

3 Magnetic Field Safety

4
5 NIST S 7101.53

6 Document Approval Date: 01/05/2021

7 Effective Date: 04/01/2014
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9

10 1. PURPOSE

11 The National Institute of Standards and Technology (NIST) Magnetic Field Safety Program has
12 been developed to reduce the risk of exposure to magnetic fields in excess of the recommended
13 exposure limits. The primary objective of the NIST Magnetic Field Safety program is to
14 provide guidance for NIST employees on control measures, exposure limits, hazard signage, and
15 training for working with and in the vicinity of magnetic fields.
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18 2. BACKGROUND

19 None.
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22 3. APPLICABILITY

- 23 a. The provisions of this program apply to all NIST facilities and to all NIST employees who
24 work with and around devices and equipment designed to generate magnetic fields, both
25 static and time varying with frequencies up to 30 kilohertz (kHz) with the exceptions noted in
26 NIST O 710.01, Occupational Safety and Health Order.
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28

29 4. REFERENCES

- 30 a. 29 CFR 1910.97, [Occupational Safety and Health Administration, Non-Ionizing Radiation](#).
31
32 b. 47 CFR 1.1307(b), [Environmental Assessments](#).
33
34 c. *TLVs and BEIs based on the Documentation of the Threshold Limit Values for Chemical*
35 *Substances and Physical Agents and Biological Exposure Indices*, American Conference of
36 Governmental Industrial Hygienists (current edition).
37

- 38 d. *Guidelines on Limits of Exposure to Static Magnetic Fields*, International Commission on
39 Non-Ionizing Radiation Protection (2009).
40
41 e. *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic*
42 *Fields (Up to 300 GHz)*, International Commission on Non-Ionizing Radiation Protection
43 (1998).
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45

46 **5. APPLICABLE NIST DIRECTIVES**

- 47 a. NIST S 7101.52: [*Cryogen Safety*](#)
48
49 b. NIST S 7101.20: [*Work and Worker Authorization Based on Hazard Reviews*](#)
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51 c. NIST S 7101.22: *Hazard Signage*
52
53 d. NIST S 7101.24: [*Incident Reporting and Investigation*](#)
54
55 e. NIST S 7101.23: [*Safety Education and Training*](#)
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58 **6. REQUIREMENTS**

- 59 a. General Magnetic Field Safety Requirements
60
61 (1) This section describes the basics of magnetic field safety, biological effects, and exposure
62 limits to be used at NIST.
63
64 (2) Since there are varying types of magnetic field sources and numerous equipment
65 configurations, the general approach to safety is to define the quantities that must be
66 measured, and follow established limits on the values to assure that no adverse health
67 effects will occur.
68
69 (3) Magnetic field hazards shall be managed in accordance with NIST S 7101.20: *Work and*
70 *Worker Authorization Based on Hazard Reviews*, Organizational Unit implementations
71 thereof, and the requirements of this program.
72
73 b. Program Categories
74
75 (1) Although both static and time-varying magnetic fields and associated electromagnetic
76 fields are not known to cause apparent long-term health effects, there are hazards, under

77 some circumstances that need to be recognized and controlled to avoid accidents or
78 injury.

79
80 (2) All equipment capable of generating magnetic fields that may exceed the recommended
81 exposure limits established for the general workplace of 2T (20,000 G) at accessible
82 areas, should be inventoried, appropriately labeled, and used only by authorized/trained
83 personnel.

84
85 (3) Exposure limits for magnetic fields and requirements for engineering and administrative
86 controls are listed in the following subsections.

87
88 c. Static and Time-Varying Fields up to 30 kHz

89
90 (1) General

91
92 (a) The primary safety concern with exposure to static and time-varying magnetic fields
93 is the attraction of magnetic objects in or on the body in an external magnetic field
94 gradient that could lead to a “missile effect” or striking hazard, injuring body tissue.
95 Additionally, magnetic objects may rotate in a magnetic field, which could result in
96 the tearing of body tissue. Exposure to a static magnetic field may temporarily
97 reprogram cardiac pacemakers and inhibit implantable cardioverter-defibrillators.

98
99 (2) Exposure Limits for Static Magnetic Fields

100
101 (a) TLVs recommended by the ACGIH and by the International Commission on Non-
102 Ionizing Radiation Protection (ICNIRP) will be followed at NIST as consensus
103 standards for employee protection. These TLVs are based on an assessment of
104 available data from laboratory research and human exposure studies. Table 1
105 provides the TLVs for static magnetic fields.

106
107 (b) Routine occupational exposures to static magnetic fields should not exceed 2 T
108 (20,000 G) in the general workplace but can have ceiling values up to 8 T (80,000 G)
109 in a controlled area. See Table 1.

Table 1. Recommended Limits of Exposure to Static Magnetic Fields

[For reference, see Sections 3d (2011 edition) and 3e.]

Exposure Characteristics	Magnetic Flux Density (Ceiling Value)
Whole body (General workplace)	< 2 T (20,000 G)
Whole body (Controlled area)	2-8 T (20,000-80,000 G)
Limbs	20 T (200,000 G)
Medical device wearers	0.5 mT (5 G)
General public*	400 mT (4,000 G)

Note: While SI is the adopted method of units used at NIST, cgs units of Gauss (G) are included for the convenience of the staff.

117 *Note: The ACGIH does not have an exposure limit for the general public. This value was
118 taken from *Guidelines on Limits of Exposure to Static Magnetic Fields*, ICNIRP (2009).

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120

121 (3) Exposure Limits for Time-Varying Magnetic Fields with Frequencies (f) in the range 0 Hz
122 $< f < 1$ Hz

123

124 (a) Time-varying magnetic fields with frequencies in this range are considered, for the
125 purposes of this suborder, to be static fields. The recommended limits of exposure
126 provided in Table 1 apply.

127

128 (4) Exposure Limits for Time-Varying Magnetic Fields from 1 to 30 kHz.

129

130 (b) TLVs for time-varying magnetic fields recommended by the ACGIH will be followed
131 at NIST as consensus standards for employee protection.

132

133 (c) The TLVs in Table 2 refer to the amplitude of the magnetic flux density (B) of sub-
134 radiofrequency (sub-RF) magnetic fields at frequencies (f) in the range of 1 to 30 kHz
135 to which it is believed that nearly all workers can be exposed repeatedly without
136 adverse health effects. The magnetic field strengths in these TLVs are root-mean-
137 square values.

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Table 2. Limits of Exposure to Time-Varying Magnetic Fields

[For reference, see Sections 3d (2011 edition) and 3e.]

Exposure Characteristics		Magnetic Flux Density (Ceiling Value)
1 Hz to 300 Hz	Whole body	$(60 / f)$ mT
	Arms and legs	$(300 / f)$ mT
	Hands and feet	$(600 / f)$ mT
300 Hz to 30 kHz	Whole body and partial body	0.2 mT
50 / 60 Hz	Individuals having implanted pacemakers	0.1 mT

Note: $1 \text{ mT} = 10 \text{ G}$; f in Hz

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(5) Requirements for Engineering and Administrative Controls

- (a) All areas where individuals could be exposed to magnetic fields that exceed or could exceed 0.5 mT (5G) for static magnetic fields or 0.1 mT (1 G) for time-varying magnetic fields shall be surveyed to establish appropriate safety limits; postings, including hazard signage (refer to Appendix A for examples of hazard signs); and barriers. The Magnetic Field Safety Program Manager can assist with these measurements.
- (b) A “Danger” sign (imminent threat to life or health) shall be posted at every entrance or access point to any laboratory or facility where exposure to magnetic fields may exceed the recommended medical-device-wearer exposure limits of 0.5 mT (5G) for static magnetic fields or 0.1 mT (1 G) for time-varying magnetic fields. Medical-device wearers shall not be exposed to fields in excess of the medical-device-wearer exposure limits.
- (c) A “Danger” sign (imminent threat to life or health) shall be posted at every entrance or access point to any laboratory or facility where exposures to static magnetic fields may exceed the recommended medical-device-wearer exposure limits of 0.5 mT (5 G) for static magnetic fields or 0.1 mT (1 G) for time-varying magnetic fields and where static magnetic fields – or time varying magnetic fields with frequencies below 1 Hz – could exceed the general workplace limit of 400 mT (4,000 G).

168 (d) A “Danger” sign (imminent threat to life or health) shall be posted at every entrance
169 or access point to any laboratory or facility where exposures to magnetic fields may
170 exceed the recommended medical-device-wearer exposure limits of 0.5 mT (5G) for
171 static magnetic fields or 0.1 mT (1 G) for time-varying magnetic fields and where
172 static magnetic fields – or time-varying magnetic fields with frequencies below 1 Hz
173 – could exceed the general workplace exposure limit of 2 T (20,000 G), in which case
174 access is limited to trained workers (see Section 6e). In addition to posting the hazard
175 sign at the entrance, it is recommended that around the magnet where general
176 workplace exposure limits of 2 T (20,000 G) may be exceeded, a line be painted or
177 taped on the floor or a physical barrier such as a plastic chain or rope be used to mark
178 the exposure area. This is not necessary if the laboratory serves as the controlled area
179 and is identified as such on a sign posted at the entrance. Other engineering or
180 administrative controls can also be used after consulting with the Magnetic Field
181 Safety Program Manager.

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183 (e) A general magnetic field warning label should be posted on any device capable of
184 producing external magnetic fields in excess of the recommended general workplace
185 exposure limit of 2T (20,000 G).

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187 d. Special Considerations – Use of Cryogenic Liquids to Cool Magnets or Associated
188 Equipment

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190 (1) Because of the very low temperature of cryogenic liquids, contact can produce frostbite
191 or cold burns. Unprotected skin that comes into contact with non-insulated items of the
192 cold equipment may become stuck and the skin may be torn on removal.

193
194 (2) When a magnet quenches, the loss of magnetic field and sudden boil-off of cryogenic
195 coolant can pose a significant safety risk. The released gases displace oxygen in the air,
196 and this can cause rapid asphyxiation and unconsciousness without warning.

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198 (3) When working with cryogenic liquids, follow procedures specified in the NIST Cryogen
199 Safety Program.

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201 e. Training and Recordkeeping

202
203 (1) Training on the NIST Magnetic Field Safety Suborder is required for NIST supervisory
204 and line management personnel of employees working in areas where exposures to static
205 magnetic fields – or time-varying magnetic fields with frequencies below 1 Hz – could
206 exceed the general workplace limit of 2 T (20,000 G), to any part of the body.

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208 (2) Training on Magnetic Field Safety is required for employees working in areas where
209 exposures to static magnetic fields – or time-varying magnetic fields with frequencies
210 below 1 Hz – could exceed the general workplace limit of 2 T (20,000 G) to any part of
211 the body.

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213 (3) Training on this program and pertinent OU/division policies and procedures shall be
214 provided, documented, and recorded in accordance with requirements of the NIST Safety
215 Education and Training Program.

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218 7. DEFINITIONS

219 a. Administrative Controls – Controls that alter the way work is done, including timing of work,
220 policies, training, and other rules.

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222 b. Authorized personnel – NIST employees who could be exposed to magnetic fields above 2 T
223 (20,000 G) to any part of the body and have successfully completed the required Magnetic
224 Field Safety Training.

225
226 c. B Field – Magnetic flux density or magnetic induction. Units are tesla (T) and gauss (G).
227

228 d. Controlled Area – An area where exposures of personnel to magnetic fields may exceed 2 T
229 (20,000 G) and to which access is limited to trained workers.

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231 e. E Field – Electric field strength, measured in units of volts per meter (V/m).
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233 f. Engineering Controls – Controls that Include designing or modifying laboratories,
234 equipment, ventilation systems, and processes to reduce or eliminate the exposure to
235 hazardous sources or conditions. Engineering controls are used to remove a hazard or place a
236 barrier between the worker and the hazard.

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238 g. Exposure Limit – Value to which an individual may be exposed without harmful effects and
239 with an acceptable safety factor.

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241 h. General Public – For the purposes of this suborder, NIST visitors, i.e., individuals on a NIST
242 site or in a NIST facility who are neither NIST employees nor NIST associates.

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244 i. H Field – Magnetic field strength, measured in units of amps per meter (A/m).
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246 j. Hertz – The oscillation frequency of the electromagnetic field in cycles per second (Hz).
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- 248 k. Magnetic Field – A field (H field) created by a magnet or as a consequence of the movement
249 of electric charges. Its intensity is measured in units of A/m.
250
- 251 l. Non-ionizing Radiation – Radiation in the part of the electromagnetic spectrum where there
252 is insufficient energy to cause ionization. It includes electric and magnetic fields, radio
253 waves, microwaves, infrared, ultraviolet and visible radiation.
254
- 255 m. Occupational Exposure – Exposure of individuals to non-ionizing radiation as a consequence
256 of their employment, who have been made aware of the potential of exposure, and who can
257 exercise control over their exposure through the use of administrative or engineering controls
258 or safe work practices.
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- 260 n. Quenching – Process in which the coil of a superconducting magnet reverts to a resistive
261 state, which results in loss of magnetic field and a rapid boil-off of the cryogenic coolant.
262
- 263 o. Signal word "Danger" – Indicates an imminently hazardous situation that, if not avoided, **will**
264 result in death or serious injury.
265
- 266 p. Signal word, "Caution" – Indicates a potentially hazardous situation that, if not avoided, **may**
267 result in minor or moderate injury.
268
- 269 q. Signal word, "Notice" – The preferred word to address situations not related to personal
270 injury.
271
- 272 r. Signal word, "Warning" – Indicates a hazardous situation that, if not avoided, **could** result in
273 death or serious injury.
274
- 275 s. Static Magnetic Field – Field that varies at frequencies below 1 Hz and is created by either a
276 permanent magnet or a direct-current electromagnet.
277
- 278 t. Time-Varying Magnetic Field – Field produced by alternating currents of frequencies up to
279 30 kHz.
280
- 281 u. Threshold Limit Value (TLV) – An occupational limit that workers may be exposed to
282 repeatedly without adverse health effects. TLVs are published by the American Conference
283 of Governmental Industrial Hygienists (ACGIH).
284
- 285 v. Whole-Body Exposure – Exposure of the head, trunk, arms above the elbow, and/or legs
286 above the knee.
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288 **8. ACRONYMS**

- 289 a. ACGIH – American Conference of Governmental Industrial Hygienists
290
291 b. BEI – Biological Exposure Indices
292
293 c. CFR – Code of Federal Regulations
294
295 d. ICNIRP – International Commission on Non-Ionizing Radiation Protection
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297 e. IEEE – Institute of Electrical and Electronics Engineers
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299 f. MPE – Maximum Permissible Exposure
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301 g. NIOSH – National Institute for Occupational Safety and Health
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303 h. NIST – National Institute of Standards and Technology
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305 i. TLV – Threshold Limit Value
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308 **9. RESPONSIBILITIES**

- 309 a. The OUs are responsible for ensuring that the requirements in Section 6 are met.
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312 **10. AUTHORITIES**

313 There are no authorities specific to this suborder alone.
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316 **11. DIRECTIVE OWNER**

317 Chief Safety Officer
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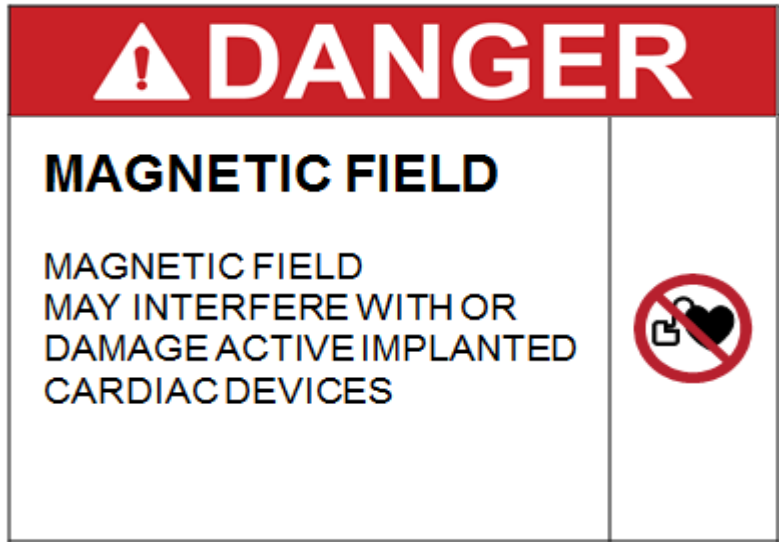
320 **12. APPENDICES**

- 321 a. Appendix A. Magnetic Field Hazard Signage
322 b. Appendix B. Revision History
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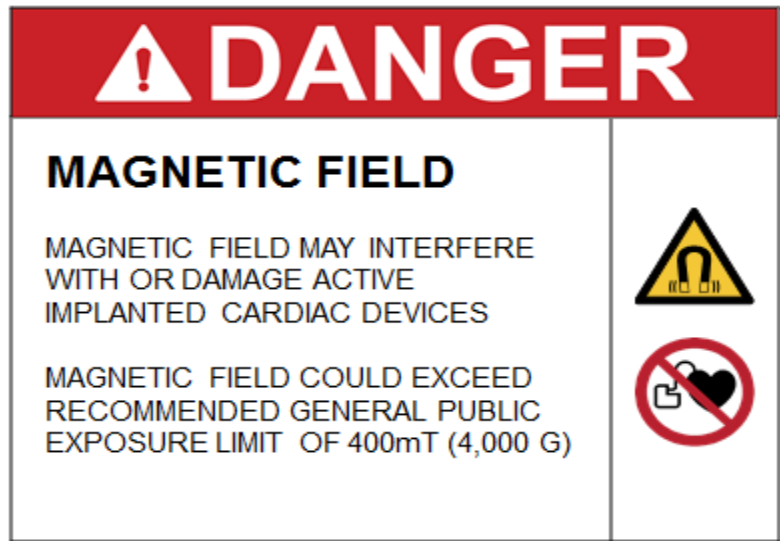
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Appendix A. Magnetic Field Hazard Signage

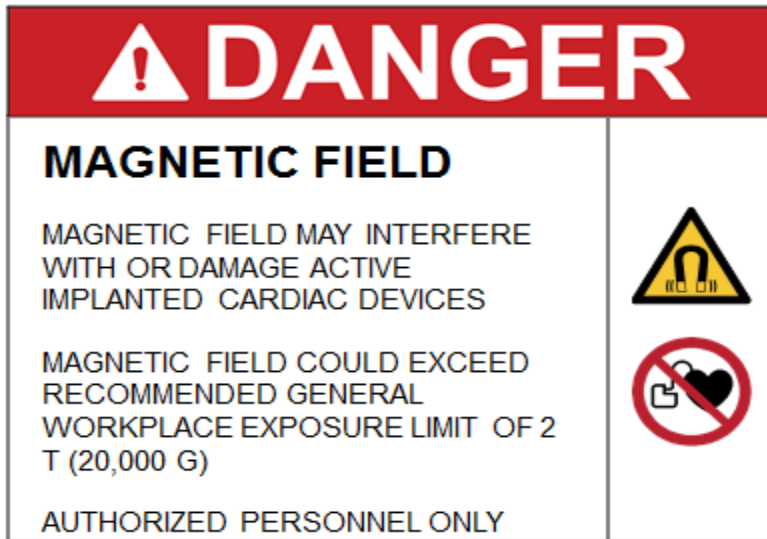


- a. Danger Sign– Magnetic Field May Interfere with or Damage Implanted Cardiac/Medical Devices.



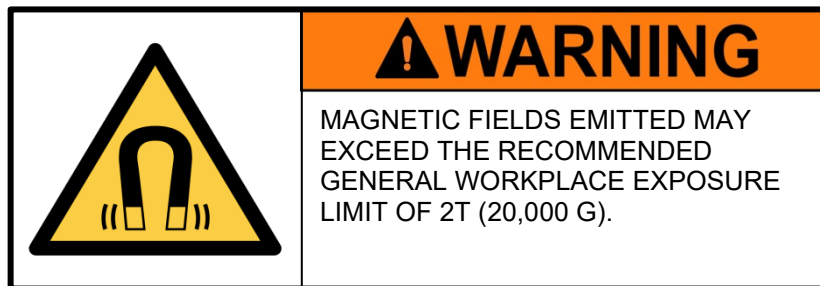
- b. Danger Sign- Magnetic Fields May Interfere with or Damage Implanted Cardiac/Medical Devices and Could Exceed the Recommended General Public Exposure Limits.

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- c. Danger Sign – Magnetic Fields May Interfere with or Damage Implanted Cardiac/Medical Devices and Could Exceed the Recommended General Workplace Exposure Limits.

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- d. Warning Label - Device capable of producing external magnetic fields in excess of the recommended general workplace exposure limit of 2T (20,000 G).

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Appendix B. Revision History

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Revision No.	Approval Date	Responsible Person	Brief Description of Change; Rationale
1	1/5/21	April Camenisch	Updated suborder links. Added Revision History appendix.

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