# INFORMATION TRANSFER FROM BEAM DATA ACQUISITION SYSTEMS

**Report of Task Group 11**
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## ABSTRACT

This document specifies a formalism for data transfer between beam data acquisition systems and radiotherapy treatment planning systems. In this protocol, all machine and data acquisition parameters are defined as either static or dynamic, thus allowing for flexibility in the method of beam data acquisition. Furthermore, the protocol accommodates expansion and ongoing developments, such as dynamic therapy. To allow for this expansion, a format is used which employs keyword-value strings in which the keyword defines the meaning of data following it. New keywords can be added as required. Wherever possible, all keywords and definitions are defined in a manner consistent with the International Electrotechnical Commission. For ease of transfer and end-user inspection, these keyword-value strings are transferred in ASCII format. This simple formalism should allow for straightforward implementation, and hopefully encourage support by the manufacturing community.

## I. INTRODUCTION

The increased functionality of computer controlled treatment machines allows the use of complex treatment techniques that require the setting and control of a large number of machine parameters. Therefore, substantial amounts of data must be transferred among different equipment. Recent advances in electronic communication have allowed for much of this information to be transferred digitally. To fully utilize this technology, users need the ability to purchase equipment from different manufacturers and be assured that digital communication among these units can be achieved in a seamless fashion.

This document addresses the data that need to be transmitted between the beam data acquisition systems and radiotherapy treatment planning systems; therefore, it includes only the data items essential for data acquisition with radiotherapy equipment. This protocol should accommodate future additions of equipment supplied by various manufacturers. Furthermore, it should accommodate expansion and ongoing developments, such as dynamic therapy. To allow for this expansion, a format is used which employs keyword-value strings in which the keyword defines the meaning of data following it. New keywords can be added as required.

Manufacturers may use their own interchange methodology and may display data in a format acceptable to a given radiotherapy facility. It is expected, however, that each vendor will provide a gateway for appropriate flow of data between his equipment and the equipment supplied by another manufacturer.

## II. DESIGNATION OF COORDINATE SYSTEM AND EQUIPMENT MOVEMENTS

It is expected that all data will be transferred in a manner consistent with the coordinate systems defined by the International Electrotechnical Commission (IEC). For a complete description of the IEC's radiotherapy coordinate systems, the reader is referred to IEC document

1217 (1), and only a brief description is provided here. The IEC defines an individual coordinate system for each major portion of the treatment machine that can be potentially moved in relation to one another. Each major portion is defined with respect to its own coordinate system. In addition, a fixed or "world" coordinate system is defined. The major coordinate systems defined by the IEC are shown in Figure 1. As seen in the figure, all coordinate systems are right-handed Cartesian systems. Wherever possible, equipment movements will be stated in the fixed coordinate system, which is defined by a horizontal coordinate axis Xf directed to the viewer's right when facing the gantry, a horizontal coordinate axis Yf directed from the isocenter toward the gantry, and a vertical coordinate axis Zf directed upwards from the isocenter. Other coordinate systems defined by the IEC are designed to rotate with a portion of the machine, and thus remain stationary relative to the rotating components of the treatment machine. For example, the gantry coordinate system, which is defined by the coordinate axes Xg, Yg, and Zg, rotates with the gantry. Similarly the beam limiting device coordinate system, which is defined by the coordinate axes Xb, Yb, and Zb, rotates with the machine collimator.

Relevant equipment movement designations are listed in Table 1, and shown graphically in Figures 2 and 3, which were adapted from IEC 1217. These equipment designations are also related to the keywords used for transfer of data between beam data acquisition systems and treatment planning systems. Axes (1), (4), and (5) refer to the rotation of the gantry, collimator, and patient support unit, respectively. The gantry rotation is equal to zero when the radiation beam axis is directed vertically downward and passes through the isocenter. The gantry increases from 0° to 359° with clockwise rotation of the gantry as viewed from the isocenter. Axis (4), which corresponds to collimator rotation, is zero when the Y1 and Y2 edges are perpendicular to the gantry rotation axis. The collimator angle increases from 0° to 359° with counter-clockwise rotation of the collimator as viewed from the radiation source. Axis (5), which corresponds to rotation of the patient support unit, increases from 0° to 359° with counter-clockwise rotation as viewed from above.

Dimension (14) and Dimension (15) refer to the radiation field size in the FX and FY directions, respectively. The FX axis is perpendicular to the gantry rotation axis and the FY axis is parallel to the gantry rotation axis when the collimator rotation (Axis (4)) is set to zero. Directions (20) through (23) allow for definition of asymmetric field sizes, and correspond to jaw designations X1, X2, Y1, and Y2. When facing the gantry (assuming the collimator is at its home position), X2 is on the right side of X1, and Y2 is on the gantry side of Y1.

If multileaf collimator (multi-element beam limiting device, in IEC nomenclature) parameters are transferred, the edge of each element is to be labeled by element numbers X101 to X1N, X201 to X2N, Y101 to Y1N, and Y201 to Y2N (where N indicates the number of multi-elements along one field edge). The X element labels increase from X101 to X1N (and X201 to X2N) toward the gantry. Similarly, the Y element labels increase from left to right as the viewer faces the gantry.

Direction (24), Direction (25), and Direction (26) specify the dosimetry probe displacements in the xf, yf, and zy directions of the fixed IEC coordinate system shown in Figure 1. All three have zero values when the probe is at isocenter. Direction (24) is increasing positive directed to the viewer's right when facing the gantry, Direction (25) is increasing positive from the isocenter toward the gantry, and a Direction (26) is increasing positive from the isocenter toward the radiation source.

## III. DATA FILE FORMATS

To provide for scan data transfer a system of coordinates and keywords has been adopted. Such a system exists within the International Electrotechnical Commission (IEC) framework.

Specifically, IEC Document 1217 provides a coordinate system that allows a user to specify the exact orientation of a teletherapy unit and provides a coordinate system for detailing the position of specific measurement points around the teletherapy beam. This document contains a table of keywords (Table 1 page 31). The pertinent keyword definitions from IEC 1217 are reproduced in Table 1 of this report. In conjunction with other keywords defined in this protocol and listed in Table 2, this keyword system enables a simple protocol to be established and adopted for use in transferring the specification of conditions under which scanned data has been obtained. The use of these keywords uniquely identifies the data scanned and the conditions under which that scan was obtained. The actual transfer process, whether it is via disk, tape or electronic, is not a part of this protocol. Neither is the naming convention of the files that contains the scanned data. Each manufacturer is responsible for providing the protocol specifications that will allow the user to carry out the transfer process.

Keywords and their explanations (i.e. to designate the probe position and reading) are listed in Table 2. Units of measure are not explicitly stated, and the following default units are to be utilized for the transferred data.

Geometric Parameters:

| | |
|---|---|
| Linear | centimeters |
| Rotational | degrees |
| Energy | MeV |
| Dose | Gy |

It is anticipated that dosimetry measurements will most often be transferred as normalized values, and will require no units. A keyword, *units*, is provided, however, to allow transfer of either ionization or dose values.

The transfer language supports three distinct data types: VALUE, NATURAL, ENUM, which are defined as follows.

VALUE A generic data type that is used when the type of default attribute is dependent on the radiotherapy equipment parameter whose properties are being specified. The data transferred are any positive or negative floating-point number.

NATURAL The set of natural numbers, i.e. whole numbers greater than 0.

ENUM A set of discrete enumerated values, e.g. (yes, no).

It is often desirable to examine scan data either before or after the transfer process. For this reason all data files will be in ASCII format and all transfers will be ASCII transfers. If a manufacturer desires to produce a proprietary transfer system that is utilized within their own scanners, linear accelerators, and treatment planning systems they are free to do so. This protocol is intended to provide a common specification for users who must transfer data between different vendors. However, it is hoped that all vendors will adopt the same protocol thus allowing for less confusion during the data transfer process.

This protocol defines the scan data into static and dynamic data. Static data, or the static parameters, describe the linear accelerator, dosimetry probe, and phantom settings that remain fixed during the scan process, while the dynamic parameters are those that vary during the scan process. The ASCII files will be organized with the static parameters grouped in the beginning of the file and the dynamic parameters to follow. The labels STATIC_PARAMETERS and DYNAMIC_PARAMETERS will indicate these groupings. Within each grouping of static and dynamic parameters, the order in which keywords are listed is not required to follow a specific format. Furthermore, all keywords are case insensitive; it is recommended, however, that upper and lower case not be mixed within a given keyword since not all programming languages can handle mixed cases. For static parameters, each line of data represents a keyword-value string. The data is presented in a two-column set. The first column lists the static keyword. Each data value is white space separated from its keyword, and a carriage return is inserted at the end of the line. For ease of inspection of the ASCII files, the dynamic parameters are organized as a two line set. The first line lists the dynamic parameters. These parameters are white space separated, and a carriage return is inserted at the end of the line. The second line of each pair contains numeric data. Each data item is white space separated and a carriage return is inserted at the end of the line. An end data marker signifies the end of the file.

For ease of implementation, two different file types will be supported. The keyword *file_type* allows for the selection of either file type 1 or file type 2. File type 1 has a fixed format that will allow straightforward transfer of the majority of current scan files. A list of the required keywords for file_type 1 is shown in table 3. All linear accelerator parameters will be assumed static, and the only allowed dynamic parameters (which are required to always be listed as dynamic), are the source-to-surface distance (keyword *SSD*) and the dosimetry probe position and reading (keywords *Xp*, *Yp*, *Zp*, *field)*. While it is anticipated that only normalized data will be transferred between scanners and planning systems, a keyword defining a reference reading has been added to the table in the event such a data item is needed or desired. A sample file_type 1 is shown in figure 4. This example illustrates that file format for a simple percent depth dose scan of a 6 MV x-ray beam using no wedges, blocks, or multi-element field defining devices. The gantry, beam-limiting device (collimator), and patient support unit are all at their home positions. A symmetric 10x10 $cm^2$ field size is set (FX = FY = 10 cm, X1 = X2 = Y1=Y2 = 5 cm). The source-to surface distance is set to 100 cm, and the probe remains on the beam central axis (Xp = Yp = 0). The source-to-image distance is 100 cm. The only changing parameters are Zp, and the dosimetry readings. The depth of the probe can be calculated as depth = SID – (SSD + Zp). Note in the example that, although Xp, Yp, and SSD have static values, they are all defined as dynamic parameters and a value must be provided for each measurement point. Although this is cumbersome, the rigid generic format of file type 1 allows manufacturers to quickly implement a simple transfer file format. Furthermore, these six dynamic parameters allow the manufacturers to support the most common scan types obtained today. These include any scan in which the linac parameters remain constant while the scanning probe and/or phantom change, such as percent-depth-dose, cross-plots, diagonal scans, and tissue-phantom-ratio scans.

File type 2 is more complex to implement, because it allows for a more free form of the file. File type 2 requires the same keywords as listed in Table 2, but there are no explicit requirements for a parameter to be either static or dynamic. File type 2 allows for any linac parameter to be changed, and is therefore general enough to allow for the transfer of any scan data currently obtainable. For example, if a simple depth dose scan is obtained, all linac coordinates can be defined as static parameters. These include gantry angle, collimator settings, wedge settings, and phantom settings. The only dynamic parameters are the distance of the probe from the isocenter and the reading at each probe position. For other scanning situations, such as data acquisition for a dynamic wedge, the dynamic parameter may be the movement of a secondary jaw while the probe reading will actually be a static integrated reading. Alternatively, this measurement could be with multiple detectors, as in a diode or chamber array. Each of these detectors may have separate positions and readings that may be considered dynamic parameters, and the measurement would actually be the integration of the reading over the whole movement of the jaw. Field size dependence measurements can also be transferred using file type 2, because the data acquisition requires dynamic movement of the linear accelerator jaws between datum point acquisitions. In this case, the jaws could all be considered static parameters. There are no requirements regarding the number of dynamic parameters that can be specified for each line of data. Figure 5 shows an example type 2 file for transfer of total scatter factor measurements. In this example, the probe remains stationary at the isocenter and a depth of 5 cm in water, while the field size changes symmetrically from 4x4 to 40x40 cm.

In example 2 note that, while the keywords shown in table 3 are required, no specific dynamic or static parameters are necessarily required. It is not required that all keywords be used in each file. It is anticipated that manufacturers will sort the files based on keyword-value strings, and expect neither a specific number nor a specific order of these strings. Including more descriptive keywords is useful in labeling the type of scan obtained and the specific conditions under which the data were obtained. Alternatively, this labeling could be accomplished using the free-form *comment* keyword. Again, limiting the number of keywords transferred increases the ambiguity of the transferred file.

For both file types, data from multiple scan acquisitions can be included in one file. For each new set of data, a new *file_type* keyword should be entered. This is to be followed by other descriptive keywords for this scan data, and then the data values. For any keywords that are not re-entered, it is assumed that the parameters remain the same as for the first set of scan data. The file will be continued until the *end data* marker is reached.

## IV. CONCLUSION

A formalism has been introduced for data transfer between beam data acquisition systems and treatment planning systems. The formalism employs keyword-data strings transferred in ASCII format. The keywords and coordinate systems were selected to be consistent with IEC conventions. Two separate file formats are supported by the formalism. The first provides a mechanism for straightforward implementation by equipment manufacturers, while the second format is more flexible and provides a mechanism for transferring new data formats as required by both physicists and manufacturers. It is hoped that employing such a strategy will encourage quick and ongoing support of the standard by manufacturing community.

**REFERENCES**

1. International Electrotechnical Commission. IEC1217: Radiotherapy equipment-Coordinates, movements and scales, 1996.

***Table 1 - EQUIPMENT movements and designations*** – The data keywords that are IEC defined words are listed in italics here. Directions 24, 25, and 26 are not IEC defined keywords, but were defined here to account for the dosimetry probe motion. The numbers correspond to the labels in Figures 2 and 3. All of these parameters may be defined as either static or dynamic parameters.

| Figure Label | Description using IEC keywords |
|---|---|
| Axis (1) | Rotation of *gantry* |
| Axis (4) | Rotation of the *beam limiting device* (collimator) |
| Axis (5) | Isocentric rotation of the *patient support* |
| Dimension (14) | Dimension *FX* of the radiation field in the Xb direction at a specified distance from the radiation source (usually at the normal treatment distance) |
| Dimension (15) | Dimension *FY* of the radiation field in the Yb direction at a specified distance from the radiation source (usually at the normal treatment distance) |
| Direction (20) | Displacement from radiation beam axis to radiation field edge *Xl* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Direction (21) | Displacement from radiation beam axis to radiation field edge *X2* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Direction (22) | Displacement from radiation beam axis to radiation field edge *Y1* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Direction (23) | Displacement from radiation beam axis to radiation field edge *Y2* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Direction (24) | Displacement from radiation beam isocenter to dosimetry probe in the *Xf* direction (Figure 1). |
| Direction (25) | Displacement from radiation beam isocenter to dosimetry probe in the *Yf* direction. |
| Direction (26) | Displacement from radiation beam isocenter to dosimetry probe in the *Zf* direction (Figure 1). |
| Dimension (28) | Distance from radiation source to the phantom surface (i.e., source-to-surface-distance, SSD). |

***Table 2 – Keyword definitions***: Relevant keywords with their data type and description.

| Keyword | Data Type | Description |
|---|---|---|
| file_type | ENUM(1, 2) | Files of type 1 have a fixed form, while files of type 2 may have a free form to accommodate future innovations. |
| institution | | Name of hospital or institution where measurement was obtained. |
| treatment_ unit | | Name of treatment unit on which measurement was obtained |
| Date | | Date stamp indicating the date that dosimetry data were obtained. Should be in the format YYYYMMDD. |
| Scan_type | ENUM(pdd, tpr, cross_plot, diagonal, isodose, fanline, other) | Type of scan to be obtained. |
| comment | | The comment keyword indicates a free-form comment line. |
| medium | ENUM(water, air, plastic, other) | Medium in which measurement is obtained |
| modality | ENUM (x-rays, electrons, protons) | Type of radiation |
| energy | NATURAL | Energy (MeV) of radiation |
| SID | NATURAL | Source to isocenter distance |
| detector | ENUM (Chamber, Diode, Film, TLD, other) | Type of radiation detector used to make measurement. |
| units | ENUM (dose, ionization, relative) | Quantity of measurement being transferred. Dose values are to be transferred in Gy, ionization measurements are to be transferred in C, and relative measurements are assumed normalized to some value and have no units. |
| wedgea | ENUM (in,out) | An additional automatic filter affecting the attenuation across the radiation field collection |
| wedgem | ENUM (0,1,2,3,…) | An additional manual filter affecting the attenuation across the radiation field collection. 0 means no wedge |
| wedge_rot ation | NATURAL | Rotation of a manual wedge filter relative to the collimator coordinate system. |
| mlcx | NATURAL | A multileaf collimator affecting the shape of the radiation field along the Xb axis. The value indicates the number of multi-elements along one field edge in the Xb direction. 0 means no MLC. If a number other than 0 is input, the multi-element positions can be input X101 to X10N and X201 to X20N as described in section II. |

| | | |
|---|---|---|
| mlcy | NATURAL | A multileaf collimator affecting the shape of the radiation field along the Yb axis. The value indicates the number of multi-elements along one field edge in the Yb direction. 0 means no MLC. If a number other than 0 is input, the multi-element positions can be input Y101 to Y10N and Y201 to Y20N as described in section II. |
| comp | ENUM (yes, no) | An additional manual compensator modulating the radiation field collection. |
| applicator | ENUM (0,1,2..) | An additional applicator (cone) for electron fields. 0 means no applicator. |
| insert | ENUM (0,1,2,…) | An additional insert used specifically with electron applicators. 0 means no insert. |
| gantry | VALUE | Rotation of *gantry* |
| diarot | VALUE | Rotation of the *beam limiting device* (collimator) |
| tabroti | VALUE | Isocentric rotation of the *patient support* |
| FX | VALUE | Dimension *FX* of the radiation field in the Xb direction at a specified distance from the radiation source (usually at the normal treatment distance) |
| FY | VALUE | Dimension *FY* of the radiation field in the Yb direction at a specified distance from the radiation source (usually at the normal treatment distance) |
| X1 | VALUE | Displacement from radiation beam axis to radiation field edge *Xl* at a specified distance from the radiation source (usually at the normal treatment distance) |
| X2 | VALUE | Displacement from radiation beam axis to radiation field edge *X2* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Y1 | VALUE | Displacement from radiation beam axis to radiation field edge *Y1* at a specified distance from the radiation source (usually at the normal treatment distance) |
| Y2 | VALUE | Displacement from radiation beam axis to radiation field edge *Y2* at a specified distance from the radiation source (usually at the normal treatment distance) |
| bFX | VALUE | Blocked field size in the Xb direction. |
| bFY | VALUE | Blocked field size in the Yb direction. |
| Irreg | NATURAL | Number of vertices to be specified in description of irregular field shape. 0 means no irregular field. If a number n other than 0 is input, then a stream of n comma delimited x, y coordinates (in the beam limiting device coordinate system) that describe the vertices will be listed directly following the irreg keyword and specification. |
| Xp | VALUE | Displacement from radiation beam axis to dosimetry probe in the *Xf* direction. If the data transferred are ionization measurements converted to dose, it is assumed that this value will reflect the actual dose point and not the physical probe position. |

| | | |
|---|---|---|
| Yp | VALUE | Displacement from radiation beam axis to dosimetry probe in the *Yf* direction. If the data transferred are ionization measurements converted to dose, it is assumed that this value will reflect the actual dose point and not the physical probe position. |
| Zp | VALUE | Displacement from radiation beam axis (isocenter) to dosimetry probe in the *Zf* direction. If the data transferred are ionization measurements converted to dose, it is assumed that this value will reflect the actual dose point and not the physical probe position. |
| thickness | VALUE | Thickness of phantom material between radiation source and detector (i.e. for narrow-beam attenuation measurements) |
| SSD | VALUE | Distance from radiation source to the phantom surface (i.e., source-to-surface-distance, *SSD*). |
| field | VALUE | The field dosimetry measurement |
| reference | VALUE | The reference dosimetry measurement |

Table 3: Required keywords for both file types. While other keywords may be included, this basic set is mandatory. The parameters are required to be either static or dynamic as listed in the table below for file type 1. File type 2 allows flexibility in parameter type designation.

| Keyword | Parameter type |
|---|---|
| File_type | Static |
| Scan_type | Static |
| Modality | Static |
| Energy | Static |
| SID | Static |
| Wedgea | Static |
| Wedgem | Static |
| Gantry | Static |
| Diarot | Static |
| FX | Static |
| FY | Static |
| Xp | Dynamic |
| Yp | Dynamic |
| Zp | Dynamic |
| SSD | Dynamic |
| Field | Dynamic |
| Reference | Dynamic |
| | |
| | |

**FIGURE LEGENDS**

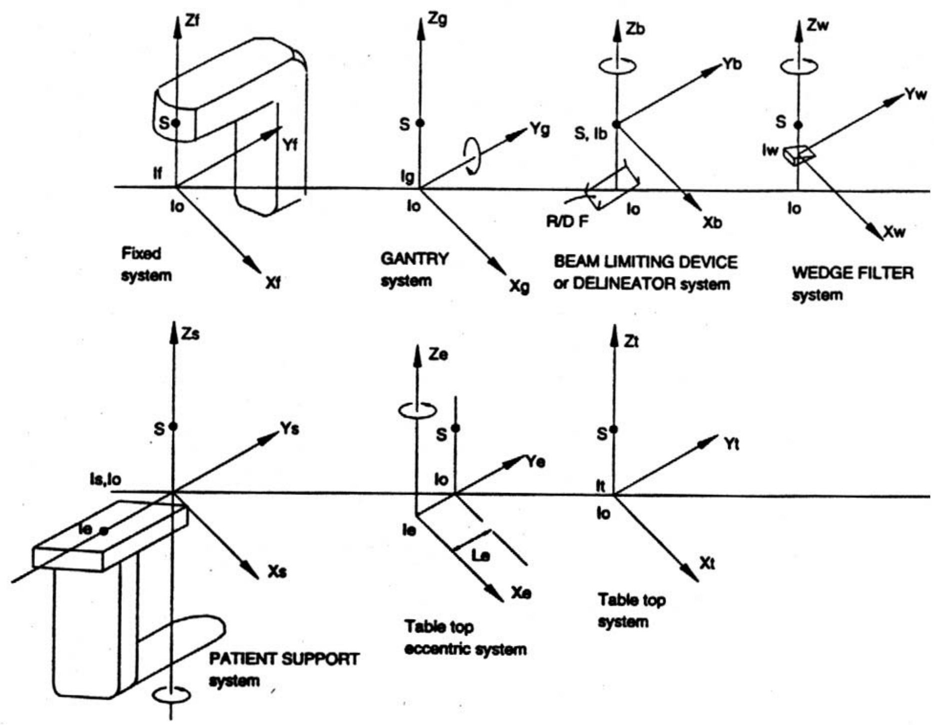
**Fig. 1** Description of IEC coordinate systems with all angular positions set to zero. Wherever practical, data should be stated in the fixed coordinate system. Figure adapted from IEC document 1217 (1).

**Fig. 2** Description of equipment designations and movements. All numbers in the figure are related back to the descriptions in Table 1. Figure adapted from IEC document 1217 (1).

**Fig. 3** Description of the beam limiting device designations and movements. Again, all numbers are related back to the descriptions in Table 1. The view is from the beam's-eye-view. Figure adapted from IEC document 1217 (1).

**Fig 4** Example 1: Example of a percent depth dose scan transferred using a file_type 1 format.

**Fig 5** Example 2: Example of total scatter factors transferred using a file_type 2 format.




S = Radiation source

Io = Isocentre

R/D F = Radiation field or delineated radiation field

Figure 1.

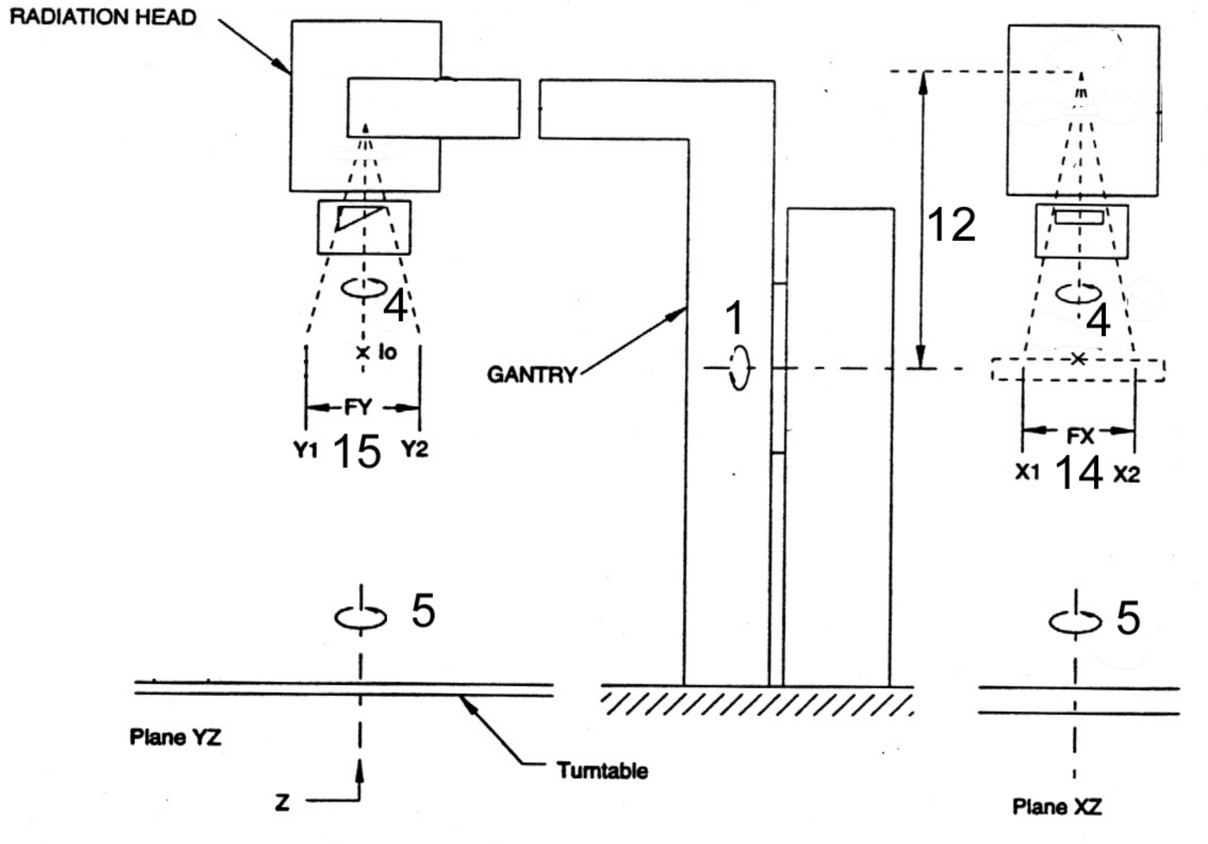

RADIATION HEAD
12
4
1
4
× Io
GANTRY
FY
Y1 15 Y2
FX
X1 14 X2
5
5
Plane YZ
Turntable
Z
Plane XZ

Figure 2.

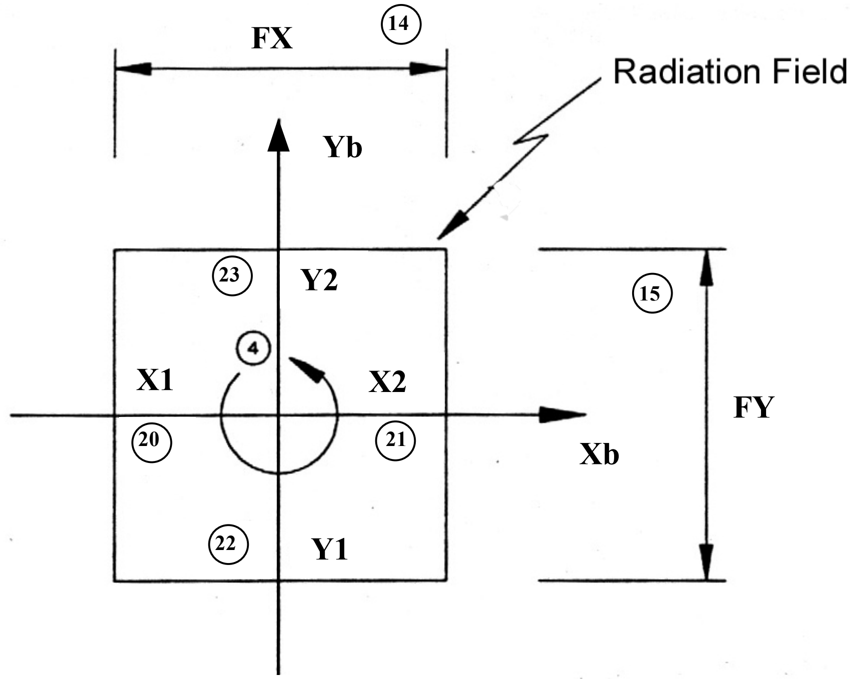



Figure 3.

Figure 4

STATIC_PARAMETERS

| | |
|---|---|
| file_type | 1 |
| scan_type | pdd |
| medium | water |
| comment | this is an example of a file for a percent depth dose scan |
| detector | chamber |
| Modality | x-rays |
| Energy | 6 |
| SID | 100 |
| WedgeA | 0 |
| WedgeM | 0 |
| Irreg | 0 |
| MLCX | 0 |
| MLCY | 0 |
| Comp | 0 |
| gantry | 0 |
| DiaRot | 0 |
| TabRotI | 0 |
| FX | 10 |
| FY | 10 |
| X1 | 5 |
| X2 | 5 |
| Y1 | 5 |
| Y2 | 5 |

DYNAMIC_PARAMETERS

| Xp | Yp | Zp | SSD | field | reference |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 100 | 125 | 345 |
| 0 | 0 | -0.5 | 100 | 130 | 344 |
| 0 | 0 | -1.0 | 100 | 145 | 345 |
| 0 | 0 | -1.5 | 100 | 140 | 344 |
| 0 | 0 | -2.0 | 100 | 138 | 345 |
| 0 | 0 | -2.5 | 100 | 136 | 355 |

…

…

end data

Figure 5

STATIC_PARAMETERS

| | |
|---|---|
| file_type | 2 |
| scan_type | other |
| medium | water |
| comment | this is an example of a file for total scatter factors obtained in water |
| detector | chamber |
| Modality | x-rays |
| Energy | 6 |
| SID | 100 |
| WedgeA | 0 |
| WedgeM | 0 |
| gantry | 0 |
| DiaRot | 0 |
| Xp | 0 |
| Yp | 0 |
| Zp | 0 |
| SSD | 95 |
| reference | 1.0 |

DYNAMIC_PARAMETERS

| FX | FY | field |
|---|---|---|
| 4 | 4 | 0.915 |
| 5 | 5 | 0.940 |
| 6 | 6 | 0.957 |
| 7 | 7 | 0.971 |
| 8 | 8 | 0.982 |
| 9 | 9 | 0.991 |
| 10 | 10 | 1.000 |
| 11 | 11 | 1.007 |
| 12 | 12 | 1.014 |
| 13 | 13 | 1.020 |
| 14 | 14 | 1.026 |
| 15 | 15 | 1.030 |
| 16 | 16 | 1.035 |
| 17 | 17 | 1.039 |
| 18 | 18 | 1.043 |
| 19 | 19 | 1.048 |
| 20 | 20 | 1.052 |
| 25 | 25 | 1.068 |
| 30 | 30 | 1.079 |
| 35 | 35 | 1.088 |
| 40 | 40 | 1.089 |

end data