DIAGNOSTIC IMAGING & COMMUNICATIONS IN MEDICINE
(DICOM)

PART 12

Media Formats and Physical Media for Media Storage



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Digital Imaging and Communications in Medicine (DICOM)
Part 12: Media Formats and Physical Media for Media Interchange

Approved by:

The American College of Radiology
The American College of Cardiology

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FOREWORD

The American College of Radiology (ACR), American College of Cardiology (ACC) and the National Electrical Manufacturers Association (NEMA) formed a joint committee to develop a standard for Digital Imaging and Communications in Medicine (DICOM). This DICOM Standard was developed according to NEMA procedures.

This standard is developed in liaison with other standardization organizations including CEN TC251 in Europe and JIRA/IS&C in Japan, with review also by other organizations including IEEE, ASTM, HL7 and ANSI in the USA.

The DICOM Standard is structured as a multi-part document using the guidelines established in the following document:

- ISO/IEC Directives, 1989 Part 3 : Drafting and Presentation of International Standards

This document is one part of the DICOM Standard which consists of the following parts:

PS 3.1: Introduction and Overview
PS 3.2: Conformance
PS 3.3: Information Object Definitions
PS 3.4: Service Class Specifications
PS 3.5: Data Structures and Encoding
PS 3.6: Data Dictionary
PS 3.7: Message Exchange
PS 3.8: Network Communication Support for Message Exchange
PS 3.9: Point-to-Point Communication Support for Message Exchange
PS 3.10: Media Storage and File Format for Media Interchange
PS 3.11: Media Storage Application Profiles
PS 3.12: Media Formats and Physical Media for Media Interchange
PS 3.13: Print Management Point to Point Communication Support

These parts are related but independent documents. Their development level and approval status may differ. Additional parts may be added to this multi-part standard. PS 3.1 should be used as the base reference for the current parts of this standard.

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1 Scope and field of application

This part of the DICOM Standard facilitates the interchange of information between digital imaging computer systems in medical environments. This interchange will enhance diagnostic imaging and potentially other clinical applications. The multi-part DICOM Standard defines the services and data that shall be supplied to achieve this interchange of information.

This Part specifies:

a) A structure for describing the relationship between the Media Storage Model (see PS 3.10) and a specific physical media and media format

b) Specific physical media characteristics and associated media formats

2 Normative references

The following standards contain provisions that, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibilities of applying the most recent editions of the standards indicated below.

ISO/IEC 10090 Continuous Composite Format and Cartridge Standard

ISO/IEC 10089 Continuous Composite Format and Cartridge Standard

ECMA-184 and ISO/IEC 13549 Continuous Composite Format and Cartridge Standard

ANSI X3.171 - One and Two Sided High Density, Unformatted, 90 mm (3.5 in), 5.3 tpmm (135 tpi), Flexible Disk Cartridge for 15916 bpr Use

ISO 9660: 1988 (E) Information processing - Volume and file structure of CD ROM for information interchange

ISO/IEC 10149 Information technology - Data interchange on read-only optical discs (CD-ROM), 1989

Part II: CD-WO version 2.0 in Orange Book

Note: This reference will be replaced by the corresponding ISO reference when available.

System Description CD-ROM XA (eXtended Architecture) Specification

Note: This reference will be replaced by the corresponding ISO reference when available.

3 Definitions

For the purposes of this standard, the following definitions apply.

3.1 DICOM MEDIA STORAGE AND FILE FORMAT DEFINITIONS

This Part of the Standard makes use of the following terms defined in NEMA PS 3.10 of the DICOM Standard.

a) Application Profile

b) DICOM File Service

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c) DICOM File
d) DICOMDIR File
e) File
f) File ID
g) File-set

3.2 PC FILE SYSTEM

A PC file system is commonly used for storing and exchanging files on removable media. This file system is available as either standard or optional software for most models of personal computers. It is available as standard or optional software for most models of workstations. A public domain implementation of this file system, known as "mtools," was developed by the U.S. Army and is available from various public servers on the Internet.

4 Symbols and abbreviations

The following symbols and abbreviations are used in this part of the standard.

ACR American College of Radiology
ANSI American National Standards Institute
ASTM American Society for Testing and Materials
CD-R Compact Disc – Recordable
CD-WO Compact Disc – Write Once
CEN Comite Europeen de Normalisation
DICOM Digital Imaging and Communications in Medicine
DIS Draft International Standard
ECMA European Computer Manufacturers Association
HL7 Health Level 7
IEC International Electrotechnical Commission
IEEE Institute of Electrical and Electronics Engineers
ISO International Standards Organization
IS&C Image Save and Carry
JIRA Japan Industries Association of Radiation Apparatus
NEMA National Electrical Manufacturers Association
UID Unique Identifier

5 Conventions

Words are capitalized in this document to help the reader understand that these words have been previously defined in Section 3 of this document and are to be interpreted with that meaning.

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6 Relationship to the DICOM media storage model

PS 3.10 defines various media storage concepts. The implementation of these generic concepts on a specific medium and file system is defined in an annex. For each physical medium and file system a mapping is described between these media storage concepts and the specific physical media and file system facilities:

a) File-set ID - The method for providing a File-set ID
b) File ID - The method for mapping a DICOM File ID into a specific file system
c) File creation/update date and time - The specific file system mechanisms used to provide this information
d) File-set location

Processing of DICOM removable media requires that the DICOMDIR be in a known location. Most file systems provide a hierarchical directory structure with a root directory for an entire medium or medium partition. The annex defines where the DICOMDIR(s) are located. When only one File-set is permitted on one medium, the DICOMDIR shall be in the root directory of that medium. When multiple File-sets are permitted on a single medium, the annex will describe how File-sets are found and identified. When a File-set is permitted to span multiple pieces of physical media, the appropriate annex will describe how this is managed.

Figure 6-1 illustrates the structure of a DICOM removable medium that supports a single DICOM File-set per medium partition. Figure 6-2 illustrates the structure of a DICOM medium that supports multiple File-sets per partition. DICOM File-sets shall not intersect when media permit multiple File-sets.

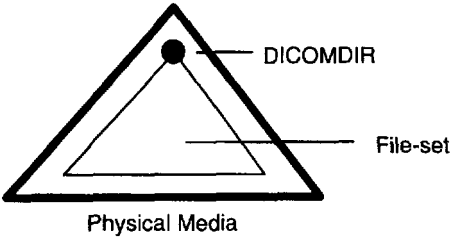

Figure 6-1
MEDIA SUPPORTING A SINGLE FILE-SET

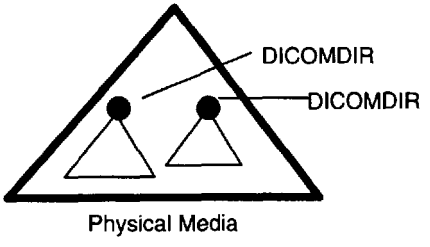

Figure 6-2
MEDIA SUPPORTING MULTIPLE FILE-SETS

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Media and file systems that do not utilize the directory concept will specify the equivalent usage in these annexes that describe these media.

Note: Many applications will need to automatically create many image files and assign them unique File IDs. Maintaining File ID uniqueness without sacrificing performance will require some care. The approach of taking a basic name part, e.g. "IMAGE," and appending sequence numbers, e.g. "IMAGE001, IMAGE002, ..." can easily result in delays finding the next available File ID.

Some approaches that can rapidly generate unique File IDs include:

a) Generating a unique subdirectory per sequence, then using increasing file numbering within the subdirectory

b) Using a random number generator and seed, then using a prime hash function with probes to find unused filenames. An eight character File ID component permits a large prime value for the hash

c) Using the current time (in seconds, milliseconds) as a pseudo-random number to generate one of the File ID components, and resolving collisions with sequential or prime hash probes

All of these approaches result in File IDs that are of limited semantic content. The semantic information that describes file contents is in the DICOMDIR and the file contents to which it points.

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Annex A PC File System (Normative)

A.1 PC FILE SYSTEM MAPPING TO MEDIA FORMATS

Several of the removable media utilize the PC file system. For any media that use the PC file system, the following rules apply, except as overridden in the applicable annex.

A.1.1 File-set ID mapping

The PC File System mapping does not provide a File-set ID.

Note: On systems that permit user access to the media volume label, the volume label can be used to provide a File-set ID. Not all operating systems permit routine user access to this information.

A.1.2 File ID Mapping

The PC File System provides a hierarchical structure for directories and files within directories. Each structure has a root directory that may contain references to both files and subdirectories. Subdirectories may contain references to both files and other subdirectories. The nomenclature for referring to files and directories in the PC File System is:

a) \ – For the root directory
b) \filename – For a file in the root directory
c) \subdir\filename – For a file in the subdirectory subdir

The PC File System name corresponding to a File ID shall be the DICOM File ID prefixed with the character "\", with the "\" character separating File ID components.

Note: Example File ID mappings

File ID	PC File system name
DICOMDIR	\DICOMDIR
FILENAME	\FILENAME
SUBDIR\FILENAME	\SUBDIR\FILENAME

The DICOMDIR file shall be in the root directory for media that do not support multiple file-sets on a single medium. DICOMDIR location is described for the multiple file-set situation in the annex for such media.

Note: It is recommended but not required that the File-set Descriptor File ID (0004,1141) be "README" (see PS 3.10).

A.1.3 File management information

The PC File System provides the following information for each file:

Table A.1-1
PC FILE SYSTEM FILE INFORMATION

Filename	1 to 8 characters
Extension	0 to 3 characters
Time	Time of last modification (or creation)
Date	Date of last modification (or creation)

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Size	Size of file (in bytes)

The PC File System Filename shall correspond to a DICOM File ID Component. The PC File System Extension for a DICOM file shall not contain any characters. The PC File System date and time shall be used to provide the DICOM facilities for examining the modification or creation date and time. Unused characters in Filename and Extension (see Table A.1-1) should be filled with null characters.

Notes: 1. The PC File System does not specify or control the time base used for date and time. Coordination of reference time zones is outside the scope of this standard.

2. The typical written form of a filename is filename.extension (e.g. "FILE.EXT"). The period between filename and extension is a convention used in most programs for entering and displaying the filename and extension. The period is not actually recorded on disk and is not permitted as part of a filename. A file with no extension is recorded as a file with zero extension characters (i.e. all null filled) although it is often written and displayed without the period.

The PC File system does not provide ownership or access control facilities. Write protection is addressed in the relevant physical media specific annex. Protection mechanisms are not available for the generic PC File System.

A.2 LOGICAL FORMAT

The PC File System requires that the media be organized into 512 byte sectors. The media specific mechanism for doing this is in each media annex.

The PC File System shall be organized as an "mtools" unpartitioned file system, using either 12-bit or 16-bit File Allocation Table (FAT). The layout of the boot sector shall be as shown in Table A.2-1. The FAT and related file structures are compatible with the DOS 4.0 and later file systems. Two byte integers shall be encoded in little endian.

The boot sector, sector 0 of track 0, shall be formatted as follows:

Table A.2-1
BOOT SECTOR

Byte(s)	Value	Description
00 - 02	varies	Jump instruction to loader (NOPs) (see note 1)
03 - 10	"ddddddd"	The formatting DOS(vendor specific) (see note 2)
11 -12	0200H	512 bytes/sector
13	see note 5	sectors/cluster
14 - 15	0001H	1 sector in boot record
16	02H	2 File Allocation Tables (FAT) (see note 3)
17 - 18	200H	512 root directory entries
19 - 20	0000H	Flag for more than 65536 sector/disk. Use offset 32 value
21	see note 5	Flag for disk type; F0H if not otherwise specified
22 -23	varies	sectors/FAT
24 - 25	see note 5	sectors/track
26 - 27	see note 5	side (head) per disk
28 - 31	00000000	0 reserved or hidden sectors
32 - 35	varies	Total sector/disk. Varies from disk to disk
36 - 37	0000	Physical Drive number = 0

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38	29H	Extended boot record signature = 41
39 - 42	undefined	Volume serial number. (see note 4)
43 - 53	varies	The volume ID (vendor specific)
54 - 61	varies	The file system label
62 - 509	varies	Don't care. Any contents acceptable
510 - 511	55AAH	Signature flag

Notes:

1. These three bytes should either be EB0090H (indicating a relative jump) or 909090H indicating NOPs. The bytes are for booting off the optical drive which DICOM does not standardize. Some programs use them to validate the disk. The use of EB0090H is known to be more commonly used and is the recommended choice. Readers of DICOM disks that use the PC File System should ignore this field.

2. While eight characters appear to be valid in this field, the use of "MSDOS4.0" is known to be the preferred choice for this string. Some systems, upon finding this field not set to "MSDOS4.0" will ignore the sectors/FAT field and use their own calculation. This may cause an error due to the calculation resulting in a different value than the sectors/FAT field. (MS-DOS is a trademark of Microsoft)

3. Two FATs are recommended. One FAT could also be used but again may cause some incompatibility.

4. The serial number may be any four bytes. A random or sequential number is preferred but is not required.

5. These values are specified in the annex for each particular type of media.

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Annex B 1.44 MB diskette (Normative)

B.1 DICOM MAPPING TO MEDIA FORMATS

Only one DICOM File-set shall be stored onto a single diskette.

B.2 MEDIA FORMATS

The media format comprises two distinct components:

a) The Recording format, which addresses magnetic recording, track definition, sector headers, etc.

b) The Logical format, which addresses the organization of the data portion of sectors to support the semantics of a file system.

B.2.1 Recording format

The magnetic recording format for the 1.44MB diskette shall comply with the recording definitions of ANSI X3.171 using the following parameters:

Table B.2
RECORDING FORMAT PARAMETERS

Parameter	Value
Sector Size	512 bytes
Tracks on floppy disk	80
Sectors per track	18
Sides	2

These parameters correspond to the commonly used 512-byte sector configuration for diskettes.

B.2.2 Logical format

The Logical format selected for the 3.5 inch floppy diskette is the PC File System (Annex A).

The boot sector defined in Annex A shall have the following values.

Table B.2-2
BOOT SECTOR PARAMETER VALUES FOR 1.44 MB DISKETTE

Byte(s)	Value	Description
13	2	sectors / cluster
21	F0H	Flag for disk type
24 - 25	0012H	18 sectors/track
26 - 27	0002H	2 sides

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B.3 PHYSICAL MEDIA

The physical media and recording format shall be as defined in ANSI X3.171. The specific mechanisms and interfaces used to read and write these media are outside the scope of this standard. Any mechanism that maintains the physical and logical formatting specified in this annex is appropriate.

Note: This format is commonly known as the 1.44MB floppy diskette or the 3-1/2 inch MF DS/HD floppy disk. These diskettes are available for most personal computers and workstations.

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Annex C 90 mm 128mb magneto-optical disk (Normative)

C.1 DICOM MAPPING TO MEDIA FORMATS

Only one DICOM File-set shall be stored onto a single 90 mm disk.

C.2 MEDIA FORMATS

The media format comprises two distinct components:

a) The Recording format, which addresses magnetic recording, track definition, sector headers, etc.

b) The Logical format, which addresses the organization of the data portion of sectors to support semantics of the file system.

C.2.1 Recording format

The low level formatting shall be done using the ISO/IEC 10090 Format A. The Secondary Defect Management Table shall be used.

C.2.2 Logical format

The Logical format for the 90 mm 128MB disk shall be the PC File System (see Annex A).

The boot sector defined in Annex A shall have the following values.

Table C.2-1
BOOT PARAMETER VALUES FOR 128MB MAGNETO-OPTICAL DISK

Byte(s)	Value	Description
13	10H or 20H	sectors / cluster, either 16 or 32. Note: 32 is preferred.
21	F8H	Flag for disk type F8H = Hard Disk
24 - 25	0019H	25 sectors/track
26 - 27	0001H	1 head

Note: When formatted the total formatted capacity of the disk is approximately 125MB.

C.3 PHYSICAL MEDIA

The physical media shall be the 90 mm Magneto-Optical Rewritable disk with 512 bytes per sector. It shall be compatible with the standards defined in ISO/IEC 10090 Continuous Composite Format and Cartridge Standard.

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Annex D 130 mm 650MB magneto-optical disk (Normative)

D.1 DICOM MAPPING TO MEDIA FORMATS

Only one DICOM File-set shall be stored onto each side of a single 130 mm disk.

D.2 MEDIA FORMATS

The media format comprises two distinct components:

a) The Recording format, which addresses magnetic recording, track definition, sector headers, etc.

b) The Logical format, which addresses the organization of the data portion of sectors to support semantics of the file system.

D.2.1 Recording format

The low level formatting shall be done using the ISO/IEC 10089-2A. The Secondary Defect Management Table shall be used.

D.2.2 Logical format

The Logical Format for the 130 mm 650MB disk shall be the PC File System (see Annex A).

The boot sector defined in Annex A shall have the following values.

Table D.2-1
BOOT PARAMETER VALUES FOR 650MB MAGNETO-OPTICAL DISK

Byte(s)	Value	Description
13	10H or 20H	sectors / cluster, 16 or 32. Note: 32 is preferred.
21	F8H	Flag for disk type F8H = Hard Disk
24 - 25	001FH	31 sectors/track
26 - 27	0001H	1 head

Note: When formatted the total formatted capacity of a disk side is approximately 300MB.

D.3 PHYSICAL MEDIA

The physical media shall be the 130 mm 650 MB magneto-optical rewritable disk with 512 bytes per sector. It shall be compatible with the standards defined in ISO/IEC 10089 Continuous Composite Format and Cartridge Standard.

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Annex E 130 mm 1.2GB magneto-optical disk (Normative)

E.1 DICOM MAPPING TO MEDIA FORMATS

Only one DICOM File-set shall be stored onto each side of a single 130 mm disk.

E.2 MEDIA FORMATS

The media format comprises two distinct components:

a) The Recording format, which addresses magnetic recording, track definition, sector headers, etc.

b) The Logical format, which addresses the organization of the data portion of sectors to support semantics of the file system.

E.2.1 Recording format

The low level formatting shall be done using the ECMA-184 and ISO/IEC 13549 standards. The Secondary Defect Management Table shall be used.

E.2.2 Logical format

The logical format for the 130 mm 1.2GB disk shall be the PC File System (Annex A). The boot sector defined in Annex A shall have the following values.

Table E.2-1
BOOT PARAMETERS FOR 1.2GB MAGNETO-OPTICAL DISK

Byte(s)	Value	Description
13	10H or 20H	sectors per cluster, 16 or 32. Note: 32 is preferred.
21	F8H	Flag for disk type F8H = Hard Disk
24 - 25	1FH	31 sectors/track
26 - 27	0001H	1 head

Note: When formatted the total formatted capacity of a disk side is approximately 600MB.

E.3 PHYSICAL MEDIA

The physical media shall be the 130 mm 1.2GB magneto-optical rewritable disk with 512 bytes per sector. It shall be compatible with the standards defined in the ECMA-184 and ISO/IEC 13549 Continuous Composite Format and Cartridge Standard.

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Annex F 120mm CD-R Medium (Normative)

The terms "CD-R" and "CD-WO" refer to the same medium and are used interchangeably. Originally this medium was designated CD-WO, but the most common vernacular today is CD-R. There are mixed references in this annex to accommodate the common CD-R usage unless a specific reference to CD-WO is required to reflect the historical documents accurately. The term "CD-ROM," when used in reference to a disc, is a disc fabricated with all the digital data already on it. "CD-R" media is a fabricated blank, with the ability to have digital data written to it. The term "CD-ROM" is also used to refer to a CD reader, e.g., "CD-ROM drive." A CD-ROM drive can read either CD-R discs or CD-ROM discs.

Note: Capitalization in this annex is inconsistent with other DICOM standards in order to be consistent with historical usage for terms.

F.1 DICOM MAPPING TO MEDIA FORMAT

Only one File-set shall be stored onto a single CD-R.

F.1.1 DICOM file-set

The ISO 9660 Standard provides a Volume Identifier in byte position 41 to 72 of the Primary Volume Descriptor. A DICOM File-Set is defined to be one volume, and the File-Set ID shall be placed in the Volume Identifier, starting with byte position 41. Extra bytes within the Volume Identifier shall be spaces (20H).

The Volume Identifier for a File-Set ID consisting of zero characters shall consist of all spaces (20H).

Notes: 1. The character set for File IDs and File-set IDs (see PS 3.10) is a subset of the ISO 9660 character set, therefore no further restrictions need to be imposed.

2. Multiple ISO 9660 File-Sets on a single volume are achievable, but this profile does not support multiple file-sets.

F.1.2 DICOM file ID mapping

The ISO 9660 standard provides a hierarchical structure for directories and files within directories. Each volume has a root directory that may contain references to both files and subdirectories. Subdirectories may contain reference to both files and other subdirectories.

F.1.2.1 FILE ID

A volume may have at most 8 levels of directories, where the root directory is defined as level 1. The nomenclature for referring to a file in the ISO 9660 standard is dependent upon the receiving system. For the purposes of this document, the following notation will be used:

a) / – For the root directory
b) /FILENAME.;1 – For a file in the root directory
c) /SUBDIR – For a subdirectory in the root directory
d) /SUBDIR/FILENAME.;1 – For a file in the subdirectory

Given a File ID consisting of N components, referred to as Comp1 through CompN, then the corresponding ISO 9660 file shall be named /Comp1/.../CompN.;1

The ISO 9660 File Name Extension shall not be used.

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The ISO 9660 standard requires the two separators "." and ";" to demarcate a "File Name Extension" and a "Version Number". To remain compatible with the ISO standard, the version number shall be 1.

Notes: 1. The above specified file ID mapping corresponds to ISO 9660 Level 1 compliance. This ensures the greatest level of compatibility across receiving systems.

2. The following is an example of the DICOM to ISO 9660 file mapping:

DICOM File ID	ISO 9660 File Name
DICOMDIR	/DICOMDIR.;1
SUBDIRA\IMAGE1	/SUBDIRA/IMAGE1.;1

F.1.2.2 DICOMDIR FILE

A DICOMDIR file in a DICOM File-set shall reside in the root directory of the directory hierarchy, and shall be named /DICOMDIR.;1.

Multiple DICOMDIR files shall not be stored on a single volume under this annex.

F.1.3 DICOM file management information

A Directory record in ISO 9660 provides for a Recording Data and Time field which shall be set to the creation date of the file.

File modification data, file owner identification, and permissions are part of the ISO 9660 - Extended Attribute Record. The Extended Attribute Record is not required by this annex and shall be ignored at this time. To ensure future backwards compatibility and file accessibility, the Extended Attribute Record Length and File Flag of the Directory record shall be set as follows for each file. The Extended Attribute Record Length (byte position 2) shall be zero. The File Flags (byte position 26) shall have bit positions 3 and 4 set to zero.

F.2 MEDIA FORMATS

F.2.1 Physical format

The physical format of DICOM CD-R discs shall comply with the applicable definitions within ISO/IEC 10149, Part II: CD-WO in Orange Book and CD-ROM-XA (extended Architecture), with the additional modifications described in sections F.2.1.1 and F.2.1.2.

F.2.1.1 SECTOR FORMAT

All DICOM files and all data that comprise the ISO 9660 file system of the DICOM CD-R disc shall be stored within Mode 2, Form 1 sectors with CD-ROM-XA File Number = 0, Channel Number = 0 and Coding Information Byte = 0.

F.2.1.2 MULTI-SESSION FORMAT

An area on the disc consisting of a Lead-In area, a Program area, and a Lead-Out area, is called a "Session." If a disc contains or is able to contain more than one session then this disc is called a "Multi-session" disk. If the Lead-In area contains a pointer to the next session, then the disc is appendable. The Lead-In and Lead-Out areas are written at the conclusion of writing the program Area. The process of writing the Lead-In and Lead-Out areas is commonly referred to as "Finalizing the Session." The last recorded session contains all the information needed to access the entire disc.

DICOM CD-R disc may contain multiple sessions. Data are added to a disc by opening and writing a new session. A disc is non-appendable if the last recorded session is designated as the "Final Session," as defined in Part II: CD-WO version 2.0, Section 5.5.2.

CD-ROM readers shall support Multi-session CDs.

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CD-R writers may choose to support Multi-session writing.

F.2.2 Logical format

The logical format of CD-R shall conform to ISO 9660 level 1, with the extensions described in sections F.2.2.1 through F.2.2.2

F.2.2.1 SYSTEM IDENTIFIER FIELD

The ISO 9660 System Identifier Field of the PVD (Primary Volume Descriptor) shall contain "CD-RTOS CD-BRIDGE" if a CD-I (Compact Disc-Interactive) application is present. If a CD-I application is not present, then this field shall be padded with space characters.

F.2.2.2 SYSTEM AND VOLUME DESCRIPTOR AREA

The ISO 9660 System and Volume Descriptor Area (SVD) from the last session points to the set of ISO 9660 Path Tables and Directory Records that describes the file system of the DICOM CD-R disc. The SVD area starts at the first logical sector of each session and continues through to the first instance of the Volume Descriptor Set Terminator.

Adding, replacing or deleting files from the disc is accomplished by opening a new session and writing within the new session new data (if any), a new set of Path Tables, and Directory Records that reflect the changes, and an SVD area that points to the new set of Path Tables and Directory records.

F.3 PHYSICAL MEDIA

The physical medium shall be the 120 mm CD-R disc as defined in Part II: CD-WO Version 2.0 in the Orange Book.

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