Reactor Licensees to the NRC Staff
- RIS 2005-20 (Revision 2), Revision to NRC Inspection Manual Part 9900 Technical Guidance, “Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety”
- RIS 2001-15, Performance of DC-Powered MOV Actuators
- RIS 2011-13, Followup to GL 96-05 for Evaluation of Class D Valves under JOG MOV Periodic Verification Program

Regulatory Issue Summaries

- RIS 2012-08, Revision 1, Developing IST and ISI Programs Under 10 CFR Part 52
- RIS 2015-08, Oversight of Counterfeit, Fraudulent, and Suspect Items in Nuclear Industry
- RIS 2016-01, NEI Guidance for Use of Accreditation in lieu of Commercial Grade Surveys
- RIS 2016-05, Embedded Digital Devices in Safety-Related Systems
- RIS 2018-05, Supplier Oversight Issues Identified During Recent NRC Vendor Inspections

MOV Cheater Bars

- MOV maintenance activities can be hazardous if not conducted according to procedure.
- In January 2004, catastrophic MOV failure occurred at Crystal River Coal Plant with a fatal injury.
- MOV was a 20” gate valve with an SMC-2 actuator.
- On 1/22/2004, operators closed the MOV electrically and added manual force using a 24” long valve wrench to stop the valve from leaking.
- Additional manual force was in the range of 190K to 260K lbs.

MOV Cheater Bars

(continued)

- On 1/29/2004, operators attempted to open MOV:
  - 6 attempts to open electrically with 4 followed by driving valve in closed direction
  - 3 attempts to open manually with wrench on last effort.
- When valve came off seat, boiler water pressure acting over stem area generated a force ~ 26,000 lbs. into the housing.
- Actuator failed and ejected pieces of the housing which struck the employee.
- Analysis concluded that the manual closure on 1/22/2004 created multiple cracks in the housing.

Actuator Ejected Components

FIGURE REDACTED

MOV Cheater Bars

(continued)

- Each motor closure on 1/29/2004 appears to have extended the cracks.
- When valve came off seat, boiler pressure completed the cracking and ejected pieces.
- Apparent cause
  - Lack of training
  - Plant personnel unaware that using a valve wrench could cause overtorque leading to housing failure
  - Plant procedure not clear. “Pull down” interpreted to mean using valve wrench on handwheel to achieve good isolation
- Limitorque issued Safety Bulletin 6-04 emphasizing proper use of maintenance procedures and prohibition of use of cheater bars.

Magnesium Rotor Degradation

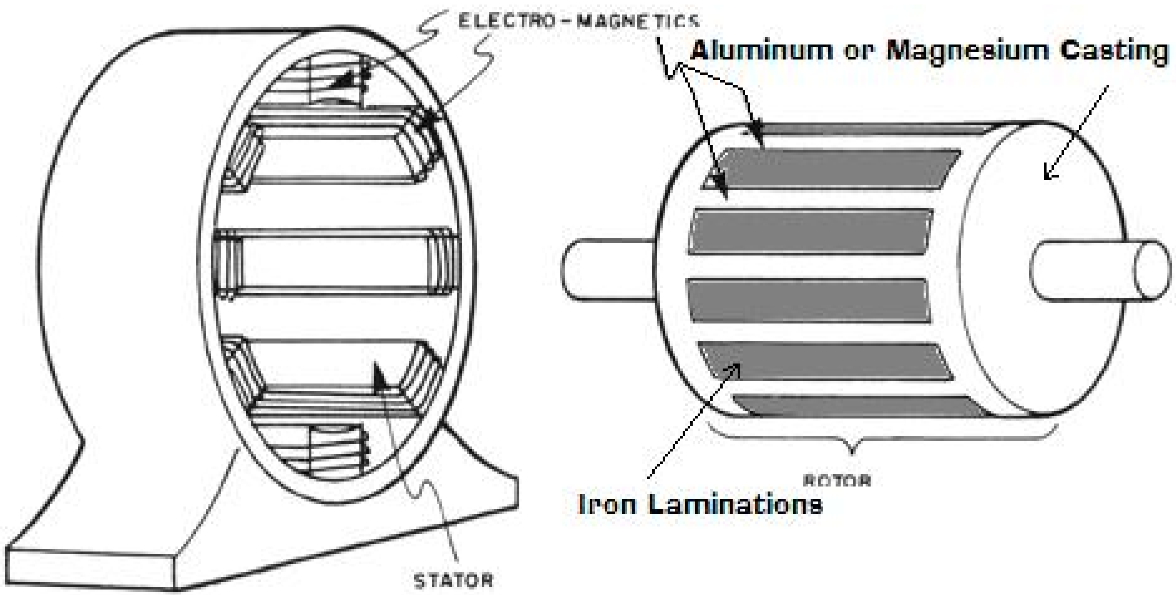
- Several MOVs with actuator motors manufactured with magnesium alloy rotors have failed.
- Failures attributed to corrosion of magnesium alloy rotors.
- GE SIL 425 (1985) and Limitorque Technical Update 06-01 (2006) provided industry guidance.
- Information Notices 1986-02, 2006-26, and 2008-20.
- NRC staff continuing to monitor magnesium rotor issue with MOV motors.

Motor Rotor Failure Experience

- 1985 – issue discovered during EQ tests
- Random motor failures have occurred since late 1980's
- Additional motor failures reported in 2005, 2006, 2007 and 2008
- Borescope inspections of motors initiated in 2007 by some licensees
  - At least 17 motors replaced when last reviewed
- Potential problem applicable to both BWR and PWR plants.

Rotor Background & Challenges

- Large percentage of MOV actuators are Limitorque design.
- Limitorque actuators mainly use Reliance 3-phase motors.
- Reliance motors designed with aluminum alloy or magnesium alloy rotors.
- All size 48 and 56 frame motors are aluminum (2 to 40 ft-lb).
- 180 size frame (60 – 400 ft-lb) are magnesium (some exceptions).
- Prior to 1995, Reliance did not maintain records on motor castings.
- Simple visual inspection cannot discern aluminum vs. magnesium.
- ASME testing and non-intrusive diagnostics have not been successful in determining internal rotor degradation.
- Converting larger frame rotor to aluminum is not easy task.
- Past preventive measures have not reduced failure rate.



Basic components of Induction AC motor

Rotor Construction

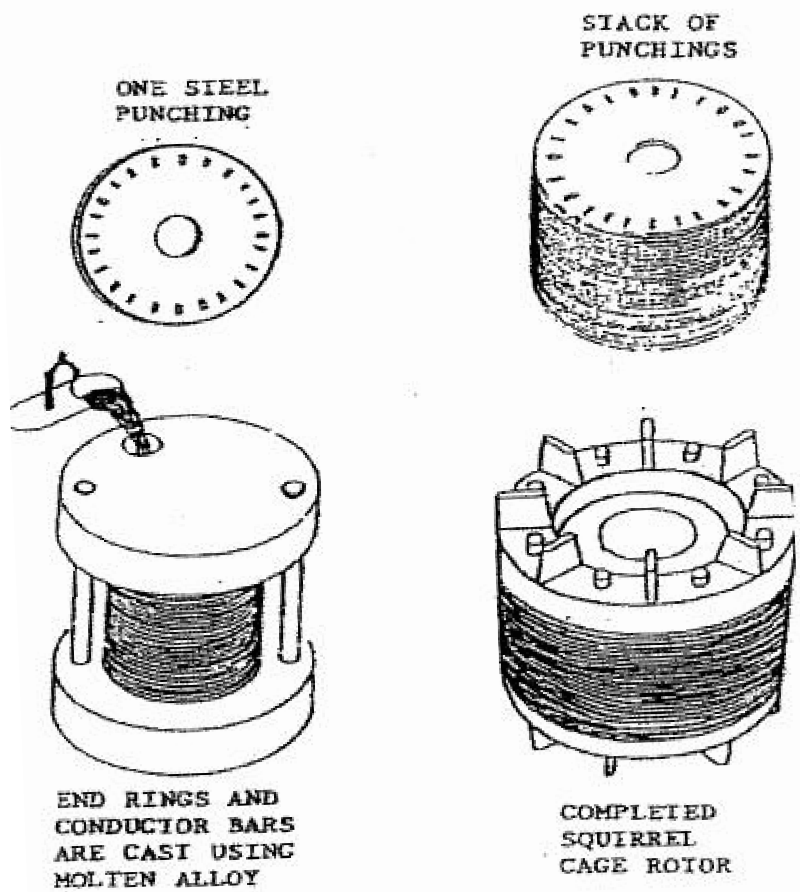


FIGURE 2. CONCEPTUAL EXPLANATION
OF ROTOR FABRICATION

Rotor Construction

PHOTOS REDACTED

Iron Lamination – Stator & Rotor

Diagram with 3 laminations