BreastAGD282 – SOFTWARE USER'S GUIDE

Joint AAPM Task Group 282/EFOMP Working Group Software: Breast dosimetry for standard and contrast-enhanced mammography and breast tomosynthesis

UG.1. General program information

The software program accompanying this document performs the calculations needed to estimate D_g for one or various breast exposures performed during acquisition of any of four different imaging modalities: digital mammography (DM), contrast-enhanced DM (CEDM), digital breast tomosynthesis (DBT), and CEDBT as specified in the *Joint AAPM Task Group 282/ EFOMP Working Group Report: Breast dosimetry for standard and contrast-enhanced mammography and breast tomosynthesis* (from now on denoted the Report).

The software runs in text-based interactive mode, TOML-format input file mode, CSV-format input file batch mode, or with a graphical user interface (GUI), and is available for Windows, Mac, and Linux operating systems (no GUI available for Linux). All four modes are explained below. The functions performed by the program are the same in all modes, although when used with input files, several dosimetry calculations can be done with one execution.

In addition, with TOML input files, DBT/CEDBT modes allow for the projection angles to be irregularly spaced and a variable tube current-exposure time product across projections to be specified. CSV input files also allow for the latter. In interactive mode, only a regular distribution of projection angles, symmetric about 0°, with constant tube output setting at each projection is allowed. Finally, in interactive mode, the number of dose estimations is limited to only a single breast or to the sets of *standard breasts*, as listed in Tables UG.2, UG.3, and UG.4, below.

UG.2. Program inputs

Table UG.1 summarizes the inputs to the program, their format, and valid ranges. All inputs to the program, in all modes, follow the same rules:

- Text input can be uppercase or lowercase.
- Yes/No inputs should be entered as Y or N (or their lowercase variants).
- In interactive mode, pressing enter with no input results in the use of the default value.

Table UG.1. Summary of inputs to the dosimetry software program, with specification of the format required, units used, and valid ranges, and the parameter names for the TOML file input (see Chapter UG.4).

Input	TOML parameter name	Unit	Format	Valid Range
Breast model	`[breast]`			
#Breast model set	`model`	-	Text	(default) standard, EU, US, none
Breast view	`view`	-	Text	CC (default) or MLO
*Breast thickness	`thickness`	mm	Integer	15 – 120
*Volumetric breast density percentile	`density_percentile`	-	Integer	5, 25, 50 (default), 75, or 95
*¶Volumetric breast density percentage	`density_percentage`	%	Integer	1 – varies by thickness (see Figure 2)
##Process pairs of breast thicknesses and densities	`pair_thickness_density`	-	Boolean	True/False
Acquisition	`[acquisitions]`			
Modality	`modality`	-	Text	DM (default), DBT, CEDM, or CEDBT
Source to dosimeter distance, l_m	`source_to_dosimeter`	mm	Integer	> 0
Source to breast support table distance, l_t	`source_to_table`	mm	Integer	> 0
DBT/CEDBT projection angle range	`angle_range`	deg	Decimal	≥ 0.0 to ≤ 60.0
§DBT/CEDBT number of projection angles	`number_angles`	-	Integer	≥ 1
†§DBT/CEDBT specific projection angles	`angle`	deg	Decimal	-30.0 – +30.0
†§DBT/CEDBT relative variation in tube current-exposure time product across projections	`dose_distribution`	-	Decimal	≥ 0.0
Spectrum model (in case of CE imaging, both low- and high-energy)	`[spectrum]` and `[high_spectrum]`			
Anode material	`anode`	-	Text	Mo, Rh, or W
Tube voltage	`voltage`	kV	Integer	20 – 49
‡Filter elements	`filter.element`	-	Text	Any chemical element symbol
‡Filter thicknesses	`filter.thickness`	mm	Decimal	> 0.0
Adjust spectrum model to 1st HVL	`specify_hvl`	-	Boolean	True/False
1st Half value layer	`hvl`	mm Al	Decimal	> 0.0
Measured air kerma, K_m	`air_kerma`	mGy	Decimal	> 0.0

[#]If either the standard, EU, or US breast model set is input, then no other input for breast model is needed.
*Multiple values for these inputs can be specified in input-file mode.
[¶]Only available when "none" is selected as breast model
[§]If provided, the number of inputs for the exposure variation with projection angle must match the number of projection angles.
[†]Inputs available in input-file mode only.
[‡]The number of inputs for filter element and thickness is unlimited, but they must be the same for these two inputs.
[##]If set to True, then an equal number of breast thicknesses and densities must be specified, and the program will process each pair of these inputs. If set to False, then all combinations of input thicknesses and densities will be processed.

As specified in Table UG.1, the software can estimate the breast glandular dose to any user-specified breast model or to three different pre-defined sets of breast models. The recommended breast model set is the *standard* breast model developed by the joint TG/WG, as described in the Report, and listed in Table UG.2.

Table UG.2. List of *standard* breasts in the population-based breast model by default evaluated by the dosimetry software program.

Breast thickness (mm)	20, 30, 40, 50, 60, 70, 80, 90
Volumetric breast density (percentile)	5^{th}, 25^{th}, 50^{th}, 75^{th}, 95^{th}

For legacy purposes, two other breast model sets are included, the EU model (Table UG.3) and the US model (Table UG.4).

Table UG.3. List of EU legacy model breasts based on the use of PMMA slabs possible evaluated by the dosimetry software program.

PMMA thickness (mm)	Equivalent breast thickness (mm)	Equivalent volumetric breast density (%)
20	21	44
30	32	39
40	45	26
45	53	19
50	60	13
60	75	6
70	90	3

Table UG.4. US legacy model breast based on the use of the American College of Radiology (ACR) Accreditation phantom evaluated by the dosimetry software program.

Equivalent breast thickness (mm)	Equivalent volumetric breast density (%)
42	35

In addition to these three breast model sets, any breast model can be specified by the user by specifying the compressed breast thickness and the volumetric breast density either in percentile or in percentage. To specify such a breast manually, *none* should be selected as the breast model to be used. Note that in batch processing (i.e., using a CSV input file) mode, only this manually-defined breast model is possible.

UG.3. Interactive mode

In interactive mode, the program is run from a terminal window, using the name of the program:

```
> BreastAGD282
```

as the single command. If executing correctly, the program will output the following:

```
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Specify breast model set to use (standard (default), EU, US or none):
```

The first prompt of the program is for which breast model set to use, if any, as listed in Tables UG.1-4. Regardless of the option chosen, the next prompt is to select a view, with either cranio-caudal (CC) or medio-lateral oblique (MLO) being possible:

```
Breast view (CC (default) or MLO):
```

If any of the pre-defined model sets (*standard, EU, or US)* was selected, then no further breast-related input is needed, and the program jumps to prompting about the modality to be processed (see below). Otherwise, the desired single breast thickness can be input:

```
Breast thickness in mm (15 – 120):
```

Next, the program asks if the user wants to specify the volumetric breast density by using one of the percentile densities, to be calculated by the program for the thickness entered, or a specific density percentage.

```
Specify volumetric breast density percentile? (Y (default) or N):
```

Depending on the selection made, one of the following queries is presented, and the desired single value should be input:

```
Volumetric breast density percentile (5, 25, 50 (default), 75, 95):
```

```
Volumetric breast density percentage (1 – 91):
```

Note that the maximum volumetric breast density in percentage that can be input will vary depending on the input breast thickness.

At this point the breast model is fully defined, and the acquisition modality needs to be specified. For this, the program prompt is:

```
Modality (DM (default)/DBT/CEDM/CEDBT):
```

If either of the two DBT modalities is chosen, the information on the projection angles is required. In interactive input mode, only a regular distribution of projection angles symmetric about 0° is allowed:

```
Number of angles:
```

```
Total angular range (deg):
```

The vertical distance from the source to the effective K_m measurement location, l_m, for use in Eq. *2*, and the distance from the source to the breast support table, l_t, for use in Eq. *3*, are input next. In most situations, the difference between these two values will be only a few mm, equivalent to the offset from the bottom of the dosimeter to its effective measurement location.

```
Distance from source to dosimeter (lm, mm):
```

```
Distance from source to breast support table (lt, mm):
```

At this point the breast model, modality, and acquisition geometry are fully defined, and the spectrum or spectra used need to be specified. If either of the two contrast-enhanced modalities was chosen, then the program loops over these prompts, once for the LE spectrum and once for the HE spectrum. Either order for the spectra is acceptable. First, the anode material and tube voltage need to be specified. Note that although it would be expected that the anode material would be the same for both acquisitions, this is not required:

```
Anode (Mo/Rh/W):
```

```
Tube voltage (kV):
```

Then the number of different elements of additional filtration is requested, and the program expects the input of the filter chemical element symbol and corresponding thickness, one by one. It is possible to repeat filter elements, and in this case the sum of the thicknesses input will be used.

```
Number of filters:
```

```
Filter element (e.g. Rh):
```

```
Filter thickness (mm):
```

As described previously, the spectrum model can be adjusted to match a measured HVL. This is recommended and the default behavior unless otherwise specified next. If the default option is chosen, then the measured HVL is requested next:

```
Specify a measured 1st half-value layer and adjust the model spectrum to match? (Y (default) or N):
```

```
1st half value layer (mm Al):
```

Finally, the measured K_m for this spectrum is input:

```
Measured air kerma (Km, mGy):
```

As mentioned previously, in the case of DBT or CEDBT, this K_m should be specified for the total tube current-exposure time product of the entire acquisition.

Below are two screen captures showing complete inputs and the resulting outputs for two different runs of the software.

The first run involves the estimation of the dose to the entire standard breast set for the CC view acquisition of digital mammography, with a spectrum model that is adjusted to fit a measured 1st half-value layer. The screen capture shows only a portion of the output, which actually consists of 40 lines of results (8 breast thicknesses * 5 breast densities). Since the spectrum model was adjusted to the measured 1st half-value layer, the added filtration thickness varied between the input (0.05 mm) and the one used by the program after HVL fitting (0.049 mm).

```
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Specify breast model set to use (standard (default), EU, US or none):
Breast view (CC (default) or MLO):
Modality (DM (default)/DBT/CEDM/CEDBT):
Distance from source to dosimeter (lm, mm): 665
Distance from source to breast support table (lt, mm): 670
Anode (Mo/Rh/W): W
Tube voltage (kV): 30
Number of filters: 1
Filter element (e.g. Rh): Rh
Filter thickness (mm): 0.05
Specify a measured 1st half-value layer and adjust the model spectrum to match? (Y (default) or N):
1st half value layer (mm Al): 0.438
Measured air kerma (Km, mGy): 1.2
Thickness   Vol. Density   Anode   Tube Voltage   Added Filtration    1st HVL     Gamma   Reference Air Kerma    Dg
  [mm]          [%]                     [kV]          [Z - mm]        [mm Al]   [mGy/mGy]        [mGy]          [mGy]
   20            10          W          30          Rh:0.049         0.438      0.288          2.188          0.630
   20            14          W          30          Rh:0.049         0.438      0.281          2.188          0.615
   20            18          W          30          Rh:0.049         0.438      0.274          2.188          0.599
   20            22          W          30          Rh:0.049         0.438      0.268          2.188          0.587
   20            28          W          30          Rh:0.049         0.438      0.264          2.188          0.577
   30            7           W          30          Rh:0.049         0.438      0.228          2.188          0.500
   30            10          W          30          Rh:0.049         0.438      0.224          2.188          0.489
   30            14          W          30          Rh:0.049         0.438      0.217          2.188          0.475
   30            19          W          30          Rh:0.049         0.438      0.209          2.188          0.458
   30            26          W          30          Rh:0.049         0.438      0.201          2.188          0.441
   40            5           W          30          Rh:0.049         0.438      0.185          2.188          0.404
   40            7           W          30          Rh:0.049         0.438      0.182          2.188          0.398
   40            10          W          30          Rh:0.049         0.438      0.179          2.188          0.391
   40            14          W          30          Rh:0.049         0.438      0.172          2.188          0.377
   40            23          W          30          Rh:0.049         0.438      0.160          2.188          0.351
   50            4           W          30          Rh:0.049         0.438      0.147          2.188          0.322
   50            5           W          30          Rh:0.049         0.438      0.146          2.188          0.320
   50            7           W          30          Rh:0.049         0.438      0.144          2.188          0.316
```

The second example run involves the estimation of the dose to a single breast in the MLO view during DBT, with a spectrum model that is not adjusted to a measured 1st half-value layer. In this case the added filtration thickness matches the input one.

```
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Specify breast model set to use (standard (default), EU, US or none): none
Breast view (CC (default) or MLO): MLO
Breast thickness in mm (15 - 120): 53
Specify volumetric breast density percentile? (Y (default) or N): Y
Volumetric breast density percentile (5, 25, 50 (default), 75, 95): 75
Modality (DM (default)/DBT/CEDM/CEDBT): DBT
Number of angles: 15
Total angular range (deg): 15
Distance from source to dosimeter (lm, mm): 665
Distance from source to breast support table (lt, mm): 670
Anode (Mo/Rh/W): W
Tube voltage (kV): 30
Number of filters: 1
Filter element (e.g. Rh): Al
Filter thickness (mm): 0.5
Specify a measured 1st half-value layer and adjust the model spectrum to match? (Y (default) or N): N
Measured air kerma (Km, mGy): 1.5
Thickness   Vol. Density   Anode   Tube Voltage   Added Filtration    1st HVL     Gamma   Reference Air Kerma    Dg
  [mm]          [%]                     [kV]          [Z - mm]        [mm Al]   [mGy/mGy]        [mGy]          [mGy]
   53            11          W          30          Al:0.500         0.339      0.111          2.736          0.305
```

UG.4. TOML Input file mode

In input file mode, all inputs to the program are written in a TOML-formatted (for more information on TOML files, see https://toml.io/en/) text file, which is then read in by the software from a terminal window, using the single command:

```
> BreastAGD282 <NAME OF TOML FILE>.toml
```

The TOML input file consists of three sections for DM and DBT estimations, while a fourth section, for the high-energy acquisition is included for CEDM/CEDBT. Each of these sections must be marked at the beginning with a line containing only the section name in square brackets. These sections describe the breast (“[breast]”), the acquisition geometry and technique used (“[acquisitions]”), the x-ray spectrum (“[spectrum]”), and, if applicable, the high-energy x-ray spectrum (“[high_spectrum]”), as listed in Table UG.1. After each section name, the parameters pertaining to that section are listed using the format:

```
<PARAMETER NAME> = <PARAMETER VALUE>
```

If the value is a text string, it must be enclosed in quotes (“”), while multiple numbers are listed as vectors in square brackets and separated by a comma. The parameter names are case sensitive and are all lower case, while the text string values are case insensitive. All section and parameter names are listed in Table UG.1 above. Any number of comments, in a line by themselves or after a parameter value, are allowed, when following a hash (“#”). The results of processing the TOML input file are saved to a CSV text file and, if there are 10 or fewer conditions evaluated, also displayed on screen.

The following is an example TOML input file, including various explanatory comments. Some parameters are commented out but are included to show the possibility to use them.

```
[breast]
#model = "none"                    # options are standard, EU, US, and none
view = "CC"                        # options are CC and MLO
thickness = [22, 53, 65]                   # mm
vbd_percentile = [5, 50, 95]
#vbd_percentage = [5]              # % fibroglandular tissue by mass

# if false, all combinations of thicknesses and densities below will be calculated
# if true, only corresponding pairs, in order, will be calculated
# if true, number of thicknesses and of densities must be equal
# default if missing is false
pair_thickness_density = true

[acquisitions]
modality = "DM"                    # options are DM, DBT, CEDM, and CEDBT
source_to_dosimeter = 640          # mm
source_to_table = 648              # mm
#angle_range = 45                  # degrees
#number_angles = 25
#angle = [-4.5, -2.2, 2.1, 4.4]    # degrees

#if dose_distribution is NOT defined then all projections are acquired at same mAs
#otherwise list relative mAs at each angle
#no need to normalize to 1
#dose_distribution = [1.0, 0.5, 0.5, 1.0]

[spectrum]
anode = "W"                        # options are W, Rh, and Mo
voltage = 29
filter.element = ["Rh"]            # number of filter elements and thicknesses must match
filter.thickness = [0.05]          # mm
specify_hvl = true                 # if true, then filter is adjusted to match input HVL to matched HVL

#if specify_hvl is true, then input HVL, otherwise ignored
hvl = 0.48                         # measured 1st HVL in mm Al
air_kerma = 5.355                  # mGy
```

This example file, included with the software, when run produces the following output:

```
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Calculating average glandular dose for 3 different condition(s) from file example_input.toml.
Saving output to file example_input.toml.out
Thickness   Vol. Density   Anode   Tube Voltage   Added Filtration    1st HVL     Gamma    Reference Air Kerma    Dg
  [mm]          [%]                    [kV]          [Z - mm]        [mm Al]   [mGy/mGy]         [mGy]          [mGy]
   22            10          W          29           Rh:0.059         0.480      0.311          9.046          2.812
   53            7           W          29           Rh:0.059         0.480      0.158          9.046          1.427
   65            13          W          29           Rh:0.059         0.480      0.117          9.046          1.055
```

UG.5. CSV File batch processing mode

In batch processing mode, all necessary inputs for a single run of the program are written in a single row of a comma-separated values (CSV) file. The file can consist of an unlimited number of rows to be processed, which will all be processed individually. This input mode only accepts manually specified breasts so that individual input file rows result in individual output file rows. The *standard*, *EU*, and *US* breast models can still be used by specifying each of the breast parameters listed in Tables UG.2, UG.3, or UG.4, respectively, in separate input file rows.

The CSV-formatted text file is read in by the software from a terminal window, using the single command:

```
> BreastAGD282 <NAME OF CSV FILE>.csv
```

Each row of the CSV file needs to specify the following parameters, in the order shown here, separated by commas, following the specifications of Table UG.1:

view
thickness
density_percentage
density_percentile
modality
number_angles
angle_range
source_to_dosimeter
source_to_table
spectrum_anode
spectrum_voltage
spectrum_filter_element (if multiple, within quotes: e.g., "Al, Rh")
spectrum_filter_thickness (if multiple, within quotes: e.g., "0.8, 0.05")
spectrum_hvl
spectrum_air_kerma
high_spectrum_anode
high_spectrum_voltage
high_spectrum_filter_element
high_spectrum_filter_thickness
high_spectrum_hvl
high_spectrum_air_kerma
dose_distribution (if provided, within quotes: e.g., “1.0, 0.75, 1.2, …”)

If an input is not applicable or is desired to be left blank, then the field can be skipped but the empty field for that input should remain, hence resulting in two commas (“,”) in a row. Any number of comment rows, denoted by starting with a “#”, can be included in the file.

The following is an example of a portion of an input CSV file.

```
#view, thickness, density_percentage, density_percentile, modality, number_angles, angle_range, source_to_dosimeter, so
CC,23,10,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,20,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,30,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,40,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,42,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,44,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,46,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,48,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,49,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,50,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,51,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,52,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,54,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,56,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,58,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,60,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,70,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,23,80,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,44,10,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,44,20,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3,,,,,,,
CC,44,30,,DM,,,620,630,W,32,"Al, Rh","0.8, 0.05",0.65,2.3
```

The results are written to a new CSV file, with each row containing the results of the processing of the corresponding input file. When running in batch mode, the output of the program is saved to file, and, if there are 50 or fewer conditions evaluated, also displayed on screen. The fields included in the output CSV file are:

Thickness [mm]
Vol. Density [%]
Anode
Tube Voltage [kV]
Added Filtration [Z - mm]
1st HVL [mm Al]
Gamma [mGy/mGy]
Reference Air Kerma [mGy]
Dg [mGy]

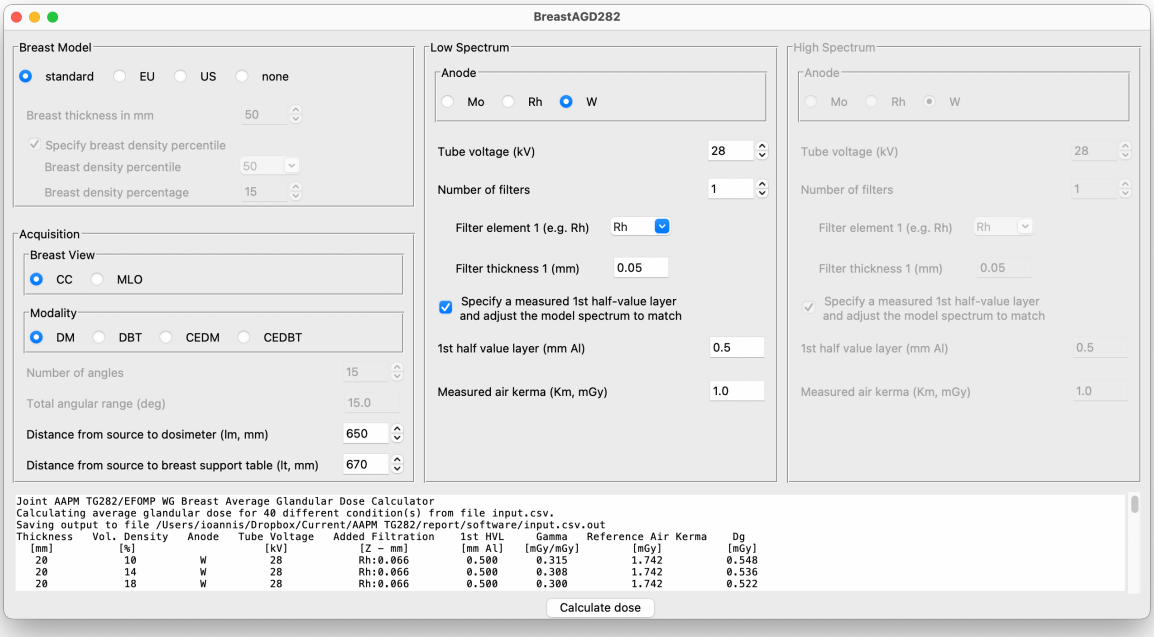
The following is a portion of the output CSV file that results from the processing of the above-shown input file:

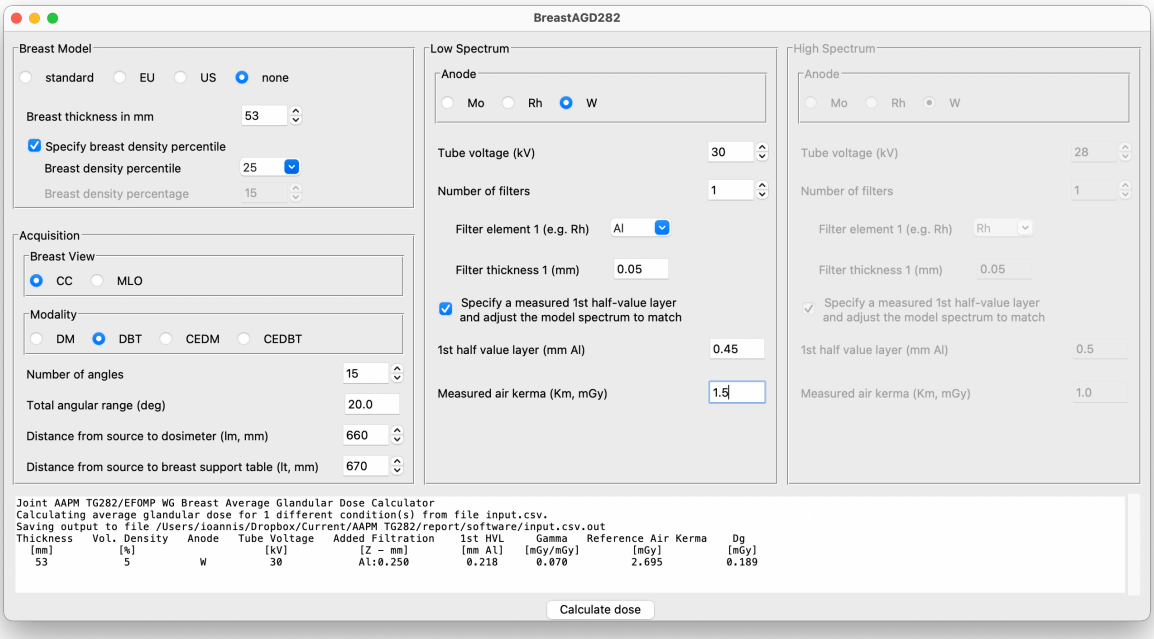
```
Thickness [mm];Vol. Density [%];Anode;Tube Voltage [kV];Added Filtration [Z - mm];1st HVL [mm Al];Gamma [mGy/m
23;10;W;32;Al - 0.800;Rh - 0.053;0.650;0.397;3.646;1.449
23;20;W;32;Al - 0.800;Rh - 0.053;0.650;0.375;3.646;1.368
23;30;W;32;Al - 0.800;Rh - 0.053;0.650;0.365;3.646;1.330
23;40;W;32;Al - 0.800;Rh - 0.053;0.650;0.360;3.646;1.311
23;42;W;32;Al - 0.800;Rh - 0.053;0.650;0.359;3.646;1.309
23;44;W;32;Al - 0.800;Rh - 0.053;0.650;0.358;3.646;1.307
23;46;W;32;Al - 0.800;Rh - 0.053;0.650;0.357;3.646;1.303
23;48;W;32;Al - 0.800;Rh - 0.053;0.650;0.357;3.646;1.301
23;49;W;32;Al - 0.800;Rh - 0.053;0.650;0.356;3.646;1.300
23;50;W;32;Al - 0.800;Rh - 0.053;0.650;0.356;3.646;1.297
23;51;W;32;Al - 0.800;Rh - 0.053;0.650;0.355;3.646;1.296
23;52;W;32;Al - 0.800;Rh - 0.053;0.650;0.355;3.646;1.295
23;54;W;32;Al - 0.800;Rh - 0.053;0.650;0.355;3.646;1.293
23;56;W;32;Al - 0.800;Rh - 0.053;0.650;0.354;3.646;1.291
23;58;W;32;Al - 0.800;Rh - 0.053;0.650;0.354;3.646;1.290
23;60;W;32;Al - 0.800;Rh - 0.053;0.650;0.354;3.646;1.289
23;70;W;32;Al - 0.800;Rh - 0.053;0.650;0.356;3.646;1.298
23;80;W;32;Al - 0.800;Rh - 0.053;0.650;0.363;3.646;1.325
44;10;W;32;Al - 0.800;Rh - 0.053;0.650;0.268;3.646;0.976
44;20;W;32;Al - 0.800;Rh - 0.053;0.650;0.247;3.646;0.902
44;30;W;32;Al - 0.800;Rh - 0.053;0.650;0.235;3.646;0.858
```

UG.6. Graphical user interface

A version of the BreastAGD282 program including a graphical user interface (GUI) is also provided for download. This version, called BreastAGD282_gui, runs in Windows and Mac. Once open, the GUI shown in Figure UG.1 can be seen. The GUI requires a screen resolution of at least 1280 x 720.

All inputs according to Table UG.1, except for irregular DBT angles and varying dose distribution across DBT/CEDBT projections, can be set in this interface, and the results are saved to a CSV text file and, if there are 50 or fewer conditions evaluated, also displayed on screen.


BreastAGD282
Breast Model
standard
EU
US
none
Breast thickness in mm
50
Specify breast density percentile
Breast density percentile
50
Breast density percentage
15
Acquisition
Breast View
CC
MLO
Modality
DM
DBT
CEDM
CEDBT
Number of angles
15
Total angular range (deg)
15.0
Distance from source to dosimeter (Im, mm)
650
Distance from source to breast support table (It, mm)
670
Low Spectrum
Anode
Mo
Rh
W
Tube voltage (kV)
28
Number of filters
1
Filter element 1 (e.g. Rh)
Rh
Filter thickness 1 (mm)
0.05
Specify a measured 1st half-value layer and adjust the model spectrum to match
1st half value layer (mm Al)
0.5
Measured air kerma (Km, mGy)
1.0
High Spectrum
Anode
Mo
Rh
W
Tube voltage (kV)
28
Number of filters
1
Filter element 1 (e.g. Rh)
Rh
Filter thickness 1 (mm)
0.05
Specify a measured 1st half-value layer and adjust the model spectrum to match
1st half value layer (mm Al)
0.5
Measured air kerma (Km, mGy)
1.0
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Calculating average glandular dose for 40 different condition(s) from file input.csv.
Saving output to file /Users/ioannis/Dropbox/Current/AAPM TG282/report/software/input.csv.out
Thickness Vol. Density Anode Tube Voltage Added Filtration 1st HVL Gamma Reference Air Kerma Dg
[mm] [%] [kV] [Z – mm] [mm Al] [mGy/mGy] [mGy] [mGy]
20 10 W 28 Rh:0.066 0.500 0.315 1.742 0.548
20 14 W 28 Rh:0.066 0.500 0.308 1.742 0.536
20 18 W 28 Rh:0.066 0.500 0.300 1.742 0.522
Calculate dose


BreastAGD282
Breast Model
standard
EU
US
none
Breast thickness in mm
53
Specify breast density percentile
Breast density percentile
25
Breast density percentage
15
Acquisition
Breast View
CC
MLO
Modality
DM
DBT
CEDM
CEDBT
Number of angles
15
Total angular range (deg)
20.0
Distance from source to dosimeter (Im, mm)
660
Distance from source to breast support table (It, mm)
670
Low Spectrum
Anode
Mo
Rh
W
Tube voltage (kV)
30
Number of filters
1
Filter element 1 (e.g. Rh)
Al
Filter thickness 1 (mm)
0.05
Specify a measured 1st half-value layer and adjust the model spectrum to match
1st half value layer (mm Al)
0.45
Measured air kerma (Km, mGy)
1.5
High Spectrum
Anode
Mo
Rh
W
Tube voltage (kV)
28
Number of filters
1
Filter element 1 (e.g. Rh)
Rh
Filter thickness 1 (mm)
0.05
Specify a measured 1st half-value layer and adjust the model spectrum to match
1st half value layer (mm Al)
0.5
Measured air kerma (Km, mGy)
1.0
Joint AAPM TG282/EFOMP WG Breast Average Glandular Dose Calculator
Calculating average glandular dose for 1 different condition(s) from file input.csv.
Saving output to file /Users/ioannis/Dropbox/Current/AAPM TG282/report/software/input.csv.out
Thickness Vol. Density Anode Tube Voltage Added Filtration 1st HVL Gamma Reference Air Kerma Dg
[mm] [%] [kV] [Z – mm] [mm Al] [mGy/mGy] [mGy] [mGy]
53 5 W 30 Al:0.250 0.218 0.070 2.695 0.189
Calculate dose

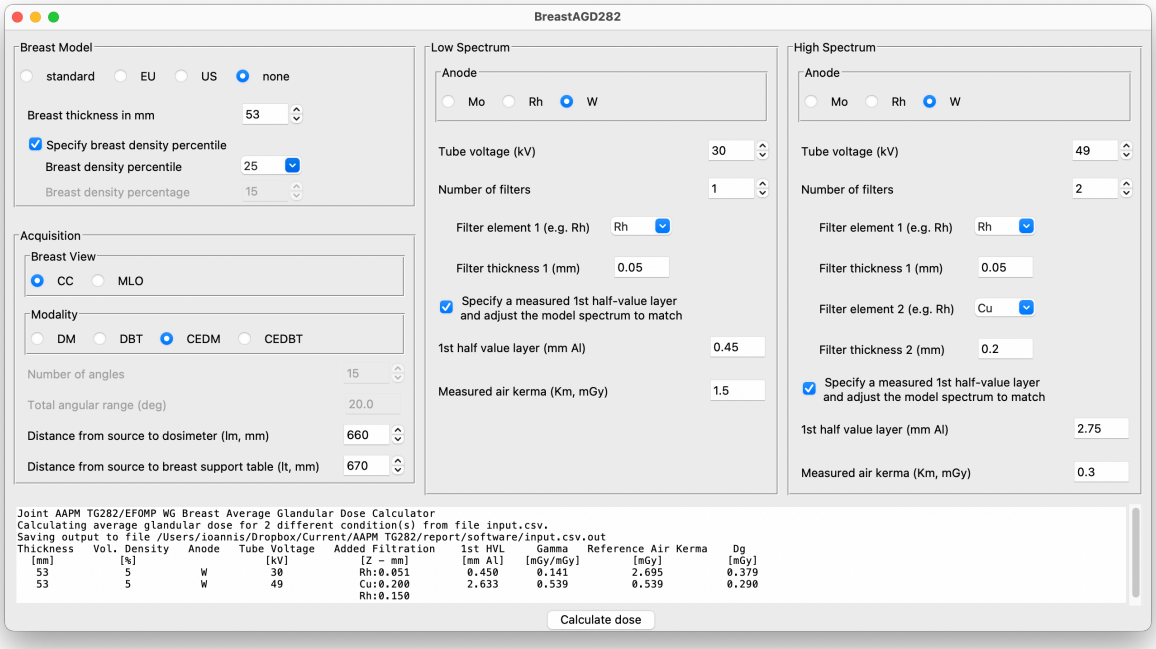


Figure UG.1. Screen captures of the GUI-based BreastAGD282 program, showing a set of inputs and the corresponding outputs for (top) a DM acquisition with the standard breast model with the output only saved to a file, (center) a DBT acquisition using a manually entered breast model, and (bottom) a CEDM acquisition with a manually entered breast model. In this last one, it can be seen that the results include the two (low energy and high energy) acquisitions, and the high-energy acquisition involved the use of two filters.

UG.7. Accompanying Data Files

The command-line program requires several data files to be available and to be in a folder named *data* directly under the folder from which the program is run. The GUI-based program has these files incorporated into the single executable, so these are not visible to the user. These files contain the data needed for the dose estimation calculations, which involve information about the breast models for the CC and MLO views, the x-ray spectra models for the three different anode sources, and, finally, the monochromatic dose conversion coefficients obtained, after post-processing, from the Monte Carlo simulations, as described in the Report. Specifically, these data files are:

Breast models:

max_CC.txt
max_MLO.txt
percentiles_CC.txt
percentiles_MLO.txt

X-ray source models:
masmics.txt
rasmics.txt
tasmics.txt
Dose conversion coefficients:
gamma_tgae_CC.txt
gamma_tgae_MLO.txt
and contain the data as described below.

max_CC.txt, max_MLO.txt

Maximum volumetric breast densities, in %, for the generic breast models of different thicknesses, for the CC and MLO views, respectively. These values are shown in Figure 2 of the Report. The file includes first an integer with the number of compressed breast thicknesses included in the file, then that number of rows, each specifying the compressed breast thickness, in mm, and the maximum volumetric breast density.

percentiles_CC.txt, percentiles_MLO.txt

Conversion from volumetric breast density in percentiles to percentages for the population-based model described in Section VII.B and listed in Tables A.2 and A.3. The first row lists the number of percentiles and their values, the second row lists the number of compressed breast thicknesses and their values, the following rows list the volumetric breast density percentages for the corresponding percentiles, with one breast thickness per row.

masmics.txt, rasmics.txt, tasmics.txt

X-ray spectrum models for unfiltered sources with Mo, Rh, and W anodes, respectively, in ph/mm^2, for x-ray energies from 9.75 keV to 49.75 keV, in 0.5 keV steps, for tube voltages from 20 kV to 49 kV, in 1 kV steps. Each column lists the values for each tube voltage, with each row lists the values for each corresponding x-ray energy level. Source: Hernandez AM, Seibert JA, Nosratieh A, Boone JM. Generation and analysis of clinically relevant breast imaging x-ray spectra. *Med Phys*. 2017;44(6):2148-2160. doi:10.1002/mp.12222.

gamma_tgae_CC.txt, gamma_tgae_MLO.txt

Monochromatic glandular dose conversion coefficients, $\gamma_{sim}(t, g, e, a)$, in mGy / mGy air kerma, for the CC and MLO views, respectively. Each file contains 79 columns, one for each x-ray energy (9.75 keV to 49.75 keV, in 0.5 keV steps), and 3,003 rows, grouped first by compressed breast thickness (10 mm, and 15 mm to 125 mm, in 10 mm steps), then by breast fibroglandular density by mass (1%, and 10% to 100%, in 10% steps), and then by projection angle (-30° to +30°, in 3° steps).