INCH-POUND

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MILITARY SPECIFICATION

SOLENOID, ELECTRICAL
GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the general requirements for electrical solenoids used to actuate various devices through the conversion of electrical signals into mechanical motion. These solenoids are of the axial stroke type and the rotary stroke type.

1.2 Classification. Solenoids are classified as follows.

Symbol	Type	Duty	Rotation
I	Pull	Continuous	N/A
II	Pull	Intermittent	N/A
III	Push	Continuous	N/A
IV	Push	Intermittent	N/A
V	Rotary	Continuous	Clockwise
VI	Rotary	Intermittent	Clockwise
VII	Rotary	Continuous	Counterclockwise
VIII	Rotary	Intermittent	Counterclockwise

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto.

SPECIFICATIONS

FEDERAL

- QQ-C-320 - Chromium Plating (Electrodeposited).
- QQ-N-290 - Nickel Plating (Electrodeposited).
- QQ-S-365 - Silver Plating, Electrodeposited, General Requirements for.

STANDARDS

MILITARY

- MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts.
- MIL-STD-1285 - Marking of Electrical and Electronic Parts.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: 88 LOG/LGME, Gentile Station, 1060 Hamilton Street, Dayton, OH 45444-5400 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 5945

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Defense Printing Service Detachment Office, Building 4D (Customer Service), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following document forms a part of this document to the extent specified herein. If the document is DoD adopted, the issue is that listed in the issue of the DODISS cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/NCSL Z540-1 - Calibration Laboratories and Measuring and Test Equipment - General Requirements.

(Application for copies should be addressed to American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B633 - Zinc on Iron and Steel, Electrodeposited Coatings of.

(Application for copies should be addressed to American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103.)

INTERNATIONAL ORGANIZATION FOR STANDARDS (ISO)

ISO 10012-1 - Quality Assurance Requirements for Measuring Equipment - Part 1: Metrological Confirmation System for Measuring Equipment.

(Application for copies should be addressed to American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Product specifications or engineering drawings. The individual item requirements shall be as specified herein and in accordance with the applicable product specification or engineering drawing. In the event of a conflict between the requirements of this specification and the product specification or engineering drawing, the latter shall govern.

3.2 First article inspection. When specified, samples shall be subjected to first article inspection (see 6.2) in accordance with 4.5.

3.3 Materials. The materials shall be as specified herein. When a definite material is not specified, a suitable material shall be used which will enable the solenoids to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of acceptance of the finished product.

3.3.1 Fungus resistant materials. Nonmetallic parts of the solenoid shall be inherently nonfungus nutrient or treated to resist fungus growth.

3.3.2 Metals. Metals shall be of a corrosion resistant type, or shall be plated or treated to resist corrosion.

3.3.2.1 Dissimilar metals. When dissimilar metals are used in intimate contact with each other, protection against electrolysis and corrosion shall be provided. The use of dissimilar metals in contact, which tend toward active electrolytic corrosion (particularly brass, copper, or steel used in contact with aluminum or aluminum alloy), is not acceptable. However, metal plating or metal spraying of dissimilar base metals to provide suitable abutting surfaces is permitted. A list of materials is included in 6.3.

3.3.3 Plastic. Plastic material shall be of a type that will enable the solenoid to meet all the performance requirements of this specification.

3.3.4 Wire.

3.3.4.1 Magnet wire and lead wire. Magnet and lead wire shall be of a type that will enable the solenoid to meet all the performance requirements of this specification.

3.4 Design and construction. Solenoids shall be of the design, construction, and physical dimensions specified in 3.1.

3.4.1 Coils. Coils shall be evenly wound and insulated to meet the performance requirements specified herein. Coils shall be completely insulated from the frame and other grounded parts, and the coil leads shall not be internally grounded. Coils shall be suitable taped and impregnated as required to prevent damage under prolonged exposure to humidity and salt-fog environmental conditions. Coils shall be securely anchored to the frame or other stationary parts in a manner that will prevent coil movement or strain on the coil leads.

3.4.2 Terminals. Terminals, including connectors, solder-type, pig-tail, or lead-in wires shall be as specified in 3.1. Terminals shall be constructed or corrosion-resistant material or shall be suitably plated to resist corrosion during service.

3.4.2.1 Plug-in terminals. Plug-in terminals shall conform to the arrangements of dimensions necessary for proper mating with the applicable connectors or sockets. The mounting arrangement of the solenoid shall be so designed that the weight of the solenoid will be supported and the stability of its mounting will be provided by mounting means other than the electrical terminals of the socket. Solenoids with plug-in terminals shall have the electrical and environmental tests, specified in section 4, performed with the appropriate or specified socket or connector assembled to the solenoid.

3.4.2.2 Terminal marking. When specified (see 3.1), terminals shall be permanently and legibly marked.

3.4.3 Case. Unless otherwise specified (see 3.1), the coil housing shall be enclosed and shall be electrically isolated from any electrical circuit and shall be magnetically shielded.

3.4.4 Mounting. The mounting means shall be an integral part of the solenoid housing or shall be securely attached thereto in a manner which will prevent any movement between the solenoid and the mounting means in service use.

3.4.5 Armature or plunger travel. The armature or plunger shall be provided with sufficient travel to completely activate the load equipment as required. Unless otherwise specified (see 3.1), positive stops shall be provided at both extremes of travel and shall be sufficiently spring loaded to force the armature and load to the normal or deenergized position with the coil deenergized and under maximum load conditions and temperature extremes.

3.4.6 Installation provisions. Clearances shall be provided for installation of power cables and mounting hardware. Unless otherwise specified (see 3.1), special installation tools shall not be required by virtue of the solenoid design.

3.4.7 Solid state components. Diodes and other solid state devices shall be of sufficient ratings to withstand peak reverse voltage transients of the utilizing electrical power system. The minimum and maximum peak inverse volts (PIV) shall be as specified in 3.1.

3.4.8 Weight (when specified, see 3.1). Solenoids shall not exceed the specified weight.

3.4.9 Tolerances. Unless otherwise specified, all electrical, environmental, and mechanical parameters contained in this specification shall have a tolerance of ±10%.

3.5 Electrical requirements.

3.5.1 Electrical characteristics.

3.5.1.1 Operating force (torque) (see 4.7.2.1). The operating force (torque) shall be as specified in 3.1. The term "force" is applicable to solenoids having linear output motion. The term "torque" is applicable to solenoids having rotary output motion.

3.5.1.2 Compensated actuating voltage (see 4.7.2.2). The solenoid shall be in the energized position.

3.5.1.3 Deactuating voltage (or current) (when specified, see 3.1 and 4.7.2.3). The solenoid shall be in the energized position with more than maximum deactuating voltage (or current) applied, and shall be in the deenergized position with less than minimum deactuating voltage (or current) applied.

3.5.1.4 Operate and release time (when specified, see 3.1 and 4.7.2.4). The time required for the solenoid to complete the energized function or to revert to the deenergized position shall not exceed the values specified.

3.5.1.5 Coil current (see 4.7.2.5). The coil current shall not exceed the specified requirements (see 3.1).

3.5.1.6 DC coil resistance (see 4.7.2.6). The dc coil resistance shall be as specified (see 3.1).

3.5.2 Insulation resistance (see 4.7.3). The insulation resistance (unless otherwise specified, see 3.1), shall be 1,000 megohms, minimum, except that the insulation resistance between coil and case at the maximum specified ambient temperature shall be 500 megohms, minimum.

3.5.3 Dielectric withstanding voltage (see 4.7.4). There shall be no evidence of damage, arcing, breakdown, or leakage current in excess of 0.5 milliampere.

3.5.4 Mounting stud and terminal strength (see 4.7.5). The mounting studs and terminals shall not loosen, nor shall there be any other damage when subjected to the static values of tension and torque specified in table I. Wire lead terminals shall meet the specified pull requirements.

TABLE I. Tension and torque loads for solenoid wire leads, solder lug or hook, stud or screw, and mounting studs.

Wire terminals		Threaded terminals or mounting studs				
Diameter (inches)	Pull tension (lbs)	Size	Pull tension (lbs)		Torque (inch-pounds)	
			Terminals	Mounting studs	Terminals	Mounting studs
.035 to .047	4.5	4	5	7	4.4	5
		6	30	25	10.0	12
Less than .035	2.0 ±0.2	8	35	35	20.0	20
		10	40	50	32.0	40
		.250	50	60	75.0	80
		.313	70	80	100.0	160
		.375	100	115	150.0	275

3.5.5 Static spring return force (when specified; see 3.1 and 4.7.6). The static spring return force shall fall within the specified limits.

3.5.6 Magnetic effect (when specified; see 4.7.7). The intensity of the magnetic field surrounding the solenoid shall not exceed the value specified (see 3.1).

3.6 Environmental requirements.

3.6.1 Thermal shock (see 4.7.8). There shall be no mechanical, electrical, or operational failure, and no cracking, peeling, or flaking of the finish. During this test, operating force (torque) and deactuating voltage shall be as specified in 3.5.1.1 and 3.5.1.3, respectively. Following the test, the compensated actuating voltage shall be as specified in 3.5.1.2.

3.6.2 Solderability (see 4.7.9). The critical examination area of solid wire lead and pin terminals shall be at least 95 percent covered with a continuous new solder coating in accordance with method 208 of MIL-STD-202. For solder-lug terminals greater than .045 inch (1.14 mm) in diameter, 95 percent of the total length of fillet, which is between the standard wrap wire and the terminal, shall be tangent to the surface of the terminal being tested and shall be free of pinholes, voids, etc. A ragged or interrupted line at the point of tangency between the fillet and the terminal under test shall be considered a failure.

3.6.3 Vibration (see 4.7.10). There shall be no evidence of loosening of parts or mechanical damage to the solenoid. Following this test, the operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively.

3.6.4 Shock (see 4.7.11). There shall be no evidence of mechanical or electrical damage, nor shall the test impair the normal operation of the solenoid. Following this test, the operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively.

3.6.5 Acceleration (when specified; see 3.1) and 4.7.12. The solenoids shall meet the specified requirements. During this test, the compensated actuated voltage and deactuating voltage (or current) shall be as specified in 3.5.1.2 and 3.5.1.3.

3.6.6 Moisture resistance. Unless otherwise specified (see 3.1), solenoids shall be tested in accordance with 4.7.13. There shall be no evidence of breaking, cracking, or spalling of the solenoids. Immediately after step 6 of the final cycle, the insulation resistance shall be at least 1 megohm, and the compensated actuated voltage shall be as specified in 3.5.1.2. After the 24 hour drying period, the insulation resistance shall be at least 50 megohms. The operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively.

3.6.7 Altitude (when specified; see 3.1 and 4.7.14). Following this test the insulation resistance, operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.2, 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively.

3.6.8 High temperature (see 4.7.15). The solenoids shall meet the operating force (torque) requirements specified in 3.5.1.1.

3.6.9 Low temperature (see 4.7.16). The solenoids shall meet the operating force (torque) requirements specified in 3.5.1.1.

3.6.10 Salt spray (see 4.7.17). There shall be no evidence of corrosion, or peeling, chipping, or blistering of the finish, nor exposure of the base metal when inspected by the unaided eye. Following this test, the insulation resistance, operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.2, 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively. For sealed or encapsulated solenoids, dielectric withstanding voltage (at sea level) (see 3.5.3) shall be applicable.

3.6.11 Sand and dust (when specified, see 3.1 and 4.7.18). Following this test, the operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be as specified in 3.5.1.1, 3.5.1.2, and 3.5.1.3, respectively.

3.6.12 Explosion (when specified, see 3.1 and 4.7.19). Solenoids shall not ignite an ambient explosive atmosphere.

3.7 Life (see 4.7.20). The solenoid shall remain mechanically and electrically operative. There shall be no indication of mechanical resonance due to the frequency of the energizing voltage. Following this test, the coil resistance shall be within ±2 percent of the prelife value, and the insulation resistance and dielectric withstanding voltage (at sea level), shall be as specified in 3.5.2 and 3.5.3, respectively.

3.7.1 Coil life (see 4.7.21). The coil current (see 4.7.2.5) and DC coil resistance (see 4.7.2.6) shall be within five percent of the prelife value. Following the test, insulation resistance and dielectric withstanding voltage shall be as specified in 3.5.2 and 3.5.3, respectively.

3.8 Marking. Unless otherwise specified (see 3.1), solenoids shall be permanently and legibly marked with either the manufacturer's name, trademark, symbol, or CAGE code and the date code, as shown in the following example; and, wherever space permits, the applicable PIN, the rated voltage (or current), and the operating frequency. Paper labels shall not be used. Other markings which in any way interfere with, obscure, or confuse those specified herein, are prohibited. Markings shall remain legible after all tests.

Example:	12345	-	Manufacturer's CAGE code
	6824	-	Date code

3.8.1 Date code and manufacturer's source code. The date code and manufacturer's CAGE code shall be in accordance with MIL-STD-1285.

3.9 Workmanship. Solenoids shall be processed so that they are uniform in quality and shall be free from cracked or deformed parts, sharp edges, burrs or other defects which could affect their life, serviceability, or appearance.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (inspections and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Test equipment and inspection facilities. The supplier shall establish and maintain a calibration system in accordance with ANSI/NCSL Z540-1, ISO 10012-1, or equivalent.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows.

a. Materials inspection (see 4.3).

b. First article inspection (see 4.5).

c. Quality Conformance inspection (see 4.6).

4.3 Materials inspection. Materials inspection shall consist of certification that the materials used are of a type that will ensure that the solenoid meets all the requirements of this specification.

4.4 Inspection conditions. Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in the General Requirements section of MIL-STD-202.

4.5 First article inspection. First article inspection shall be performed at a laboratory acceptable to the Government on sample units produced with equipment and procedures normally used in production.

4.5.1 Sample size. Twelve solenoids shall be subjected to the first article inspection.

4.5.2 Inspection routine. The sample shall be subjected to the inspections specified in table II, in the order shown, except that groups II and III may be conducted concurrently. All sample units shall be subjected to the inspection of group I.

TABLE II. First article inspection.

Inspection	Requirement paragraph	Method paragraph	Number of sample units to be inspected	Number of failures allowed
Group I				
Visual and mechanical inspection	3.1, 3.4, 3.5 3.8, and 3.9	4.7.1	12	0
Electrical characteristics	3.5.1	4.7.2		
Insulation resistance	3.5.2	4.7.3		
Dielectric withstanding voltage (at sea level)	3.5.3	4.7.4.1		
Group II				
Mounting stud and terminal strength	3.5.4	4.7.5	6	0
Static spring return force (when specified)	3.5.5	4.7.6		
Thermal shock	3.6.1	4.7.8		
Solderability	3.6.2	4.7.9		
Vibration	3.6.3	4.7.10		
Shock	3.6.4	4.7.11		
Acceleration (when specified)	3.6.5	4.7.12		
Moisture resistance	3.6.6	4.7.13		
Life	3.7	4.7.20		
Group III				
Static spring return force (when specified)	3.5.5	4.7.6	6	0
Magnetic effect (when specified)	3.5.6	4.7.7		
Altitude (when specified)	3.6.7	4.7.14		
High temperature	3.6.8	4.7.15		
Low temperature	3.6.9	4.7.16		
Salt spray	3.6.10	4.7.17		
Sand and dust (when specified)	3.6.11	4.7.18		
Explosion (when specified)	3.6.12	4.7.19		
Coil life	3.7.1	4.7.21		

4.5.3 Failures. One or more failures shall be cause for refusal to grant first article approval.

4.6 Quality Conformance inspection.

4.6.1 Inspection lot. An inspection lot shall consist of one week's production of solenoids of the same design, materials, and production processes, produced under essentially the same conditions and offered for inspection at one time. Where production is less than 200 solenoids per week, a lot shall consist of two consecutive weeks production. The date code shall indicate that the solenoids were produced during the first week.

4.6.2 Group A inspection. The group A inspection shall consist of the inspections specified in table III, in the order shown.

TABLE III. Group A inspection.

Inspection	Requirement paragraph	Method paragraph
Subgroup 1		
Dielectric withstanding voltage	3.5.3	4.7.4
Subgroup 2		
DC coil resistance	3.5.1.6	4.7.2.6
Coil current	3.5.1.5	4.7.2.5
Compensated actuating voltage	3.5.1.2	4.7.2.2
Insulation resistance	3.5.2	4.7.3
Visual and mechanical examination	3.1,3.4, 3.5, 3.8, and 3.9	4.7.1
Deactuating voltage (when specified)	3.5.1.3	4.7.2.3
Operate and release time (when specified)	3.5.1.4	4.7.2.4

4.6.2.1 Sampling plan.

4.6.2.1.1 Subgroup 1. All solenoids offered for inspection shall be subjected to the dielectric withstanding voltage test. Lots having more than five percent total rejects shall not be furnished on the contract. Solenoids out of specification limits shall not be shipped with the lot.

4.6.2.1.2 Subgroup 2. A sample of parts shall be randomly selected in accordance with table IV. If one or more defects are found, the lot shall be rescreened and the defective parts removed. A new sample of parts shall then be randomly selected in accordance with table IV. If one or more defects are found in the second sample, the lot shall be rejected and shall not be supplied to this specification.

TABLE IV. Group A, subgroup 2 inspection sampling plan.

Lot size	Electrical characteristics (number of sample units) 1/	Visual and mechanical inspection	
		Major	Minor
2 - 8	all	100 percent	3
9 - 15	all	13	3
16 - 25	20	13	3
26 - 50	20	13	5
51 - 90	20	13	6

1/ Electrical characteristics shall include coil resistance, coil current, and compensating actuating voltage.

4.7 Methods of inspection.

4.7.1 Visual and mechanical inspection. Solenoids shall be inspected to verify that the materials, design, construction, physical dimensions, marking, and workmanship are in accordance with the specified requirements (see 3.1, 3.4, 3.5, 3.8, and 3.9).

4.7.2 Electrical characteristics.

4.7.2.1 Operating force (torque) (see 3.5.1.1). Unless otherwise specified (see 3.1), the operating force (torque) of the solenoids shall be tested in accordance with the following details.

4.7.2.1.1 For first article inspection.

a. Points of measurement:

(1) At the beginning of the solenoid's stroke (0 percent to 5 percent).

(2) Full stroke force or torque (95 percent to 100 percent of stroke (when specified, see 3.1).

(3) Holding force (when specified, see 3.1).

b. Magnitude of test voltage and temperature: This test shall be conducted at the values of the upper and lower, and lower and upper limits of the voltage and temperature ranges, respectively.

c. Nature of potential: With specified load applied to the solenoid (see 3.1).

d. Duration of applied voltage: The duty cycle of intermittent duty solenoids shall not be exceeded.

e. Attitude(s) during testing: See 3.1.

f. Applied load: A static load equal to the specified force (torque) (see 3.1) shall be applied to the armature or plunger.

g. Force (torque) measurement: With the solenoid mounted in the specified attitude(s) and at ambient temperature, and with a load in accordance with 4.7.2.1.1f, the output force (torque) shall be equal to or exceed the static output force (torque) with the specified voltage applied to the coil.

4.7.2.2 Compensated actuating voltage (see 3.5.1.2). Unless otherwise specified (see 3.1), the compensated actuating voltage of the solenoids shall be tested in accordance with the following details.

a. Magnitude of test voltage and temperature: This test shall be conducted at the voltage equivalent to minimum voltage at maximum temperature.

b. Nature of potential: See 3.1.

c. Duration of applied voltage: The duty cycle of the intermittent duty solenoids shall not be exceeded (see 3.1).

d. Mounting the solenoid for test: The solenoid shall be mounted by its normal mounting means and in its normal mounting attitude.

e. Temperature and load: With the solenoid at a stabilized temperature of 25°C ±2°C, it shall generate sufficient mechanical force (torque) at the specified compensated actuating voltage (or current) (see 3.1) to cause full plunger (or armature) travel in the energized position against the specified value (see 3.1) or load (force or torque).

f. Observe the position of the armature.

4.7.2.3 Deactuating voltage (or current) (see 3.5.1.3). With rated mechanical load attached to the armature or plunger as specified (see 3.1), the solenoid shall be energized with rated load applied. Observe the position of the armature. Further reduce the voltage (or current) to a value equal to the minimum deactuating voltage specified (see 3.1). Observe the position of the armature. For qualification inspection, unless otherwise specified (see 3.1), the deactuating voltage (or current) shall fall within the required limits when the solenoid is mounted in each of three mutually perpendicular planes, one of which shall be that where the plunger gravity force opposes the return spring force.

4.7.2.4 Operate and release time (see 3.5.1.4). Nominal rated voltage (or current) (see 3.1), shall be applied to the solenoid. The test shall be performed with the solenoid at a stabilized ambient temperature of 25°C ±2°C and at the rated high and low temperatures. The time interval between the application of voltage (or current) and the full travel of the solenoid; and time interval between the removal of voltage (or current) and the full return travel of the plunger or armature to the deenergized position shall be measured.

4.7.2.5 Coil current (see 3.5.1.5). Coil current shall be measured with the coil at a stabilized ambient temperature of 25°C ±2°C and rated voltage and with the coil at a stabilized low temperature rating and maximum rated voltage (see 3.1). The current shall be measured within 10 seconds of application of coil voltage.

4.7.2.6 DC coil resistance (see 3.5.1.6). Solenoids shall be tested in accordance with method 303 of MIL-STD-202.

4.7.3 Insulation resistance (see 3.5.2). Solenoids shall be tested in accordance with method 302 of MIL-STD-202. The following details shall apply:

a. Test condition letter: A, for solenoids having a voltage rating of less than 60; B, for solenoids having a voltage rating of 60 or greater.

b. Point of measurement: Between the coil and the case.

4.7.4 Dielectric withstanding voltage (see 3.5.3 and table V).

4.7.4.1 At sea level. Solenoids shall be tested in accordance with method 301 of MIL-STD-202. The following details shall apply:

a. Magnitude of test voltage: The magnitude of the test potential shall be based on the coil voltage rating (see table V).

b. Nature of potential: Alternating current (ac).

c. Duration of test voltage: Five to 15 seconds for the quality conformance inspection.

d. Point of application of test voltage: Between the coil and the case.

After the test, solenoids shall be inspected for any evidence of damage, arcing, and breakdown. Leakage current shall be measured.

TABLE V. Dielectric withstanding voltage (at sea level) potential.

Voltage rating	RMS test voltage
Less than 60	1,000
60 to 250, inclusive	1,500 + rated voltage
Over 250 to 500, inclusive	2 X voltage rating + 1,000

4.7.4.2 At reduced barometric pressure (high altitude). Solenoids shall be tested in accordance with method 105 of MIL-STD-202. The following details shall apply:

a. Test condition letter: See 3.1.

b. Magnitude of test voltage: The magnitude of the test potential shall be 350 volts ±10 volts.

c. Nature of potential: Alternating current (ac).

d. Duration of test voltage: Five to 15 seconds for quality conformance inspection.

e. Point of application of test voltage: Between the coil terminals and the case.

After the test, solenoids shall be inspected for any evidence of damage, arcing, and breakdown. Leakage current shall be measured.

4.7.5 Mounting stud and terminal strength (see 3.5.4). The solenoid studs, as applicable, shall be subjected to the tensile and torque loads specified in 3.6.4 and applied parallel to the axis of the studs for a period of 1 minute. There shall be no mechanical failure resulting from these tests. Lead wire terminals No. 22 AWG or larger shall be subjected to 4.5 pounds pull for a minimum of 30 seconds. There shall be no mechanical or electrical impairment resulting from the test. Lead wires smaller than No. 22 AWG shall be tested as specified (see 3.1).

4.7.6 Static spring return force (see 3.5.5). The static spring return force (torque) shall be measured in pounds or inch-pounds at the following percentages of plunger travel (with coil deenergized): (0-5) and (95-100). The attitude of the solenoid during the test shall be such that the plunger gravity force does not oppose the spring force (torque).

4.7.7 Magnetic effect (see 3.5.6). The solenoid shall not produce a magnetic field greater than the field produced by a straight bus bar carrying a direct current of 15 times the coil current of the solenoid. The coil current shall be that produced when the temperature of the coils is 25°C ±2°C and maximum operating voltage is impressed thereon. The field shall be measured by a suitable fluxmeter with the search coil adjacent to the coil housing or bus bar in the position causing the greatest deflection of the meter.

4.7.8 Thermal shock (see 3.6.1). Solenoids shall be tested in accordance with method 107 of MIL-STD-202. The following details shall apply:

a. Test condition: See 3.1. Exposure time shall be one hour at each temperature extreme.

b. Measurement during cycling: During the last 10 minutes of the fifth temperature cycle at both high and low temperatures, the solenoid shall meet the requirements of operating force (torque) (see 3.5.1.1) and deactuating voltage (or current) (see 3.5.1.3) and shall return to room temperature.

c. Measurement after cycling: Compensated actuating voltage shall be tested as specified in 4.7.2.2. The solenoids shall then be inspected for cracking, peeling, and flaking of the case and finish.

4.7.9 Solderability (see 3.6.2). Solenoids having solderable terminals shall be tested in accordance with method 208 of MIL-STD-202, except that the dipping device need not be used.

a. Number of terminations of each part to be tested: Two.

b. Solder dip: Not applicable.

c. Inspection of terminations: Fillet area.

4.7.10 Vibration (see 3.6.3). The solenoids shall be tested in accordance with method 204 of MIL-STD-202. The following details shall apply:

a. Mounting: Solenoids shall be rigidly mounted by a normal mounting means in a suitable test jig. The vibration shall be monitored on top of the test jig as near as practicable to the support points of the solenoids.

b. Electrical load conditions: The solenoids shall be energized with rated coil voltage (or current) for half the required test time and deenergized for half the required test time in each of the three mutually perpendicular directions.

c. Test condition letter: See 3.1.

d. Tests and measurements after vibration: After vibration, operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be tested as specified in 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively. Solenoids shall be inspected externally for evidence of damage such as cracks or loosening of parts.

4.7.11 Shock (see 3.6.4). Solenoids shall be tested in accordance with 4.7.11.1, 4.7.11.2, or 4.7.11.3, as applicable (see 3.1).

4.7.11.1 Shock 1. Solenoids shall be tested in accordance with method 205 of MIL-STD-202. The following details shall apply:

a. Test condition letter: C.

b. Electrical operating conditions: In each direction of shock, the coil shall be deenergized during two shocks and energized with rated voltage (or current) during one shock.

c. Measurements after shock: Following this test, the operating force (torque), compensated actuating voltage, and deactuating voltage (current) shall be tested as specified in 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively.

4.7.11.2 Shock 2. Solenoids shall be tested in accordance with method 213 of MIL-STD-202. The following details shall apply:

a. Mounting method and accessories: Normal mounting means.

b. Test condition letter: A.

c. Electrical operating conditions: As specified in 4.7.11.1b.

d. Measurements after shock: As specified in 4.7.11.1c.

Following the shock test, there shall be no evidence of mechanical or electrical damage, nor shall the test impair the normal operation of the solenoid.

4.7.11.3 Shock 3. Solenoids shall be tested in accordance with method 207 of MIL-STD-202. The following details shall apply:

a. Mounting fixtures: Normal.

b. Height of hammer drop: See 3.1.

c. Electrical operating conditions: As specified in 4.7.11.1b.

d. Measurements after shock: Following this test, the operating force (torque), compensated actuating voltage, and deactuating voltage shall be tested as specified in 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively. There shall be no evidence of mechanical or electrical damage or impairment of the operation of the solenoid.

4.7.12 Acceleration (see 3.6.5). The solenoids shall be rigidly mounted on the centrifuge and then subjected to an acceleration force of 10 g's in both directions in three mutually perpendicular axes, one of which is parallel to the longitudinal axis of the solenoid coil. During the test, the solenoids shall deliver the specified actuating force within the specified voltage limits (see 3.1).

4.7.13 Moisture resistance (see 3.6.6). Solenoids shall be tested in accordance with method 106 of MIL-STD-202. The following details shall apply:

a. Mounting: On a corrosion-resistant metal panel using normal mounting means.

b. Initial measurement: Insulation resistance as specified in 4.7.3.

c. Polarization: During steps 1 to 6 inclusive, 100 V dc shall be applied between the coil (positive) and the mounting frame (negative) of one-half of the solenoids. Within 5 minutes after the end of the conditioning, the operating force (torque) shall be tested as specified in 4.7.2.1.

d. Final measurements: After a 24 hour drying period at a relative humidity of 50 percent ±5 percent, solenoids shall be inspected for evidence of breaking, cracking, spalling, and loosening of the terminals. The insulation resistance, operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall then be tested as specified in 4.7.3, 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively.

4.7.14 Altitude (see 3.6.7). Solenoids shall be tested in accordance with method 105 of MIL-STD-202. The following details shall apply:

a. Mounting: Solenoids shall be rigidly mounted by their normal mounting means.

b. Test condition letter: See 3.1.

c. Tests during subjection to reduced pressure: With the complete solenoid at stabilized ambient temperature of 25°C ±2°C, measure the coil resistance with ±0.5 percent accuracy. Then, with pressure reduced to the specified altitude and the ambient temperature specified for altitude conditions (see 3.1), the solenoid, with the coil energized with maximum rated voltage, shall be subjected to the specified conditions for a minimum of two hours. The duty cycle of intermittent duty solenoids shall be as specified in 3.1. Within the last 5 minutes to 10 minutes of the exposure to reduced pressure, the coil resistance shall be measured in order to enable calculation of the coil temperature. The calculated coil temperature shall be within the temperature limits of the coil magnet wire. Immediately following the coil resistance measurement, the compensated actuating voltage shall be tested as specified in 4.7.2.2 with the solenoid in its normal attitude. Immediately following the compensated actuating voltage test, the dielectric withstanding voltage shall be tested as specified in 4.7.4.2 at maximum rated altitude. After return to room temperature and sea level pressure, the insulation resistance, operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be tested as specified in 4.7.3, 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively.

4.7.15 High temperature (see 3.6.8). The solenoid shall be energized with rated voltage and 98 percent to 102 percent of rated load, and shall be subjected to maximum rated ambient temperature and maximum rated altitude for a period of two hours. Immediately at the end of the conditioning, and while in the specified ambient temperature, the operating force test specified in 4.7.2.1 shall be performed.

4.7.16 Low temperature (see 3.6.9). The deenergized solenoid shall be subjected to the specified minimum temperature condition (see 3.1) for at least four hours. At the end of the conditioning, and while still subjected to the low temperature, with minimum rated voltage applied, the operating force test specified in 4.7.2.1 shall be performed.

4.7.17 Salt spray (see 3.6.10). Solenoids shall be tested in accordance with method 101 of MIL-STD-202. The following details shall apply:

a. Applicable salt solution: Five percent.

b. Test condition letter: B.

c. Measurements after exposure: After exposure, solenoids shall be washed, shaken, and air blasted, and then permitted to dry for 24 hours at room temperature. They shall then be inspected for evidence of corrosion, peeling, chipping, blistering of the finish, and exposure of base metal. The insulation resistance, dielectric withstanding voltage (sea level), operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall then be tested as specified in 4.7.3, 4.7.4, 4.7.2.1, 4.7.2.2, and 4.7.2.3 respectively.

4.7.18 Sand and dust (see 3.6.11). Solenoids shall be tested in accordance with method 110 of MIL-STD-202. The following details shall apply:

a. Test condition letter: A.

b. Measurement: At the end of the test period, the operating force (torque), compensated actuating voltage, and deactuating voltage (or current) shall be tested as specified in 4.7.2.1, 4.7.2.2, and 4.7.2.3, respectively.

4.7.19 Explosion (see 3.6.12). Solenoids shall be tested in accordance with method 109 of MIL-STD-202. The following details shall apply:

a. Mechanical and electrical load: Rated voltage and no mechanical load.

b. Chamber temperature condition: See 3.1.

4.7.20 Life (see 3.7). Measure the coil resistance. Solenoids shall then be tested for life cycle with specified load (see 3.1). Each solenoid shall be connected to a load in the range of 95 percent to 100 percent of that specified for the maximum operating force. Continuous duty rating solenoids shall be subjected to an ambient temperature of 25°C ±2°C for a period of 168 hours with the coil energized with rated voltage (or current). Intermittent duty solenoids shall be energized for 168 hours at 25°C ±2°C ambient temperature and with a continuous voltage (or current) such that the watts input shall be equal to the product of rated input watts times duty cycle. The solenoid shall then be operated for a minimum of 25,000 operations: 12,500 at the maximum rated temperature and 12,500 at the minimum rated temperature. The rate of cycling shall be 10 cycles per minute minimum with coil energized approximately 66 percent of the cycle and deenergized approximately 33 percent of the cycle. For intermittent duty solenoids, the duty cycle shall be as specified (see 3.1). Following the test, the coil resistance shall be measured, and the insulation resistance and dielectric withstanding voltage (at sea level) shall be tested as specified in 4.7.3 and 4.7.4.1, respectively.

4.7.21 Coil life (see 3.7.1).

4.7.21.1 Continuous duty solenoids. Unless otherwise specified (see 3.1), continuous duty solenoids shall be subjected to 90 percent of maximum rated temperature with rated voltage applied to the coil for a period of 280 hours. The solenoid shall be suspended by twine or other poor heat conducting material. Where the solenoid is a part of an assembly and mounted thereon, the maximum rated temperature and rated voltage shall be applied. At the end of the high temperature conditioning and while maintaining high temperature, the solenoids shall be cycled, unless otherwise specified (see 3.1), at a rate of 2 seconds "on" and 2 seconds "off" for 5,000 cycles of operation.

4.7.21.2 Intermittent duty solenoids. Intermittent duty solenoids shall be cycled at the specified duty cycle temperature rating and duration as specified (see 3.1). Following coil life and cycling, coil current, DC coil resistance, insulation resistance, and dielectric withstanding voltage (sea level) shall be measured as specified in 4.7.2.5, 4.7.2.6, 4.7.3, and 4.7.4.1, respectively.

5. PACKAGING

5.1 Packaging. For acquisition purposes, packaging requirements shall be as specified in the contract or purchase order (see 6.1.1).

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. Solenoids conforming to this specification are intended for use in direct or alternating current (single or multiphase) electrical systems. Their principle areas of application are aircraft, missiles, spacecraft, and ground support equipment. This does not preclude the use of these solenoids in other military applications.

6.1.1 Acquisition requirements. The contract or purchase order should specify the following, as a minimum:

a. Title, number, and date of this specification.

b. Title, number, and date of the applicable product specification or engineering drawing.

c. Issue of DODISS to be cited in the solicitation, and, if required, the specific issue of individual documents referenced (see 2.1).

d. Levels of preservation, packaging, packing, and marking (see 5.1).

6.2 First article inspection. When first article inspection is required (see 3.2), the contracting officer should provide specific guidance to offerors on whether the item(s) should be a preproduction sample, a first article sample, a first production item, a sample selected from the first 13 production items, or a standard production item from the contractor's current inventory. The number of items to be tested should be as specified in 4.5. The contracting officer should also include specific instructions in acquisition documents regarding arrangements for inspections, approval of first article test results, and disposition of first articles. Invitations for bids should specify that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who wish

to rely on such production or testing, must furnish evidence with the bid that prior Government approval is appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

6.3 Grouping of metals. The grouping specified below is intended to serve as a guide in selecting materials to be used in electronic equipment, and should not be construed to waive requirements herein or in the applicable specification sheet to corrosion resistance of components and assemblies.

Group I

Magnesium alloys (most anodic)

Group II

Aluminum
Aluminum alloys
Zinc
Tin
Corrosion resistant steel

Group III

Zinc
Steel
Lead
Tin
Corrosion resistant steel

Group IV

Copper and copper alloys
Nickel and nickel alloys
Chromium
Corrosion resistant steel
Gold
Silver (most cathodic)

6.3.1 Application. Unless specifically approved by the Government, all metals not listed in 6.3 should be considered dissimilar with respect to one another and with respect to any of the materials listed. Except for zinc, cadmium, and tin (as listed in group II and group III), and for corrosion resistant steel (as listed in group II, group III, and group IV), contact between a member of one group and a member of any other group should be considered dissimilar. Such contact should not be made unless necessary, in which case it should be demonstrated that the contact is not detrimental. When reference is made to a metal in a particular group, the reference applies to the metal on the surface of the part; that is zinc means zinc coating as well as zinc electroplate, zinc hot dip, or zinc metal spray. Different metals in contact, even though similar, should be employed in assemblies in such a manner that the smaller part is cathodic (or protected) and the larger part is anodic (or corroded), if any corrosion takes place. Care should be exercised in using different aluminum alloys against each other or against differing material.

6.4 Definitions.

6.4.1 Deactuating voltage. The coil voltage at which the coil releases the plunger or armature to its deenergized position with rated mechanical load.

6.4.2 Maximum operating voltage. The maximum anticipated voltage at which a solenoid is required to operate.

6.4.3 Minimum operating voltage. The minimum anticipated voltage at which a solenoid is required to operate.

6.4.4 Rated stroke. The linear or angular (as applicable) travel of the armature from the deenergized position to the energized position.

6.4.5 Compensated actuating voltage. The voltage that will provide at 25°C ±2°C stabilized solenoid temperature a force equivalent to that produced at maximum rated temperature and minimum rated voltage.

6.4.6 Rated force. The force in pounds a solenoid will produce at the rated stroke and minimum voltage over a specified temperature range in accordance with the characteristic curve submitted by the manufacturer.

6.4.7 Rated torque. The torque in pound-inches a solenoid will produce at a rated stroke and minimum voltage over a specified temperature range in accordance with the characteristic curve submitted by the manufacturer.

6.4.8 Return force. The spring force in pounds available to move the solenoid armature and load to their deenergized position.

6.4.9 Return torque. The torque in pound-inches available to return the armature from its energized position.

6.4.10 Net starting torque. The static torque produced by the solenoid within 0 percent to 5 percent of rated stroke when rated voltage is applied.

6.4.11 Duty cycle. The duty cycle is the ratio of the "on" time to the total time.

Example:

$$\text{Duty cycle} = \frac{\text{Time on} \times 100}{\text{Time on} + \text{time off}} \%$$

6.4.12 Continuous duty solenoid. A solenoid that is capable of continuous operation without damage, overheating, or malfunction when operated, with rated voltage applied, for one hour or more at a specified ambient temperature.

6.4.13 Intermittent duty solenoid. A solenoid that is capable of operating at the specified duty cycle without damage or malfunction with energized periods less than one-half hour.

6.4.14 Direction of rotation (rotary solenoids). Rotation is defined as clockwise when, facing the armature or power take-off end of a solenoid, the armature moves in a clockwise direction when the solenoid is energized. When a solenoid is energized and the armature moves in a counterclockwise direction, the rotation is defined as counterclockwise.

6.5 Subject term (key word) listing.

Axial stroke type
Pull type
Push type
Rotary stroke type

6.6 Part or Identifying Number (PIN) requirements. All specification sheets previously associated with this basic specification have been cancelled; therefore, military PIN information is no longer applicable.

6.7 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

CONCLUDING MATERIAL

Custodians:
Army - ER
Navy - EC
Air Force - 85

Review activities:
Army - AR, AT, AV, GL, MI
Navy - AS, MC
Air Force - 99
DLA - ES

Preparing activity:
Air Force - 85

Agent:
DLA - ES

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