Guidance for Industry and FDA Staff - Information for Manufacturers Seeking Marketing Clearance of Diagnostic Ultrasound Systems and Transducers - Sections 4 Through 6 and Appendix A Through H

Section 4. Definitions and Formulae

This section provides precise definitions for the pertinent technical terms used in this document. Unless explicitly noted in this section, the definitions provided are in concurrence with equivalent definitions in AIUM/NEMA 2004a, AIUM/NEMA 2004b. Where used in this guidance, the terms defined below are in **bold** letters.

4.1 GENERAL DEFINITIONS

acoustic pressure : The value of the total pressure minus the ambient pressure.

Symbol: *p*
Unit: Pascal, Pa

ALARA :As low as reasonably achievable.

autoscan (autoscanning) : The electronic or mechanical steering of successive ultrasonic pulses or series of pulses, through at least two dimensions.

bandwidth : The difference between the most widely separated frequencies f 1 and f 2 at which the transmitted **acoustic pressure** spectrum is 71 percent (–3 dB) of its maximum value.

Symbol: *BW*
Unit: Hertz, Hz

beam axis : A straight line joining the points of maximum **pulse intensity integral** measured at several different distances in the **far field**. Calculated according to regression rules, this line extends back to the **transducer assembly** surface.

beam cross-sectional area : The area on the surface of a plane perpendicular to the **beam axis** consisting of all points where the **pulse intensity integral** is greater than 25 percent of the maximum **pulse intensity integral** in that plane. For situations in which the relative **acousticpressure waveform** does not change significantly across the **beam cross-sectional area**, the **beam cross-sectional area** may be approximated by measuring the area on the surface of a plane perpendicular to the **beam axis** consisting of all points where the **acoustic pressure** is greater than 50 percent of the maximum **acoustic pressure** in the plane.

Symbol: *A*
Unit: centimeter squared, cm^2

bounded-square output power : **Power** emitted in the **non-autoscanning mode** from the contiguous one square centimeter of the active area of the transducer through which the highest **ultrasonicpower** is transmitted.

Symbol: W_{01x1}
Unit: milliwatt, mW

center frequency : Defined as

$$f_c = (f_1 + f_2)/2$$

where
f_1 and f_2 are frequencies defined in **bandwidth**

Symbol: f_c
Unit: Hertz, Hz

conventional : (as used with the musculo-skeletal application) Structures located at a depth greater than 1.5 cm.

declaration of conformity : a document that declares that a product is in conformance with the provisions of a recognized standard (See FDA-3654 Standards Data Report form at **http://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Forms/UCM081667.pdf (http://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Forms/UCM081667.pdf)**).

derating (derating factor, derated) : A factor applied to acoustic output parameters intended to account for ultrasonic attenuation of tissue between the source and a particular location in the tissue. As referred to in this document, the average ultrasonic attenuation is assumed to be a 0.3 dB/cm-MHz along the **beam axis** in the body. **Derated** parameters are denoted with a subscript ".3".

Symbol: *a*
Unit: decibel per centimeter - megahertz, dB $cm^{-1}MHz^{-1}$

Design History File : Documentation established and maintained by the manufacturer for each type of medical device. The Design History File shall contain or reference the records necessary to demonstrate that the design was developed in accordance with the approved design plan and the requirements of 21 CFR Part 820 - Quality System Regulation. See CDRH Device Advice, Quality System (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/PostmarketRequirements/QualitySystemsRegulations/default.htm (/MedicalDevices/DeviceRegulationandGuidance/PostmarketRequirements/QualitySystemsRegulations/default.htm)**) and 21 CFR 820.30(j) Design History File.

designated standard mode : Consists of the following specific operating modes: A-mode, B-mode, M-mode, PW Doppler, CW Doppler and Color Doppler.

duty factor: The product of the **pulse duration** and the **pulse repetition frequency** for a pulsed waveform.

entrance beam dimensions : The dimensions of the –12 dBbeam width where the beam enters the patient. For contact transducers, these dimensions can be taken as the dimensions of the radiating element if so stated.

Symbol: EBD
Unit: centimeter, cm

entrance dimensions of the scan :For **autoscan** systems, the dimensions of the area of the surface through which the scanned ultrasound beams enter the patient, consisting of all points located within the -12 dB beam width of any beam passing through that surface during the scan.

Symbol: EDS
Unit: centimeter, cm

envelope : A smooth curve tangent to and connecting the peaks of successive cycles of a **waveform**.

far field : That region of the field in which the acoustic energy flow proceeds essentially as though coming from a point source located in the vicinity of the **transducer assembly**. (For an unfocused **transducer assembly**, the **far field** is commonly at a distance greater than $S/\pi\lambda$ where S is the **radiating cross-sectional area** and λ is the acoustic **wavelength** in the medium.)

focal surface: The surface which contains the smallest of all **beam cross-sectional areas** of a focusing **transducer assembly**.

Symbol: (none)
Unit: centimeter squared, cm^2

global maximum: The greatest value of a quantity evaluated over all times, over all locations, and over all **operating conditions** for any given operating **mode**.

intensity : The **ultrasonicpower** transmitted in the direction of acoustic wave propagation, per unit area normal to this direction, at the point considered. For measurement purposes, this point is restricted to points where it is reasonable to assume that the **acoustic pressure** and particle velocity are in phase, viz., in the **far field** or the area near the **focal surface**.

intensity, instantaneous : The instantaneous **ultrasonicpower** transmitted in the direction of acoustic wave propagation, per unit area normal to this direction, at the point considered. It is given in the **far field** by:

$$i = p^2/\rho c$$

where
p is the instantaneous **acoustic pressure**;
ρ is the density of the medium;
c is the speed of sound in the medium.

Symbol: i
Unit: Watt per square-centimeter, W cm^{-2}

intensity, pulse-average :The ratio of the **pulse intensity integral** (energy fluence per pulse) to the **pulse duration**.

Symbol: I_{PA}
Unit: Watt per square-centimeter, W cm^{-2}

intensity, spatial-average temporal-average : For **autoscanning** systems, the **temporal-average intensity** averaged over the **scan cross-sectional area** on a surface specified (may be approximated as the ratio of **ultrasonic power** to the **scan cross-sectional area** or as the mean value of that ratio if it is not the same for each scan); for **non-autoscanning** systems, the **temporal-average intensity** averaged over the **beam cross-sectional area** (may be approximated as the ratio of **ultrasonic power** to the **beam cross-sectional area**).

Symbol: I_{SATA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

intensity, spatial-peak pulse-average : The value of the **pulse-average intensity** at the point in the acoustic field where the **pulse-average intensity** is a maximum or is a local maximum within a specified region.

Symbol: I_{SPPA}
Unit: Watt per square-centimeter, W cm^{-2}

intensity, spatial-peak temporal-average :The value of the **temporal-average intensity** at the point in the acoustic field where the **temporal-average intensity** is a maximum, or is a local maximum within a specified region.

Symbol: I_{SPTA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

intensity, temporal-average : The time average of **intensity** at a point in space. For **non-autoscan** systems, the average is taken over one or more **pulse repetition periods**. For **autoscan** systems, the **intensity** is averaged over one or more **scan repetition periods** for a specified operating **mode**. For **autoscanmode**s, the average includes contributions from adjacent lines that overlap the point of measurement. For **combined modes** the average includes overlapping lines, from all constituent **discrete operating mode** signals.

Symbol: I_{TA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

intensity, temporal peak : The peak value of the **intensity** at the point considered.

Symbol: I_{TP}
Unit: Watt per square-centimeter, W cm^{-2}

invasive probe :An ultrasound probe that is intended to contact tissue other than intact skin or the surface of the eye. These include transvaginal, transesophageal, transrectal, transurethral, intravascular and intraoperative probes.

mechanical index : The spatial-peak value of the **peak rarefactionalpressure**, derated by 0.3 dB/cm-MHz at each point along the **beam axis**, divided by the square root of the **center frequency**, that is:

$$MI = p_{r.3}(z_{sp})/(f_c^{1/2})$$

where
$p_{r.3}(z_{sp})$ is the **peak rarefactional pressure** in megapascals derated by 0.3 dB/cm-MHz to the point on the **beam axis**, z_{sp}, where the **pulse intensity integral** ($PII_{.3}$) is maximum; and
f_c is the **center frequency** in megahertz.

Symbol: *MI*
Unit: Unitless

mode : One of the following system operations: A-mode, M-mode, static B-mode, real-time B-mode, CW Doppler, pulse Doppler, static flow mapping, real-time flow mapping, or any other single display format for presenting clinical information.

non-autoscan (**non-autoscanning**): The emission of ultrasonic pulses in a single direction, where scanning in more than one direction would necessitate moving the transducer manually.

operating condition : Any one combination of the possible particular **output control settings** for a **mode**.

output control settings : The settings of the controls affecing the acoustic output of an ultrasound instrument. Such controls may include, *but are not limited to*, the **power** output control, the focal zone control, and the imaging range control.

Output Display Standard : The “Standard for real-time display of thermal and mechanical acoustic output indices on diagnostic ultrasound equipment. Revision 1,” AIUM/NEMA Standards Publication (AIUM/NEMA 2004a) or IEC 60601-2-37 “ Medical electrical equipment - Part 2-37: Particular requirements for the safety of ultrasonic medical diagnostic and monitoring equipment,” (IEC 2007).

peak rarefactional pressure; peak negative pressure : Maximum of the modulus of the negative instantaneous **acoustic pressure** in an acoustic field during an acoustic repetition period.

Symbol: p_r or p_-
Unit: megapascal, MPa

power (ultrasonic power) : A quantity describing the rate at which acoustic energy travels per unit time in the direction of propagation. Unless stated otherwise, all references to **power** measurements in this guidance will be to temporal-average values.

Symbol: W_o
Units: Watts, W

pressure : See **acoustic pressure**.

pulse-average intensity : See **intensity**.

Symbol: I_{PA}
Unit: Watt per square-centimeter, W cm^{-2}

pulse duration : 1.25 times the interval between the time when the time integral of **intensity** in an acoustic pulse at a point reaches 10 percent and when it reaches 90 percent of the **pulse intensity integral**.

Symbol: *PD*
Unit: second, s

pulse intensity integral :The time integral of **instantaneous intensity**, for any specific point and pulse, integrated over the time in which the **envelope** of **acoustic pressure** or hydrophone signal for the specific pulse is nonzero. It is equal to the energy fluence per pulse. For a **transducer assembly** operating in a **non-autoscanning mode**, it is equal to the product of **temporal-average intensity** and **pulse repetition period**.

Symbol: *PII*
Unit: Joule per centimeter-squared, J cm^{-2}

pulse repetition frequency : For a pulsed waveform, the number of pulses generated per second.

Symbol: *PRF*
Unit: Hertz, Hz

radiating cross-sectional area : The area of the surface at and parallel to the face of the active transducer element(s) and consisting of all points where the **acoustic pressure** is greater than –12 dB of the maximum **acoustic pressure** in that surface. The area of the active element(s) of the **transducer assembly** may be taken as an approximation for the **radiating cross-sectional area**.

Symbol: *S*
Unit: centimeter squared, cm^2

scan cross-sectional area : For **auto-scanning** systems, the area, on the surface considered, consisting of all points located within the **beam cross-sectional area** of any beam passing through the surface during the scan.

Symbol: (none)
Unit: centimeter squared, cm^2

spatial-average temporal-average intensity : See **intensity**.

Symbol: I_{SATA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

spatial-peak pulse-average intensity : See **intensity**.

Symbol: I_{SPPA}
Unit: Watt per square-centimeter, W cm^{-2}

spatial-peak temporal-average intensity : See **intensity**.

Symbol: I_{SPTA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

superficial : (as used with the musculo-skeletal application) Structures located at a depth of 1.5 cm or less.

temporal-average intensity : See **intensity**.

Symbol: I_{TA}
Unit: milliwatt per square-centimeter, mW cm^{-2}

temporal-peak intensity : See **intensity**.

Symbol: I_{TP}
Unit: Watt per square-centimeter, W cm^{-2}

thermal index : A quantity related to calculated or estimated temperature rise under certain defined assumptions. The thermal index is the ratio of total acoustic **power** to the acoustic **power** required to raise tissue temperature by 1ºC under defined assumptions. In the calculation of all thermal indices in the **Output Display Standard**, the average ultrasonic attenuation is assumed to be 0.3 dB/cm-MHz along the **beam axis** in the body. (See Tables 2-1, 2-2, 2-3, and 2-4 in the **Output Display Standard** for thermal index categories and formulae.)

Symbol: *TI*
Unit: Unitless

TIS_as: The soft-tissue **thermal index** at surface for **non-autoscanning mode**;

$$TIS\_as = (W_{o1x1} f_c) / 210$$

where
W_{o1x1} is the bounded-square output power in milliwatts;
f_c is the center frequency in megahertz.

Symbol: TIS_as
Unit: Unitless

transducer assembly : The transducer(s), the transducer housing (probe), any associated electronic circuitry, any liquids contained in the housing, and the integral cable, which connects the transducer probe to an ultrasound console.

ultrasonic power : See **power**.

waveform : The graphical characterization of an acoustical or electrical parameter as a function of time.

waveform record : A permanent plot or photograph of a voltage **waveform** for a specific hydrophone when excited under specified conditions.

wavelength : The ratio of the speed of sound in the medium to the **center frequency**.

Symbol: λ
Unit: centimeters per cycle, cm cycle^{-1}

4.2 LIST OF SYMBOLS

p = **acoustic pressure**
BW = **bandwidth**
A = **beam cross-sectional area**
f_c = **center frequency**
a = **derating factor**
i = **instantaneous intensity**
I_{PA} = **pulse-average intensity**
I_{SATA} = **spatial-average temporal-average intensity**
I_{SPPA} = **spatial-peak pulse-average intensity**
I_{SPTA} = **spatial-peak temporal-average intensity**
I_{TA} = **temporal-average intensity**
I_{TP} = **temporal-peak intensity**
MI = **mechanical index**
p_r = **peak rarefactional pressure**
W_o = **power, ultrasonic power**
PD = **pulse duration**
PII = **pulse intensity integral**
PRF = **pulse repetition frequency**
S = **radiating cross-sectional area**
TI = **thermal index**
TIS_as = soft tissue **thermal index** at surface
λ = **wavelength**

Section 5. References

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AIUM/NEMA: Acoustic Output Measurement Standard for Diagnostic Ultrasound Equipment, Revision 3. NEMA Standards Publication UD 2-2004; American Institute of Ultrasound in Medicine, Laurel, MD; National Electrical Manufacturers Association, Rosslyn, VA; 2004b.

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IEC: IEC 60601-2-37, Medical electrical equipment - Part 2-37: Particular requirements for the safety of ultrasonic medical diagnostic and monitoring equipment , International Electrotechnical Commission, 2007.

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UL: UL-60601-1 - Medical Electrical Equipment, Part 1: General Requirements for Safety, Underwriter’s Laboratories, Northbrook IL, 2003.

UL: UL 544 - Standard for Medical and Dental Equipment, Underwriter’s Laboratories, Northbrook IL, 1998.

Zeqiri B, Bond AD: “The influence of waveform distortion on hydrophone spatial averaging corrections - Theory and measurement”, J. Acoust. Soc. Am. 92,1809-1821, 1992.

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Section 6. Illustrative List for FDA Reviewers of Diagnostic Ultrasound 510(k) Submissions

510(k) Number: _____
Device Name: _____
Company Name: _____

Section / Item / Needed? Yes or No / Present? Yes or No

Administrative Information:
MDUFMA Cover Sheet
CDRH Premarket Review Cover Sheet
510(k) Cover Letter
Indications for Use Statement
510(k) Summary or Statement
Truthful and Accuracy Statement
Financial Certification or Disclosure
Declarations of Conformity and Summary Reports
Standards Form FDA-3654
Clinical Trials Form FDA-3674
Executive Summary
Reason for Submission
Submission Type (Track 1 or 3)

1.3 Indications for Use:
510(k) Indications for Use Form
New Indications for Use (Probes, Accessories)
Previously Cleared Indications for Use

1.4 General Device Description:
System Design
Transducer Operation
Operating Controls
New or Unique Features/Technological Characteristics

1.5 Predicate Device Comparison:
Legally Marketed Predicate Device(s)
Comparison to Predicate Device(s)
Accessories/Kits
Labeling and/or Promotional Materials

1.6 Acoustic Output Reporting:
Measurement Methodology Certifications
Test Methodology Reporting Per Section 1.6.1

1.7 General Clinical Safety & Effectiveness:
1.7.1 Clinical Measurement Range and Accuracies:
- Test Methodology for Accuracies and Sensitivities
- Doppler Sensitivity (for quantitative claims)
1.7.2 Thermal, Mechanical and Electrical Safety
1.7.3 Patient Contact Materials:
- Material Name/Chemical Composition
- Previously Cleared or Biocompatibility Data
1.7.4 Cleaning, Disinfection, Sterilization, and Pyrogenicity:
- Legally Marketed Disinfectants / Sterilants
- Recommended Procedures for Probe Processing
- Level of Required Disinfection/Sterilization (SAL)
- Information for Components Provided Sterile
- Pyrogenicity Claims
1.7.5 Software/Firmware Information (Moderate LOC):
- Summary Description of Algorithms & Explanations
- Software Description
- Software Version Number
- Device Hazard Analysis
- Software Requirements Specification (SRS)
- Architecture Design Chart
- Software Design Specifications (SDS)
- Traceability Analysis
- Software Development Environment Description
- Verification and Validation Documentation.
- Revision Level History
- Unresolved Anomalies (Bugs and Defects)

1.8 Labeling:
1.8.1 Draft Operator's Manuals / Promotional Materials
Description of System and Transducers
1.8.1.1 Indications for Use, Contraindications, Warning & Precautions
Prescription Device Statement
1.8.1.2 Clinical Instructions for Use
1.8.1.3 Compatible Accessories and Kits (with Specifications)
Probe Sheath Recommendation for Invasive Uses
and FDA Latex Alert

1.8.1.4 Clinical Measurement Accuracies and Ranges
1.8.1.5 Draft Acoustic Output Labeling with Descriptions and Measurement Uncertainties
1.8.1.6 Care, Cleaning, Disinfection, Sterilization
1.8.1.7 Special Labeling
1.8.1.8 Literature References

2 Track 1 Specific Information

2.1 Acoustic Output Reporting:
2.1.1 Mode/Application Possibilities Summary
Target Range of Values (MI or $I_{SPPA.3}$ and $I_{SPTA.3}$)
2.1.2 Fetal Heart Rate Monitor Information
2.1.3 Temperature Rise for Transcranial

2.2 Acoustic Output Labeling:
2.2.1 Draft Acoustic Output Labeling Formats
2.2.2 Explanation of Derated Acoustic Output Quantities
2.2.3 Interactive System Features
ALARA Discussion
2.2.4 Abdominal Doppler Contraindication
2.2.5 Fetal Heart Rate Monitoring

3 Track 3 Specific Information

3.1 Acoustic Output Reporting:
3.1.1 Operating Mode Possibilities Summary
3.1.2 Output Display and Measurement Method Certification
3.1.3 Description of Defaults
3.1.4 Justification of TI's>6.0
3.1.5 Global maximum TI, $I_{SPTA.3}$,MI and $I_{PA.3}@MI_{max}$ when MI/TI ≤ 1.0

3.2 Acoustic Output Labeling:
3.2.1 Draft Acoustic Output Labeling Formats
3.2.2 Description of Real-Time Display and Controls
3.2.3 Display Accuracy
3.2.4 Global maximum TI, $I_{SPTA.3}$,MI and $I_{PA.3}@MI_{max}$ when MI/TI ≤ 1.0

3.3 Education Program

Appendix A: Suggested Format and Content of Acoustic Output Measurement and Labeling Records Maintained in the Design History File

General Information

This appendix is intended to assist manufacturers in documenting the final measurement data and product labeling information, based on their production devices. This information should be maintained in the Design History File.

Suggested records:

A. LABELING/USER INFORMATION
The Design History File should contain:

1. a copy of all labeling, including acoustic output information following Sections 2.2 and 3.2 of this guidance and
2. he **global maximum derated** I_{SPTA} **intensity** values and **Mechanical Index** (or **derated** I_{SPTA}**intensity**) values obtained from production units as determined according to Section B5 below. For Track 1, you should document this information for each system/transducer/**mode**/application combination (i.e., one set of values for each applicable mode/application combination identified under Section 2.1.1.a of this guidance). For Track 3, you should document this information for each system/transducer/**mode** combination (i.e., one set of values for each applicable mode identified under Section 3.1.1.a of this guidance).

B. GMP TEST PLAN
The **Design History File** should contain:

1. the number of units tested and percentage of production lot if applicable;
2. measurement uncertainties for acoustic quantities (**power**, **pressure**, **intensities**,and **center frequency**);
3. the **operating conditions** used to obtain the measured acoustic output;
4. a statement explaining whether the **operating conditions** result in maximizing output, and if not, a justification for equivalence; and
5. the statistical plan and protocol used to ensure that the appropriate **intensity** and index values are not exceeded [$I_{SPTA.3}$ values for Track 1 (see Table 2-1); $I_{SPTA.3}$ = 720 mW/cm^2 (50 for ophthalmic) for Track 3; for Track 3 ophthalmic, Max(**TIS_as**, TIC) ≤ 1; MI = 1.9 (0.23 for ophthalmic) for both tracks].

   If 100 percent sampling is not done, then the sampling plan should provide reasonable statistical assurance that production units will not exceed the maximum acoustic output exposure levels specified in Sections 2 (Track 1) and 3 (Track 3) of the guidance. We recommend that the statistical technique known as “one-sided tolerance for normal

distributions" be used. See Hahn et al. 1991, Section 2.4 (pages 34-36), Sections 4.6.3 and 4.6.4 (pages 60-61), and Table A.12d (page 315), or see Natrella 1966, Section 2-5 (page 2-13) and Table A-7 (page T-14). This procedure has the following formulation:

$$L \geq X + Ks$$

where:

L is the relevant $I_{SPTA.3}$ or MI (or $I_{SPPA.3}$) Preamendments acoustic output exposure level (see Table 2-1)
X is the mean of the measured values
s is the standard deviation of the measured values
K is the tolerance coefficient and is a function of the confidence level (notated (1 - α) in Hahn et al. 1991 and γ in Natrella 1966), the proportion (P) of the distribution less than (X + Ks), and the sample size (n).

The choices for γ (or, equivalently, 1 - α), P, and n are at the manufacturer's discretion. However, the choices for γ, P, and n should be documented and justified in the GMP process and the **Design History File**. The values of X and s also should be documented.

For this statistical procedure to be valid, the sample size n should not be less than three. Also, please note that, if the above one-sided tolerance inequality is not met for an initial (and presumably low) sample size, you should not simply increase n to achieve a lower tolerance coefficient value (K) and continue the test. Such a sequential testing approach is invalid.

An example of applying this procedure to a population of ultrasound transducers is given in Ziskin 1993 and Ziskin 2003. However, please note that Table 2 in Ziskin 1993 is incorrect and should be replaced by either Table A-7 in Natrella 1966, Table A.12d in Hahn et al. 1991, or Table II in Ziskin 2003.

NOTE: In computing the standard deviation s, the hydrophone measurement uncertainty should not be taken into account if it is less than + 30% for **intensity** or + 15% for MI. However, if the hydrophone measurement uncertainty exceeds these values, then the acoustic output exposure levels in Section 2 (Track 1) or Section 3 (Track 6) should be reduced accordingly as described in Section 1.6, paragraphs 3 and 4.

C. STATISTICAL TECHNIQUES
For ongoing testing of production units, statistical techniques must conform to 21 CFR 820.250.

Appendix B: Non-OEM Replacement Transducers

These transducers are generally those that are manufactured by a party other than the original equipment manufacturer (OEM) and are intended to replace a transducer originally provided by the system manufacturer. They can be either new transducers or original equipment transducers that have been modified or remanufactured.

Like new OEM transducers, non-OEM, reprocessed, and remanufactured transducers are new medical devices. As such, they are subject to the 510(k) premarket notification regulations (21 CFR 807.81). They need to have a cleared 510(k) prior to being marketed.

In addition to the information recommended in the body of this guidance, we recommend the following in regard to acoustic output testing and labeling for diagnostic ultrasound replacement transducers:

1. In making the acoustic output comparison between the replacement and OEM transducers, three or more transducers of each type should be used. The use of a single OEM generator is acceptable if it operates within the OEM manufacturer's specifications.
2. Acoustic output comparisons in the basic modes of M, B, and pulsed Doppler are acceptable, but worst-case (i.e., maximum output) conditions should be identified and reported.
3. New acoustic output information (following Sections 2.2 and 3.2) should be provided in the transducer operator's manual whether or not you can demonstrate that the acoustic outputs of the replacement and OEM transducers agree within the limits of the measurement uncertainty. Moreover, if the outputs do not agree the sponsor should demonstrate that means have been incorporated into the replacement transducer to ensure the accuracy of the acoustic output real-time display indices. Furthermore, if the outputs do not agree, then the transducers should not be referred to as "replacement." Instead the transducers should be referred to as "similar to" and the differences should be noted.
4. The acoustic output measurement methodology should be completely described following Section 1.6.1 of this guidance.

Appendix C: Reprocessed "Single-Use Only" Transducers

Reprocessed single-use only transducers are ultrasound transducers that are intended by the OEM to be single-use devices (SUDs), but after such single-use they are reprocessed for use on another patient or in another procedure on the same patient. Reprocessing of SUDs requires a registered reprocessor to submit a 510(k) to the FDA for premarket clearance. See "Frequently-Asked-Questions about the Reprocessing and Reuse of Single-Use Devices by Third-Party and Hospital Reprocessors," (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070902.htm (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070902.htm)**) and "Frequently-Asked-Questions about the Reprocessing and Reuse of Single-Use Devices by Third-Party and Hospital Reprocessors; Three Additional Questions," (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070916.htm (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070916.htm)**).

The reprocessor should conduct functional testing, as well as validation of cleaning and of sterilization. For the 510(k) submission, reprocessors should address the following points in addition to providing all of the information requested in the body of this guidance.

1. You should provide a detailed discussion of how you confirm that the diagnostic ultrasound performance characteristics (i.e., image quality, acoustic output) and physical integrity of the reprocessed transducer (when used with each compatible OEM system) are substantially equivalent to the original OEM device following transducer reprocessing for the maximum recommended number of cycles.
2. You should completely describe the acoustic output test methodology following Section 1.6.1 of this guidance. You should furnish final acoustic output test results for the last recommended reprocessing cycle. You should compare these results to those for the OEM device. We recommend that you measure three or more reprocessed and OEM transducers for this comparison.
3. You should describe the testing that will be performed to verify that the repeated reprocessing procedures are not adversely affecting the acoustic output and imaging performance of the transducer, following "Validation Data in Premarket Notification Submissions (510(k)s) for Reprocessed Single-Use Medical Devices" (Validation Data guidance) (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM071434 (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm071434.htm)**).
4. If the maximum number of reprocessing cycles for the transducer is not specified, then you should test each transducer (100% sampling) for acoustic performance characteristics following each reprocessing cycle. All results should be documented and compared to the original OEM device specifications.
5. You should describe the method that you as the reprocessor use to keep track of the number of reprocessing cycles that an individual transducer has undergone. Again, this is better addressed by referring to the Validation Data guidance.

Appendix D: Cleaning, Disinfection, and Sterilization

Reusable devices should contain clear instructions for cleaning and sterilization or disinfection. The recommended cleaning and sterilization procedures should be validated by the manufacturer. Guidance on this subject is "Labeling Reusable Medical Devices for Reprocessing in Health Care Facilities," (**http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf (http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf)**).

Ultrasound probes that are non-critical devices only need to be cleaned and low-level disinfected between patient uses. Probes used in semi-critical applications should be sterilized between uses whenever feasible, but high level disinfection is minimally acceptable. In addition, the use of a sheath is recommended for every semi-critical use of the probe. Critical devices should be sterilized and the use of a sterile sheath is recommended. Please note that the use of sheaths does not change the type of processing that is recommended for the transducer. After use, the single-use sheath should be removed and discarded. The probe used in a semi-critical application should be cleaned and sterilized or at least receive high level disinfection after use even if a sheath was used. Probes used for critical applications should be cleaned and sterilized after use even if a sterile sheath was used. Sheaths can fail during use and the level of resulting contamination may not be easily visible.

For devices and accessories that can be terminally sterilized, a validated method of sterilization should be specified. The validation method used should be described. The SAL should be stated. The critical sterilization cycle parameters for each sterilization method should be provided clearly to the users along with a description of any equipment and accessories needed for sterilization of the medical device.

For steam sterilization, you should indicate whether the recommended cycle(s) are pre-vacuum or gravity cycles and state the cycle temperature and time and the recommended drying time.

For ethylene oxide gas sterilization, you should state the EO concentration recommendations, the cycle time and temperature, and the humidity needed for the sterilization process, as well as the minimum holding or exposure time in the sterilant and the aeration time needed to remove ethylene oxide residues on the device. Cycle parameters provided to users should be consistent with the validated cycles provided in sterilizers used in health care facilities.

If a non-traditional sterilization method is recommended, you should identify the exact sterilizer make and model validated as well as the critical cycle parameters of time and temperature and any post-sterilization instructions needed.

In addition, there are several special situations:

1. Neurosurgical use: Probes that contact brain tissue and cerebrospinal fluid should always be used with a sterile, endotoxin-free sheath because the disinfectant/sterilant residue left on the probe is neuro-toxic and endotoxin is pyrogenic (e.g., cause fevers). NOTE: If the probe is used on a patient with known or suspected Creutzfeldt-Jakob Disease (CJD) the probe should be destroyed. (see **http://www.cdc.gov/ncidod/qa_cjd_infection_control.htm (http://www.cdc.gov/ncidod/dvrd/cjd/infection_control_cjd.htm)**)
2. Endoscopic, rectal, and transvaginal probes should normally be used with a sterile sheath. If these probes are used to assist biopsy procedures, all of the biopsy accessories should be sterile for the procedure and should be cleaned and resterilized after each use. If the

transducer probe itself has a built-in channel for the needle guide, that channel could create a risk for contamination of the biopsy needle during use unless the channel is thoroughly cleaned and the probe is sterilized before use on another patient.

3. Due to the inherent limitation of using liquid chemicals for sterilizing medical devices, liquid chemical use should be limited to reprocessing only critical and semi-critical devices that are heat-sensitive and incompatible with other sterilization methods, such as ETO gas or heat sterilization.

   For further information see CDRH's document titled "Labeling Reusable Medical Devices for Reprocessing in Health Care Facilities: FDA Reviewer Guidance." (**http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf (http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf)**). Also, the following documents should be consulted:

4. ANSI/AAMI ST 35: 2003. Safe handling and biological decontamination of reusable medical devices in health care facilities and in nonclinical settings. Association for the Advancement of Medical Instrumentation. Arlington, VA.
5. ANSI/AAMI ST 81: 2004. Sterilization of medical devices-Information to be provided by the manufacturer for the processing of resterilizable medical devices. Association for the Advancement of Medical Instrumentation. Arlington, VA.
6. ANSI/AAMI/ISO 11607-1:2006. Packaging for terminally sterilized medical devices-Part 1: Requirements for materials, sterile barrier systems, and packaging. Association for the Advancement of Medical Instrumentation. Arlington, VA
7. ANSI/AAMI/ISO 11607-2: 2006 Validation requirements for forming, sealing and assembly processes 1ed. Association for the Advancement of Medical Instrumentation. Arlington, VA
8. ANSI/AAMI/ISO 10993: Biological evaluation of medical devices. Association for the Advancement of Medical Instrumentation. Arlington, VA.
9. U.S. Food and Drug Administration. Guideline on validation of the Limulus amebocyte lysate test as an end-product endotoxin test for human and animal parenteral drugs, biological products, and medical devices. http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/ucm070286.pdf
10. U.S. Food and Drug Administration. Guidance on the Content and Format of Premarket Notification [510(k)] Submissions for Liquid Chemical Sterilants and High Level Disinfectants. **http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm073773.htm (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm073773.htm)**

11. U.S. Food and Drug Administration. Labeling Reusable Medical Devices for Reprocessing in Health Care Facilities. **http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf (http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080268.pdf)**
12. AAMI TIR 12: 2004. Designing, Testing, and Labeling Reusable Medical Devices for Reprocessing in Health Care Facilities: A Guide for Device Manufacturers. Association for the Advancement of Medical Instrumentation. Arlington, VA.
13. AAMI TIR 30: 2003. A compendium of processes, materials, test methods, and acceptance criteria for cleaning reusable medical devices. Association for the Advancement of Medical Instrumentation. Arlington, VA.

Appendix E: Deciding if System or Transducer Modifications Require a New 510(k) Premarket Notification

In addition to the recommendations below, please refer to the guidance "Deciding When to Submit a 510(k) for a Change to an Existing Device" (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm080235.htm (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm080235.htm)**) and "The New 510(k) Paradigm, Alternate Approaches to Demonstrate Substantial Equivalence in Premarket Notifications" (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM080187 (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm080187.htm)**).

A. Addition or Modification of Transducers

We believe that the addition or modification of transducers to a particular system will need a new 510(k) except when all of the following conditions are met:

1. The system is already the subject of a submitted and cleared 510(k);
2. Indication(s) for use and **mode**(s) of operation of the system or transducer are unchanged;
3. Acoustic output of each new or modified transducer is below the Preamendments acoustic output exposure level in Table 2-1 for the respective indication(s) (Track 1) or are below $I_{SPTA.3}$ = 720 mW/cm^2 and either MI =1.9 or $I_{SPPA.3}$ =190 W/cm^2 (Track 3). For Track 3 ophthalmic applications TI = max.(**TIS_as**, TIC) and is not to exceed 1.0, $I_{SPTA.3} \leq$ 50 mW/cm^2 and MI ≤ 0.23; and
4. Acoustic output is measured and recorded according to the procedures in this 510(k) guidance; these procedures are included in the **Design History File**, and the results are

included in the **Design History File**, as part of Good Manufacturing Practices (GMP's) for that device. This condition should be met for changes that affect the output of any transducer intended for use with the system. In addition, the **Design History File** should adequately document minor changes not affecting the indications for use or acoustic output. These files may be reviewed during FDA quality system inspections. If measurement technology different from that defined in this guidance is used to document acoustic output, a 510(k) premarket notification may be necessary.

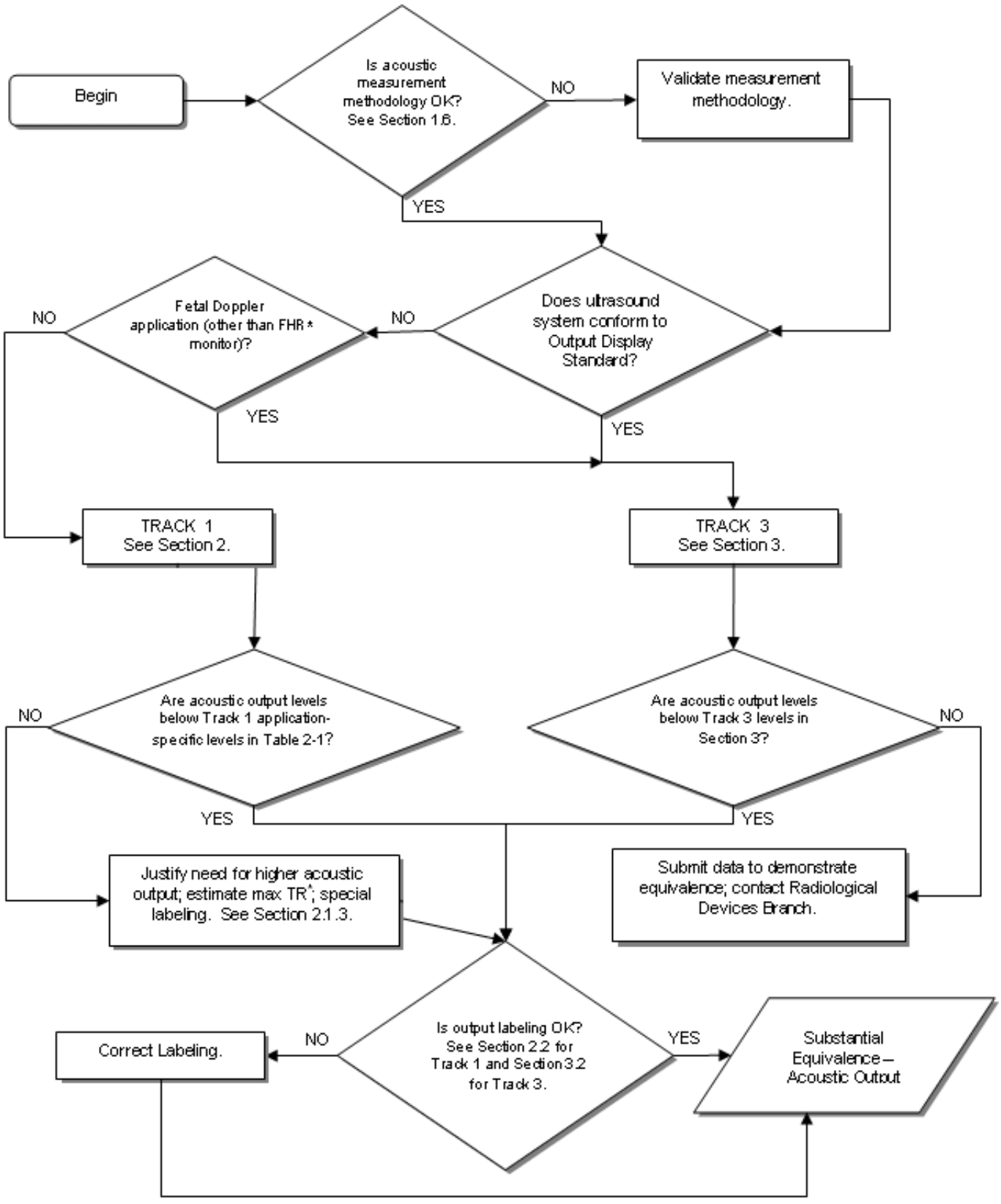
B. Modifications to Previously Cleared Diagnostic Ultrasound Systems

Modifications to a diagnostic ultrasound system that has a previously cleared 510(k) generally will not require a new 510(k) if the Track (1 or 3), indication for use, and the ultrasound generator, controls, and signal processing technologies are unchanged; no system functions are added; no significant new clinical information is provided; and the clinical application/**mode** of operation does not provide a significant new interpretation of existing information.

C. New Indications for Use

We believe that new clinical applications or new **modes** of operation may represent new indications for use and, therefore, need a new 510(k). An example format for providing the indications for use is given in Appendix G.

Appendix F: Decision Flow Chart for Tracks 1 and 3



* FHR = fetal heart rate; TR = temperature rise

Appendix G: Example Diagnostic Ultrasound Indications For Use Format

System: _____

Transducer: _____

Intended Use: Diagnostic ultrasound imaging or fluid flow analysis of the human body as follows:

Clinical Application		Mode of Operation						
General (Track 1 Only)	**Specific (Tracks 1 & 3)**	**B**	**M**	**PWD**	**CWD**	**Color Doppler**	**Combined (Specify)**	**Other* (Specify)**
Ophthalmic	Ophthalmic							
Fetal Imaging & Other	Fetal							
	Abdominal							
	Intra-operative (Specify)							
	Intra-operative (Neuro)							
	Laparoscopic							
	Pediatric							
	Small Organ (Specify)							
	Neonatal Cephalic							
	Adult Cephalic							
	Trans-rectal							
	Trans-vaginal							
	Trans-urethral							
	Trans-esoph. (non-Card.)							
	Musculo-skeletal (**Conventional**)							
	Musculo-skeletal (**Superficial**)							
	Intravascular							
	Other (Specify)							
Cardiac	Cardiac Adult							
	Cardiac Pediatric							

	Intravascular (Cardiac)							
	Trans-esoph. (Cardiac)							
	Intra-cardiac							
	Other (Specify)							
Peripheral	Peripheral vessel							
Vessel	Other (Specify)							

N = new indication; P = previously cleared by FDA; E = added under this appendix
* Examples of other modes of operation may include: A-mode, Amplitude Doppler, 3-D Imaging, Harmonic Imaging, Tissue Motion Doppler, and Color Velocity Imaging

Appendix H: Statistical Analyses

There are four areas of the submission in which a statistical analysis of measurement or performance data may be appropriate.

1. Description of clinical measurement accuracy. See Sections 1.7.1.2 and 1.8.1.4 of this guidance.
2. Description of measurement uncertainties for acoustic quantities (**power**, **pressure**, **intensities**, **center frequency**). See Section 2.2.1 (Track 1) and Section 3.2.1 (Track 3) of this guidance. In this regard, a good description of the various potential sources of Type A (random) and Type B (systematic) uncertainties for hydrophone measurements can be found in Preston et al. 1988. Also see Ziskin 2003.
3. Description of statistical sampling plan used to ensure that the specifications for acoustic output exposure levels are meaningful. See Section 1.6.1.8 and Ziskin 2003.
4. Description of display accuracy, as specified in Section 4.2.1 of AIUM/NEMA 2004a or Clause 201.7.2.101 of IEC 2007. See Section 3.2.3 (Track 3) of this guidance.

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[1] Bolded words in the text are defined in Section 4 of the guidance.

[2] For historical reasons, there is no Track 2.

[3] (see "Recognition and Use of Consensus Standards" at (**http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM077274 (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm077274.htm)**))

[4] An abbreviated 510(k) summary report is intended to explain how a device-specific guidance document was used during development and testing of your device. This is not the 510(k) summary described in 21 CFR 807.92, which may be submitted to satisfy 21 CFR 807.87(h). For additional information on abbreviated 510(k) summary reports, see section 9 of **Format for Traditional and Abbreviated 510(k)s** at **http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm084365.htm (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm084365.htm)**.

[5] If FDA makes a substantial equivalence determination based on acceptance criteria, the subject device should be tested and shown to meet these acceptance criteria before being introduced into interstate commerce. If the finished device does not meet the acceptance criteria and, thus, differs from the device described in the cleared 510(k), FDA recommends that submitters apply the same criteria used to assess modifications to legally marketed devices (21 CFR 807.81(a)(3)) to determine whether marketing of the finished device requires clearance of a new 510(k).

[6] See **http://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Forms/UCM081667.pdf (http://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Forms/UCM081667.pdf)**

[7] For further information on regulatory acoustic output comparisons, see O'Brien et al. 2002, Harris 2000, and Stratmeyer 1989.

[8] The terms "critical device" and "semi-critical device" generally refer to devices that during use contact normally sterile tissue or body spaces (critical), and those that during use contact mucous membranes or non-intact skin (semi-critical).

More in Guidance Documents (Medical Devices and Radiation-Emitting Products) (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/default.htm)

Cross-Center Final Guidance (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm081752.htm)

Office of Compliance Final Guidance (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070269.htm)

Office of the Center Director Final Guidance (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm110228.htm)

Office of Communication and Education Final Guidance (/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070271.htm)

Office of Device Evaluation Final Guidance 2010 - 2016

(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm198577.htm)

Office of Device Evaluation Final Guidance 1998 - 2009
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070272.htm)

Office of Device Evaluation Final Guidance 1976 - 1997
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm080283.htm)

Office of In Vitro Diagnostics and Radiological Health Final Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070274.htm)

Office of Surveillance and Biometrics Final Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070275.htm)

Office of Science and Engineering Laboratories Final Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm070277.htm)

Draft Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm407274.htm)

Radiation-Emitting Products Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm283507.htm)

Withdrawn Guidance
(/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm425025.htm)