Fork Detector Measurement System (FDMS)
Quick user instructions for the second field testable version of the software (version 1.02), including a summary of new features found at the end of this document.

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Introduction

The aim of the Fork detector measurement system (FDMS) software is to provide IAEA inspectors using a fork detector a real time graphical representation of the data they are collecting. With a real time graphical representation of the data, inspectors will be able to more easily trouble-shoot equipment in the field, diagnose problems, and assess the quality of data during a given inspection campaign. Future versions of this software could be used by IAEA subject matter experts to analyze fork detector data returning from the field, in their search for proliferation.

The FDMS software interacts with four files: the initialization (INI) file; the measurementplan (MP) file; the database (DB) file; and the measurements (M) file. The INI file contains fork detector, and mini-grand (or grand-3) configuration parameters, and FDMS analysis parameters. The MP, DB, and M files are all comma-delimited files (*.csv) that can be read and edited using standard computer file editors (like word and/or notepad) and can be manipulated using Excel. The MP file contains a list of the items that an inspector may choose to measure. The information in this file includes the facility name, assembly ID, and declared assembly properties like initial uranium enrichment, burn up, cooling time, cycle number, discharge date etc. If an inspector needs to measure an item not contained in the MP file, the MP file should be appended with the required information using Excel. After each measurement the MP file is updated with the measured neutron count rates observed in the mini-grand (or grand-3) pulse counting channels A, B, and C, and the gamma doses observed in the current channels 1 and 2. However, only neutron channels A and B, and gamma channel 1 are used in the analysis. The measurement status (“good”, “suspect”, or “neutral”) for each measured assembly is stored in the MP file and is updated for all measured assemblies after each measurement. The status assigned to each measurement is determined by a comparison to previous declarations and corresponding measurement data obtained on the same (or similarly calibrated) fork detector at the same (or similar) reactor complex, stored in the DB file. The attribute “good” is assigned to measurements that are consistent with the data contained in the DB file. The attribute “suspect” is assigned to measurements that appear to be inconsistent with the data contained in the DB file. A 3-sigma test is applied. If no previous data exist in the DB file that can be compared to a new measurement, or if previously measured assemblies, from the present campaign, are of a different class from the most recent measurement, then the attribute “neutral” is assigned. This will be described in greater detail later. The measurement attributes are displayed graphically and in tabular form. All measurements, including background measurements, are logged in

the M file. The INI, MP, DB, and M files are discussed in greater detail in the following sections.

Initialization (INI) file

The INI file has the file name “FDMS.INI” and contains fork detector, and mini-grand (or grand-3) configuration parameters, and FDMS analysis parameters. If this file does not exist at the time of FDMS execution then the software will generate the default version. The user will likely need to edit this default version to match their specific needs. The default INI file is shown below. At the present time there is a bug in the part of the code that generates the default INI file. If a default INI file is generated then the code crashes. The INI file is, however, generated correctly. Simply re-execute the FDMS software and it will then work with the newly generated INI file.

```
[CONFIGURATION]
DATABASE=.\database.csv
MEASUREMENTPLAN=.\measurementplan.csv
MEASUREMENTS=.\measurements.csv
DELTA_ENRICHMENT=0.15
DELTA_COOLINGTIME=5.0

[GRAND]
MINIGRAND=Yes
PORT=COM1
BAUD=9600
PARITY=NONE
DATABITS=8
STOPBITS=1
TICKLE=1000
COMMANDTIMEOUT=10
ICHVBIAS=300
HVBIAS=1000
OFFSET_CNTRL=Yes
OFFSET_CNTRL_REMOTE=No
OFFSET_LIMIT_LOW=700
OFFSET_LIMIT_HIGH=1200
OFFSET_TIME=60
BGCYCLETIME=30
BGCYCLES=3
CYCLETIME=20
CYCLES=3

[BACKGROUND]
BACKGROUND_A=0.000
BACKGROUND_B=0.000
BACKGROUND_C=0.000
BACKGROUND_1=0.000
```

BACKGROUND_2=0.000
The INI file parameters are divided into three classes or types. These are configuration, grand, and background parameters. The three parameter class headings [CONFIGURATION], [GRAND], and [BACKGROUND] must be present in the INI file followed by the corresponding parameters. Most of the parameters have default values and if any of these parameters are not defined in the INI file then the software will use the default values.

The configuration parameters are the location and names of the DB, MP, and M files, and the analysis parameters DELTA_ENRICHMENT and DELTA_COOLINGTIME. If the INI defined location and file names for the DB and MP files do not point to existing files then the software will prompt the user for new location and file names for these files, and update the INI file with this inputted information. The DELTA_ENRICHMENT and DELTA_COOLINGTIME are used in the "Assembly Verification" mode (discussed later) to determine which entries in the DB file should be compared to the most recent measurement. The default values for DELTA_ENRICHMENT and DELTA_COOLINGTIME are 0.15% and 0.2 years, respectively. For example, if the most recent measurement is of an assembly with a declared initial ^{235}U enrichments of 3.8% and a cooling time of 10.2 years and the Neutron versus Gamma test is on (see later), then this measurement will be compared to entries in the DB file with enrichments ranging from 3.65% to 3.95% and with cooling times from 10.0 years to 10.4 years. This is necessary because the relationship between decay corrected neutron rates, the declared burn up, and decay corrected gamma dose are sensitive to enrichment and cooling time. It is possible that future versions of the FDMS may include complex enrichment corrections using a more complete declared history for each assembly. The decay corrections are more accurate when comparing assemblies with similar cooling times and may become unreliable when comparing assemblies with dramatically different cooling times (when required). The DELTA_COOLINGTIME parameter stops the FDMS from comparing assemblies with dramatically different cooling times. Depending on the facility type, subject matter experts in the IAEA may wish to change the defaults values for DELTA_ENRICHMENT and DELTA_COOLING in the INI file.

The grand parameters are divided into two subclasses, communication and measurement parameters. The communication parameters are:

MINIGRAND : "Yes" for a mini-grand and "No" for a grand-3.
PORT : The serial port to which the grand is connected.
BAUD : The grand serial port Baud rate.
PARITY : The grand serial port parity.
DATABITS : The number of data bits for the grand serial port communication.
STOPBITS : The number of stop bits for the grand serial port communication.
TICKLE and COMMANDTIMEOUT :
Times that control the computer-grand handshaking.

The BAUD, PARITY, DATABITS, and STOPBITS parameters should not be changed from the default values. The TICKLE and COMMANDTIMEOUT can be adjusted, but

with caution. The PORT should be changed to match the serial port to which the grand is connected. Most desktop computers have serial ports COM1 and COM2, while many laptops have only a single serial port COM1.
The measurement parameters are :

OFFSET_CNTRL :

Controls if the user desires offset measurements in conjunction with the background measurements. This will, in general, be set to “No”. When using a new grand and/or fork detector for the first time OFFSET_CNTRL should be set to “Yes” and a background measurement should be performed. With OFFSET_CNTL=“Yes” the gamma channel current offsets will be measured and stored internally in the grand before each background measurement. This can take up to approximately 1 minute. These offset values are generally very stable for a given grand and fork detector combination and thus once the offsets have been measured and stored the OFFSET_CNTRL can be set to “No”.

OFFSET_CNTRL_REMOTE :

Controls if the user desires external offset measurements in addition to the internal offset measurements discussed above. The default value is “No”. This is because external offsets are not generally used with fork detectors.

OFFSET_LIMIT_LOW=700
OFFSET_LIMIT_HIGH=1200

The above two parameters place limits on the allowable values for the gamma channel current offset measurements. Internal grand offset measurements are made for both gamma channels 1 and 2, at 10 different current ranges. This is a total of 20 offset measurements. Each of these offset measurements is an integer in the range from 0 to 4095. If the grand is working correctly then all 20 offsets should be close to 1000, and thus the default allowable range from 700 to 1200. If any of the 20 offset measurements fall outside the allowable range defined by OFFSET_LIMIT_LOW and OFFSET_LIMIT_HIGH, then the background measurement will terminate and a warning message will appear, instructing the user to check/repair the instrument. However, the offset measurements that fail are most likely the ones that correspond to the most sensitive current (gamma) dose) ranges not used by fork detectors when measuring spent-fuel assemblies. If this is confirmed then the OFFSET_LIMIT range could be widened to force the FDMS software to ignore poor offset measurements for the most sensitive ranges.

OFFSET_TIME=60 : Maximum allowable time for the offset measurements (seconds).
ICHVBIAS=300 : High voltage bias (Volts) to be applied to the ion chambers.
HVBIAS=1000 : High voltage bias (Volts) to be applied to the fission chambers.
BGCYCLETIME=30 : Time for each background measurement cycle in seconds.
BGCYCLES=3 :

The total number of background measurement cycles per measurement. For example, if BGCYCLETIME=30 and BGCYCLES=3 then each background measurement will consistent of three 30 second measurements. There is essentially little difference between three 30-second measurements and a single cycle 90-second measurement. However, the gamma dose readings are only updated on the computer screen after every cycle. Therefore if the user wishes to

see gamma readings while measurements are in progress then BGCYCLES will need to be set to greater than 1.

CYCLETIME=20 : Time for each assembly measurement cycle in seconds.
CYCLES=3 :

The total number of measurement cycles per assembly measurement. For example, if CYCLETIME=20 and CYCLES=3 then each measurement will consist of three 20 second measurements. There is presently a minor bug in the measurements part of the software, and at present CYCLES should be set to 1, and the total measurement time should be controlled using CYCLETIME.

The background parameters store the background measurements for the three neutron channels, and for the two gamma dose channels. These are updated in the INI immediately following each background measurement.

Measurementplan (MP) file

The MP file contains a list of the items that an inspector may choose to measure. The MP file name must have the file extension "csv". The default name is "Measurementplan.csv", but the user may change the name "Measurementplan" to a name of their choice. The MP file is a comma delimited ASCII file (CSV) that is readable using both standard word processors and Excel. A MP file must exist at the time the FDMS is executed. Before any measurements are performed the MP file must contain information for each assembly that an inspector may choose to measure. This information includes the facility name, assembly ID, and facility declared properties for each assembly. After each assembly measurement the MP file is updated with the measured neutron count rates observed in the mini-grand (or grand-3) pulse counting channels A, B, and C, the gamma doses observed in the current channels 1 and 2, the measurement date, and a measurement status parameter for each measured assembly. The specific detector ID used for the measurement is also written.

A MP file is shown below. What appear to be the first two lines is in fact a single line containing header information for the MP file. This header information is not used by the FDMS software, but is makes editing MP files in Excel more straightforward. The used data starts in the 2nd line (record). There should be no blank lines or additional carriage returns after the data for the final assembly, or between data lines. That is, if a MP file contains entries for *n* assemblies then the file should be *n*+1 lines long.

```
Facility,ID,Measurement type,Status,Enrichment (%),Burnup (GWd/MT),Discharge day,month,year,cycle #,Thres
A,Thres B, Measurement day,month,year,Cooling Time (years), NA, NB, NC, G1, G2, Detector
LANL-FDET,1,2,0,1.76,21.46,18,8,1992,2,0,0,  ,  ,    ,0,74.8,76.9,0,252.8,0,
LANL-FDET,2,2,0,1.76,21.46,18,8,1992,2,0,0,  ,  ,    ,0,70.7,70,0,248,0,
LANL-FDET,3,2,0,1.76,14.16,18,8,1987,2,0,0,  ,  ,    ,0,12.8,13.2,0,129.6,0,
LANL-FDET,4,2,0,2.9,28.03,18,8,1989,2,0,0,  ,  ,    ,0,30.3,30.5,0,256.8,0,
```

Each line in the MP must contain 22 possible inputs separated by 21 commas. Each line must be followed by a single carriage return. It is not necessary for each possible input

location to contain an entry, but a comma must still follow each blank entry. The information that can be contained in the 22 columns is:

Column 1: Facility name: This can be any combination of 32 ASCII characters.
Column 2: Assembly ID: This can be any combination of 32 ASCII characters.
Column 3: Measurement type: At present, valid measurement types are 1 or 2. This signifies to the software the type of measurement/analysis to be performed on this assembly. Measurement type 1 is for cycle verification, and measurement type 2 is for assembly verification (discussed later).
Column 4: Measurement status: The measurement status will be changed by the software after a measurement has been made on this item. The measurement status can be an integer from 0 to 9, but the user only needs to know that measurement status 0 is for an unmeasured assembly. A user can force the software to consider a given assembly as "measured" by making the measurement status 5. When the software is executed, this will likely be changed by the software to a value greater than 0. The precise value is determined by a comparison to database entries in the DB file (discussed later). The measurement status is then used by the software to determine if a measurement should be labeled as "good", "suspect", or "neutral". These labels will be discussed in greater detail later.
Column 5: Enrichment: The declared initial ^{235}U enrichment (%) for each assembly.
Column 6: Burn up : The declared burn up (GWd/MT) for each assembly.
Column 7: Discharge day: An integer to represent the declared day (date) of discharge.
Column 8: Discharge month: An integer to represent the declared month of discharge.
Column 9: Discharge year: An integer to represent the declared year of discharge.
Column 10: Cycle #: An integer to represent the declared cycle number.
Column 11: Thres A: The threshold applied to neutron channel A. Not used.
Column 12: Thres B: The threshold applied to neutron channel B. Not used.
Column 13: Measurement day: The date of the month of each measurement.
Column 14: Measurement month: The month of each measurement.
Column 15: Measurement year: The year of each measurement. The software updates columns 13, 14, and 15 after each assembly is measured.
Column 16: Cooling time: The cooling time (years) for each measurement. This can be either directly declared or is calculated and updated by the software after each measurement based on a declared discharge date.
Column 17: NA: The neutron count rate observed in the grand pulse channel A.
Column 18: NB: The neutron count rate observed in the grand pulse channel B.
Column 19: NC: The neutron count rate observed in the grand pulse channel C.
Column 20: G1: The gamma dose observed in the grand current channel 1.
Column 21: G2: The gamma dose observed in the grand current channel 2.
Column 22: Detector: The ID of the detector used in this measurement

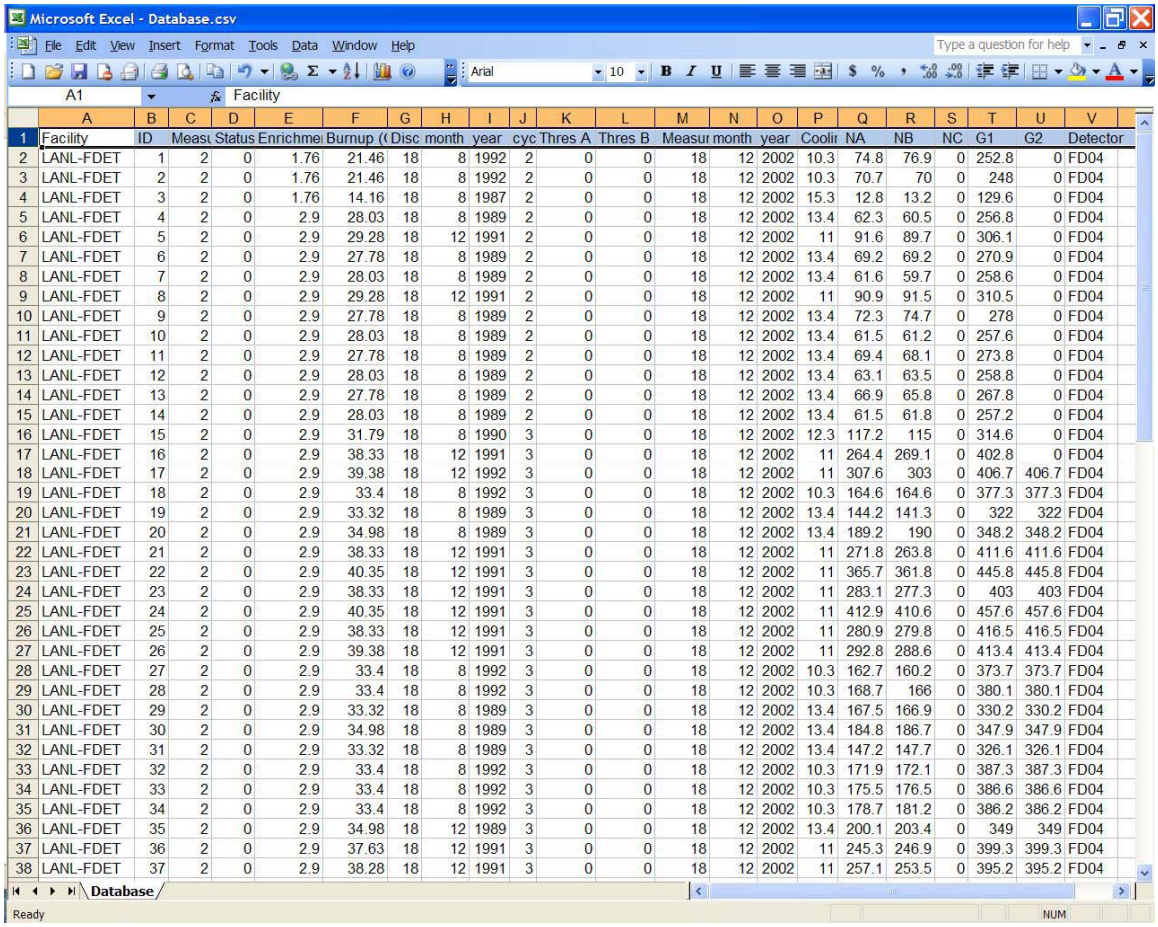
The software updates columns 17 to 22 after each assembly is measured. A declared enrichment and burn up must be entered for each type-2 measurement (assembly verification). For cycle verification measurements (type-1) the enrichment and burn up can be left blank. For each type-2 measurement there must be either a declared discharge date or a declared cooling time for each line in the MP file. If there is a declared cooling time then this is used in the analysis. If no declared cooling time exists then the declared discharge date is used in conjunction with the date obtained from the computer at the time of the measurement to calculate the cooling time. For type-1 measurements there must be a declared assembly cycle number.

Database (DB) file

The DB file has the same format as the MP file,. The first line contains header information not used by the software. All following lines contain 22 inputs separated by 21 commas. The DB file name must have the file extension "csv". The default name is "Database.csv", but the user may change the name "Database" to a name of their choice. A DB file must exist at the time the FDMS is executed. An example DB file is shown below.

```
Facility,ID,Measurement type,Status,Enrichment (%),Burnup (GWd/MT),Discharge day,month,year,cycle #,Thres A,Thres B, Measurement day,month,year,Cooling Time (years), NA, NB, NC, G1, G2 ,Detector
LANL-FDET       ,63,2,3.72,44.38,18,12,1994,3,0,0,18,12,2002,8,321.8,323.9,0,639.6,639.6,
LANL-FDET       ,64,2,3.87,48.58,18,12,1994,4,0,0,18,12,2002,8,426.1,428.7,0,700.2,700.2,
LANL-FDET       ,65,2,3.87,48.58,18,12,1994,4,0,0,18,12,2002,8,406.6,401.8,0,682.1,682.1,
LANL-FDET       ,66,2,3.87,48.58,18,12,1994,4,0,0,18,12,2002,8,413.3,414.2,0,682.2,682.2,
LANL-FDET       ,67,2,3.87,48.58,18,12,1994,4,0,0,18,12,2002,8,424.9,421.4,0,687.8,687.8,
LANL-FDET       ,68,2,3.87,53.1,18,6,1998,4,0,0,18,12,2002,4.5,762.5,747.2,0,1391,1391,
WWER-440,CV-1,1,3.6,34,18,11,2002,4,0,0,18,12,2002,0.08,1140,0,0,1725,0,
WWER-440,CV-2,1,3.6,34,18,11,2002,4,0,0,18,12,2002,0.08,1100,0,0,1660,0,
WWER-440,CV-3,1,3.6,31.81,18,11,2002,4,0,0,18,12,2002,0.08,1070,0,0,1620,0,
WWER-440,CV-4,1,3.6,33.95,18,11,2002,4,0,0,18,12,2002,0.08,1090,0,0,1525,0,
```

A DB file opened with Excel is show below.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Facility	ID	Meas	Status	Enrichme	Burnup ((	Disc	month	year	cyc	Thres A	Thres B	Measur	month	year	Coolir	NA	NB	NC	G1	G2	Detector
2	LANL-FDET	1	2	0	1.76	21.46	18	8	1992	2	0	0	18	12	2002	10.3	74.8	76.9	0	252.8	0	FD04
3	LANL-FDET	2	2	0	1.76	21.46	18	8	1992	2	0	0	18	12	2002	10.3	70.7	70	0	248	0	FD04
4	LANL-FDET	3	2	0	1.76	14.16	18	8	1987	2	0	0	18	12	2002	15.3	12.8	13.2	0	129.6	0	FD04
5	LANL-FDET	4	2	0	2.9	28.03	18	8	1989	2	0	0	18	12	2002	13.4	62.3	60.5	0	256.8	0	FD04
6	LANL-FDET	5	2	0	2.9	29.28	18	12	1991	2	0	0	18	12	2002	11	91.6	89.7	0	306.1	0	FD04
7	LANL-FDET	6	2	0	2.9	27.78	18	8	1989	2	0	0	18	12	2002	13.4	69.2	69.2	0	270.9	0	FD04
8	LANL-FDET	7	2	0	2.9	28.03	18	8	1989	2	0	0	18	12	2002	13.4	61.6	59.7	0	258.6	0	FD04
9	LANL-FDET	8	2	0	2.9	29.28	18	12	1991	2	0	0	18	12	2002	11	90.9	91.5	0	310.5	0	FD04
10	LANL-FDET	9	2	0	2.9	27.78	18	8	1989	2	0	0	18	12	2002	13.4	72.3	74.7	0	278	0	FD04
11	LANL-FDET	10	2	0	2.9	28.03	18	8	1989	2	0	0	18	12	2002	13.4	61.5	61.2	0	257.6	0	FD04
12	LANL-FDET	11	2	0	2.9	27.78	18	8	1989	2	0	0	18	12	2002	13.4	69.4	68.1	0	273.8	0	FD04
13	LANL-FDET	12	2	0	2.9	28.03	18	8	1989	2	0	0	18	12	2002	13.4	63.1	63.5	0	258.8	0	FD04
14	LANL-FDET	13	2	0	2.9	27.78	18	8	1989	2	0	0	18	12	2002	13.4	66.9	65.8	0	267.8	0	FD04
15	LANL-FDET	14	2	0	2.9	28.03	18	8	1989	2	0	0	18	12	2002	13.4	61.5	61.8	0	257.2	0	FD04
16	LANL-FDET	15	2	0	2.9	31.79	18	8	1990	3	0	0	18	12	2002	12.3	117.2	115	0	314.6	0	FD04
17	LANL-FDET	16	2	0	2.9	38.33	18	12	1991	3	0	0	18	12	2002	11	264.4	269.1	0	402.8	0	FD04
18	LANL-FDET	17	2	0	2.9	39.38	18	12	1992	3	0	0	18	12	2002	11	307.6	303	0	406.7	406.7	FD04
19	LANL-FDET	18	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	164.6	164.6	0	377.3	377.3	FD04
20	LANL-FDET	19	2	0	2.9	33.32	18	8	1989	3	0	0	18	12	2002	13.4	144.2	141.3	0	322	322	FD04
21	LANL-FDET	20	2	0	2.9	34.98	18	8	1989	3	0	0	18	12	2002	13.4	189.2	190	0	348.2	348.2	FD04
22	LANL-FDET	21	2	0	2.9	38.33	18	12	1991	3	0	0	18	12	2002	11	271.8	263.8	0	411.6	411.6	FD04
23	LANL-FDET	22	2	0	2.9	40.35	18	12	1991	3	0	0	18	12	2002	11	365.7	361.8	0	445.8	445.8	FD04
24	LANL-FDET	23	2	0	2.9	38.33	18	12	1991	3	0	0	18	12	2002	11	283.1	277.3	0	403	403	FD04
25	LANL-FDET	24	2	0	2.9	40.35	18	12	1991	3	0	0	18	12	2002	11	412.9	410.6	0	457.6	457.6	FD04
26	LANL-FDET	25	2	0	2.9	38.33	18	12	1991	3	0	0	18	12	2002	11	280.9	279.8	0	416.5	416.5	FD04
27	LANL-FDET	26	2	0	2.9	39.38	18	12	1991	3	0	0	18	12	2002	11	292.8	288.6	0	413.4	413.4	FD04
28	LANL-FDET	27	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	162.7	160.2	0	373.7	373.7	FD04
29	LANL-FDET	28	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	168.7	166	0	380.1	380.1	FD04
30	LANL-FDET	29	2	0	2.9	33.32	18	8	1989	3	0	0	18	12	2002	13.4	167.5	166.9	0	330.2	330.2	FD04
31	LANL-FDET	30	2	0	2.9	34.98	18	8	1989	3	0	0	18	12	2002	13.4	184.8	186.7	0	347.9	347.9	FD04
32	LANL-FDET	31	2	0	2.9	33.32	18	8	1989	3	0	0	18	12	2002	13.4	147.2	147.7	0	326.1	326.1	FD04
33	LANL-FDET	32	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	171.9	172.1	0	387.3	387.3	FD04
34	LANL-FDET	33	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	175.5	176.5	0	386.6	386.6	FD04
35	LANL-FDET	34	2	0	2.9	33.4	18	8	1992	3	0	0	18	12	2002	10.3	178.7	181.2	0	386.2	386.2	FD04
36	LANL-FDET	35	2	0	2.9	34.98	18	12	1989	3	0	0	18	12	2002	13.4	200.1	203.4	0	349	349	FD04
37	LANL-FDET	36	2	0	2.9	37.63	18	12	1991	3	0	0	18	12	2002	11	245.3	246.9	0	399.3	399.3	FD04
38	LANL-FDET	37	2	0	2.9	38.28	18	12	1991	3	0	0	18	12	2002	11	257.1	253.5	0	395.2	395.2	FD04

When assemblies listed in the MP file are selected and measured, these results are compared to all similar assemblies described in the DB file. If the new measurement is found to be consistent with the DB entries then the measurement status for the new measurement is “good”. If a new measurement appears to be inconsistent with the corresponding entries in the DB file then the new measurement is labeled “suspect”. If there are no entries in the DB file that can be compared to the new measurement then the new measurement status is set to “neutral”.

Measurements (M) file

The M file name must have the file extension “csv”. The default name is “Measurements.csv”, but the user may change the name “Measurements” to a name of their choice. This file has exactly the same format as the MP file. After each measurement, including background measurements, the M file is appended with the declarations and corresponding neutron count rates and gamma doses from the last measurement. For the background measurements the declaration fields are left blank. The M file does not have to exist at the time of execution. If it does exist the new

measurements will be appended to the bottom of the existing file. The M file is thus a log of all measurements in the order they were measured.

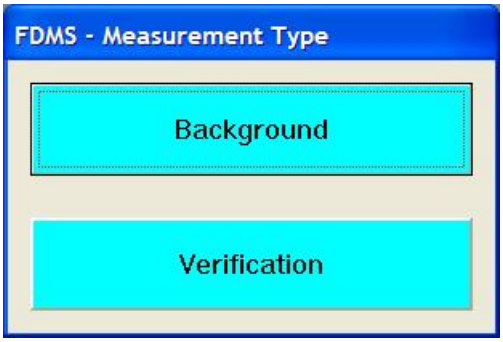
Executing and using the FDMS software

An installation disc will be made available but at the present time the required files will be zipped and e-mailed to those who need to test the FDMS software. Unzip the e-mailed files into a single directory on your computers hard-drive. The files contained in the present package are:

FDMS.exe : Executable version that can communicate with a mini-grand.
DEMOFDMSDbg.exe : Demonstration version of the software. This version simulates communication with an instrument and can be used for training and demonstration when a real instrument is not available.
Fdmsdll.dll : DLL needed to execute the FDMS software (real and demo versions).
DFORRT.DLL : DLL needed to execute the FDMS software (real and demo versions).
FDMS.INI : INI file.
Database.csv : DB file.
Measurementplan.csv: MP file.

Please open and look at these files. Open the INI file with Notepad and the *.csv files with Excel. Make backups of the INI, DB, and MP files, as the exercises that follow will change these files. Backups will enable trainees to restart from the beginning of these exercises, as needed. Please note that the sent MP file already contains measurement data for the assemblies in the MP file. The demo version of the software performs fake assembly measurements using the measurement values in the MP file. Also notice that the measurement times and number of measurement cycle parameters in the INI file has been deliberately set to small values so that the demo (fake) measurements are made in a timely fashion.

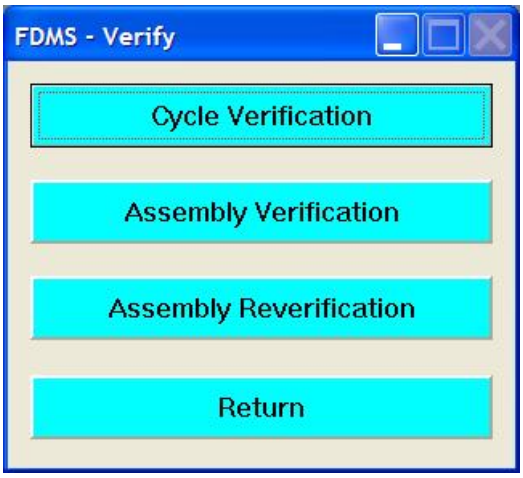
Execute DEMOFDMSdbg.exe by double clicking on the icon in your FDMS folder. The “FDMS – Measurement Type” window opens as shown below. There are two choices, to perform background measurements, or verification measurements.



Background measurements can be mimicked by the demo version of the FDMS software, but they are not used by the demo analysis. The present version of the software still has some problems making background measurements. Some times background measurements fail. Generally, this happens if a background measurement is the first measurement after a mini-grand has been turned on, or if the mini-grand power is cycled

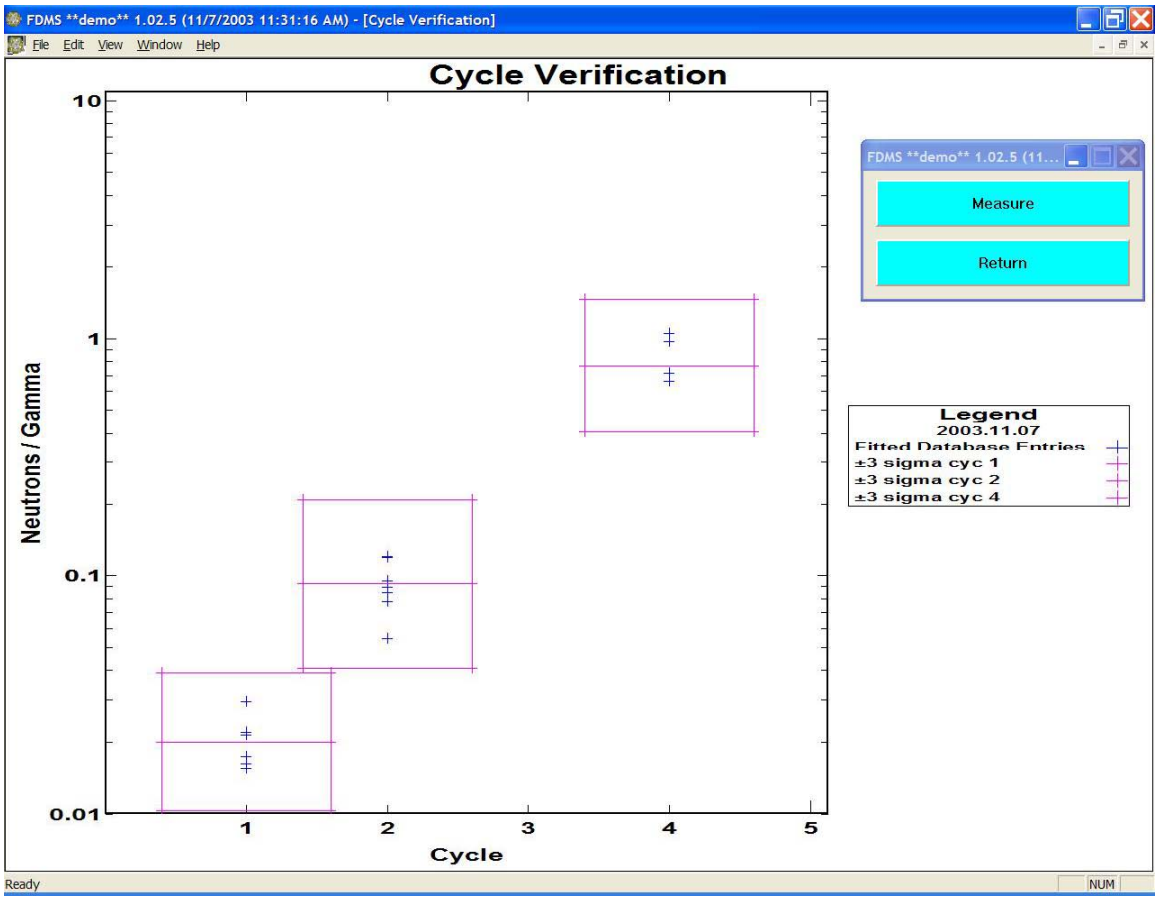
while the FDMS software is running. This problem will be rectified soon. To work around this at the present time please cancel failed background measurements and try again. If this fails then select verification and start an assembly verification measurement. Cancel the assay or reject the results and then go back to the background measurement. If this fails then exit the software, cycle the power on the mini-grand and then start again.

If verification mode is chosen then the “FDMS – Verify” window opens as shown below.



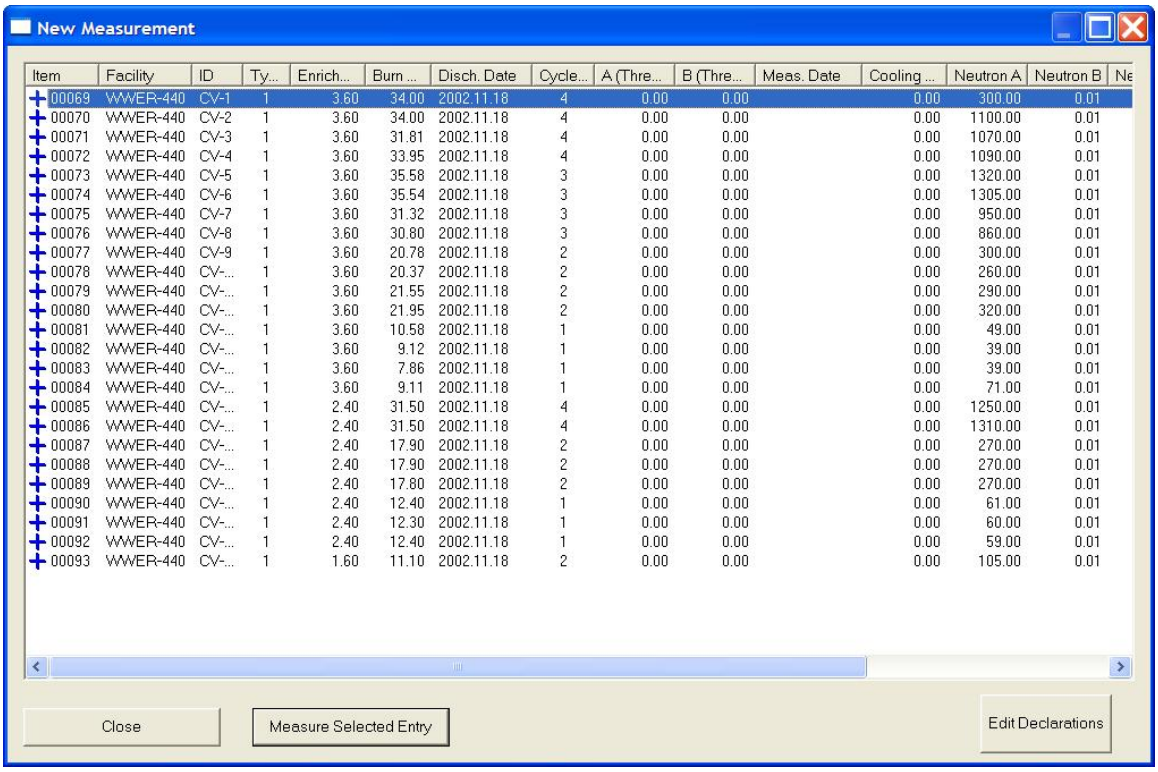
Three measurement types are displayed, Cycle Verification, Assembly Verification, and Assembly Reverification. Only the Cycle Verification and Assembly Verification are functional at the present time. In Cycle Verification a plot of the neutron count rates versus declared cycle number can be used to verify declared cycle numbers. In Assembly Verification any combination of the plots: decay corrected neutrons versus declared burn up; gamma divided by declared burn up versus declared cooling time; and decay corrected neutrons versus decay corrected gammas can be used to verify that assemblies are consistent with facility declared values. The Assembly Reverification option will be added at a later date, and will enable a measurement made on a given assembly to be decay corrected and compared directly to a previous measurement of the same assembly. It is planned that this option or an additional similar option will allow the IAEA to make multiple neutron measurements on the surface of spent-fuel dry storage casks, decay correct these measurements and compare them directly to previous measurements made on the same cask.

If the Cycle Verification option is selected then the “Cycle Verification” window opens as shown below.



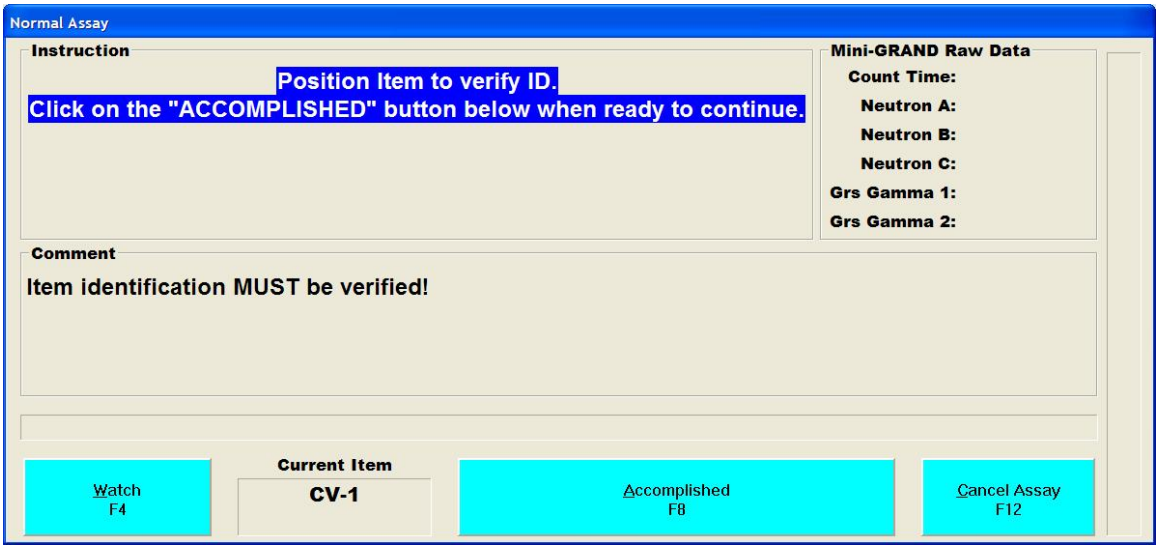
This shows the plot of Neutrons/Gamma versus Cycle number. The blue crosses show “fitted” database entries. The fitted database entries are the type-1 measurements from the DB file. In this case “fitted” means there were enough measurements per cycle to enable both an average and standard deviation to be determined for the Neutron to Gamma ratio. Notice that in this case the DB file did not contain any type-1 measurements with a declared cycle number of 3. The boxes show the 3-sigma limits for each of the cycle numbers with “fitted” database entries. By clicking in the legend each class of data point and fit can be removed and added to the plot. The software auto-scales the plot but the user can change the vertical scale by first placing the cursor to the right of the vertical axis and then using right and left mouse clicks in conjunction with the shift and Ctrl keys. The user can cycle through various combinations of plot grids by first placing the mouse in the bottom left hand corner of the plot and then using either left or right mouse clicks.

If the Measurement option is selected then the “New Measurement” window opens as shown below.

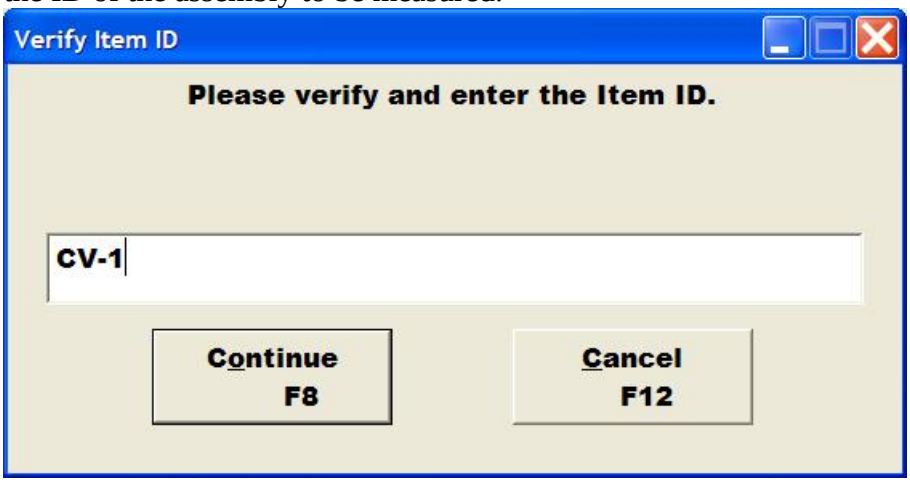


Notice that only type=1 (cycle verification) MP entries are shown. The icons on the left hand side of the table, under the “Item” heading, signify the measurement status. The blue crosses signify that these items have not been measured. The user can change the size of this window and scroll horizontally and vertically to view all the data contained in the “New Measurement” window. The user can sort on any of the headings by clicking on these headings. For example, to view the data in ascending order of enrichment, left mouse click on the “enrichment” heading. To view in descending order click on the heading a second time. Clicking on the “Item” heading can be used to get back to the original order as listed in the MP file. Column widths can be adjusted by clicking and dragging on the vertical sections between the individual headings.

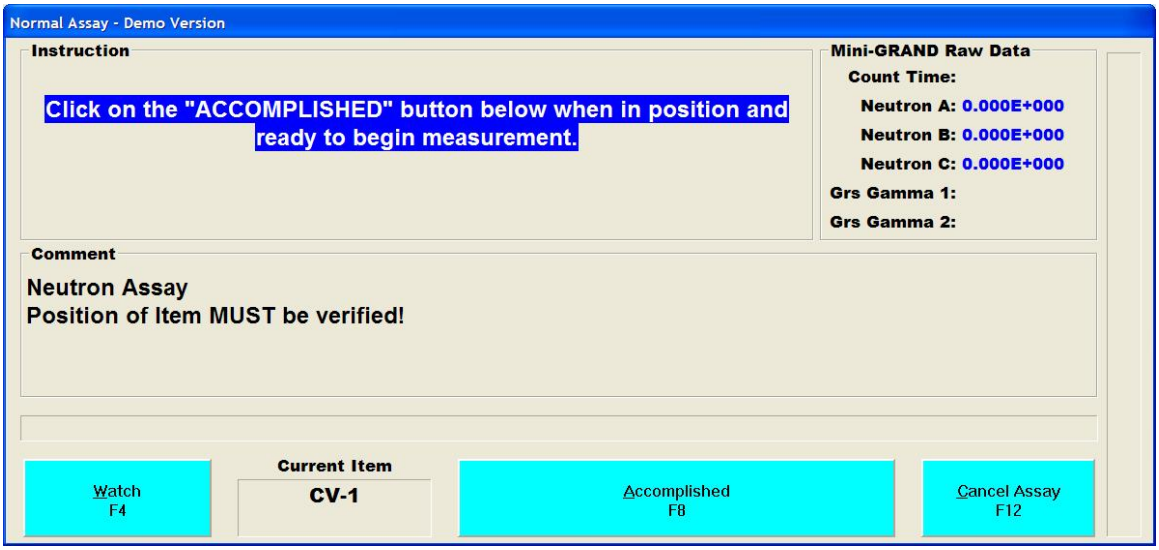
To measure a given item click on it and then click on the “Measure Selected” button. If the assembly with ID=“CV-1” is selected for measurement then the “Normal Assay” window opens as shown below.



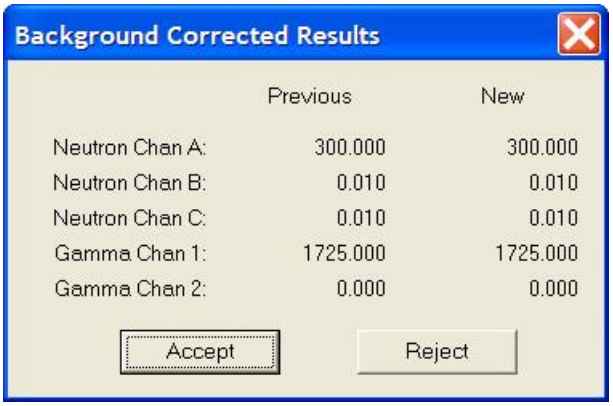
If the “Watch” button is selected then the user will be able to watch, in detail, the communication with the instrument. The measurement can be canceled using the “Cancel Assay” button. Once the inspector has positioned the assembly to verify its ID the “Accomplished” button should be pressed. The inspector will then be asked to confirm the ID of the assembly to be measured.



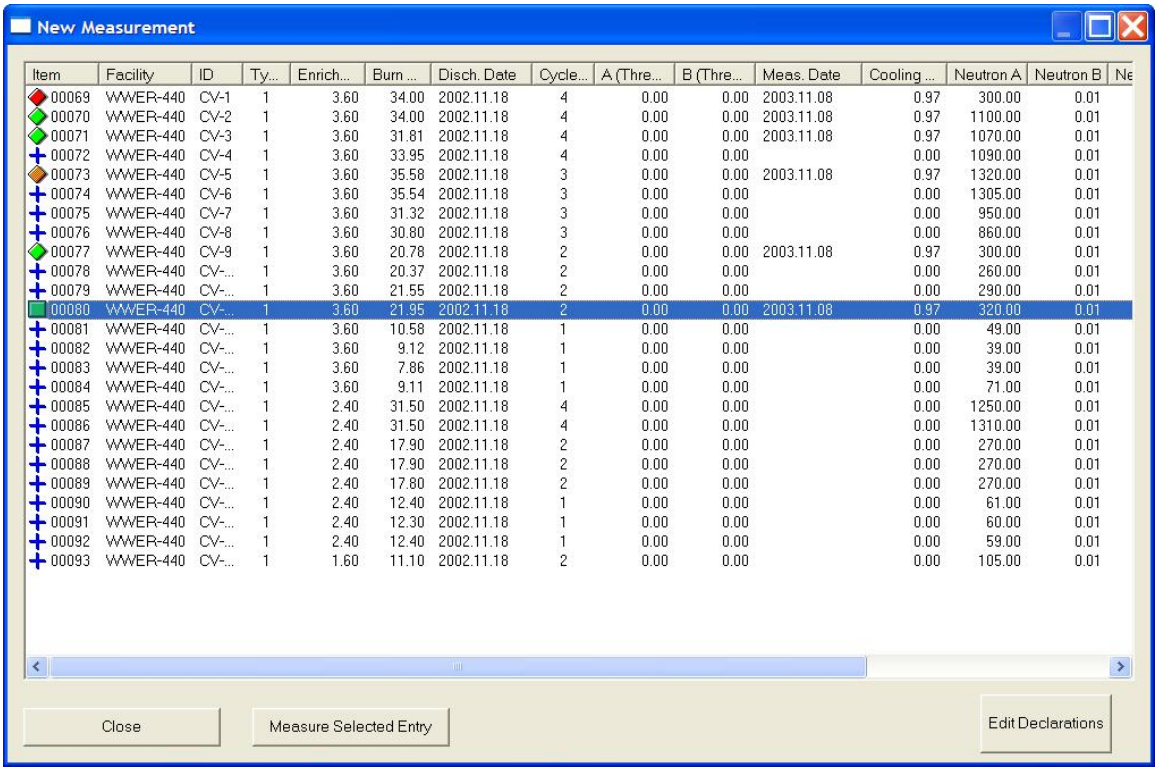
Once this is completed the “Normal Assay” window changes as shown below.



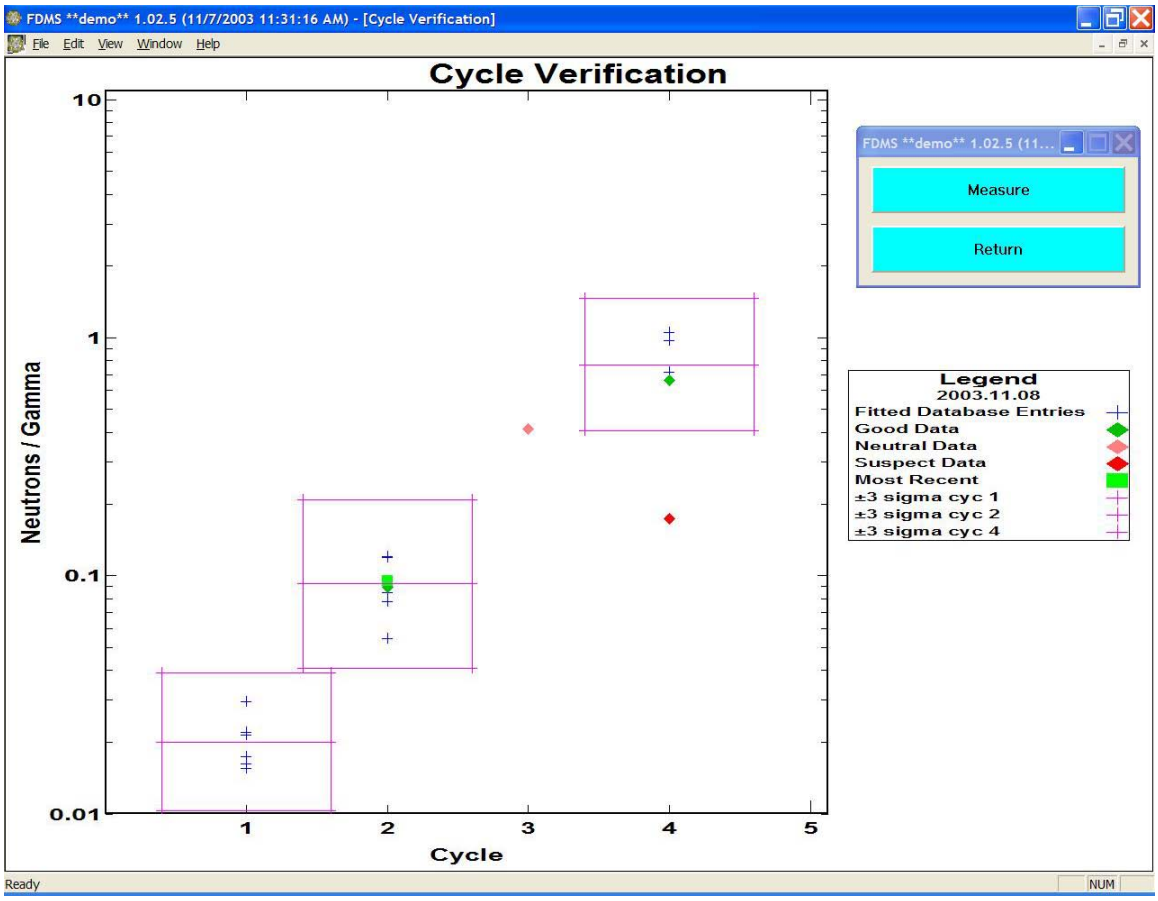
Once the instrument is in the required measurement position then the “Accomplished” button should be activated. The measurement is performed and then the “Normal Assay” window is closed and the “Measurement Results” window is opened as shown below.



Notice that in the demo version non-zero previous data appears even though this item had not been previously measured. This is because the demo version of the software makes fake measurements using the data in the MP file. In the “live” version of the software, the new measurements come from the instrument and the previous measurement data come from the MP file. If the “Accept” button is clicked then the new measurement is accepted and “New Measurements” window reopens. The status of the new measurement is updated in the “New Measurements” window, and the new measurement is plotted in graphical form. If CV-2, CV-3, CV-5, CV-9, and CV-13 are also selected, measured, and these measurements are accepted, then the “New Measurement” window will be as shown below.

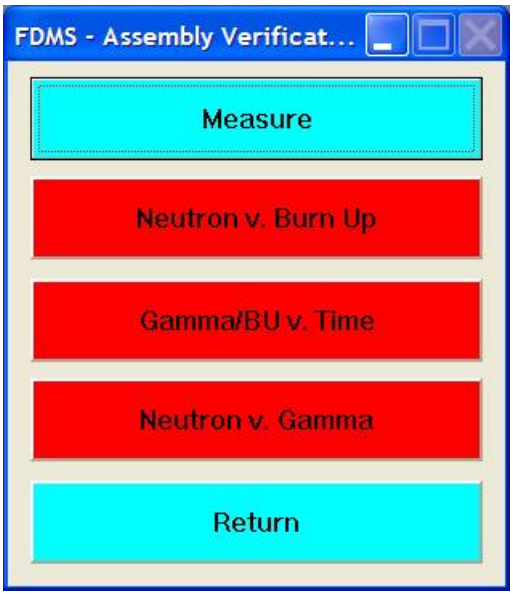


Notice that 6 entries now have icons that signify a measurement status other than the original blue crosses. A square is used to signify the most recent measurement. The colors green, red, and orange are used to signify “good”, “suspect”, and “neutral” measurements. However, if the most recent measurement is “neutral” then it is signified by a black square. The corresponding Neutrons/Gamma versus cycle plot is shown below.

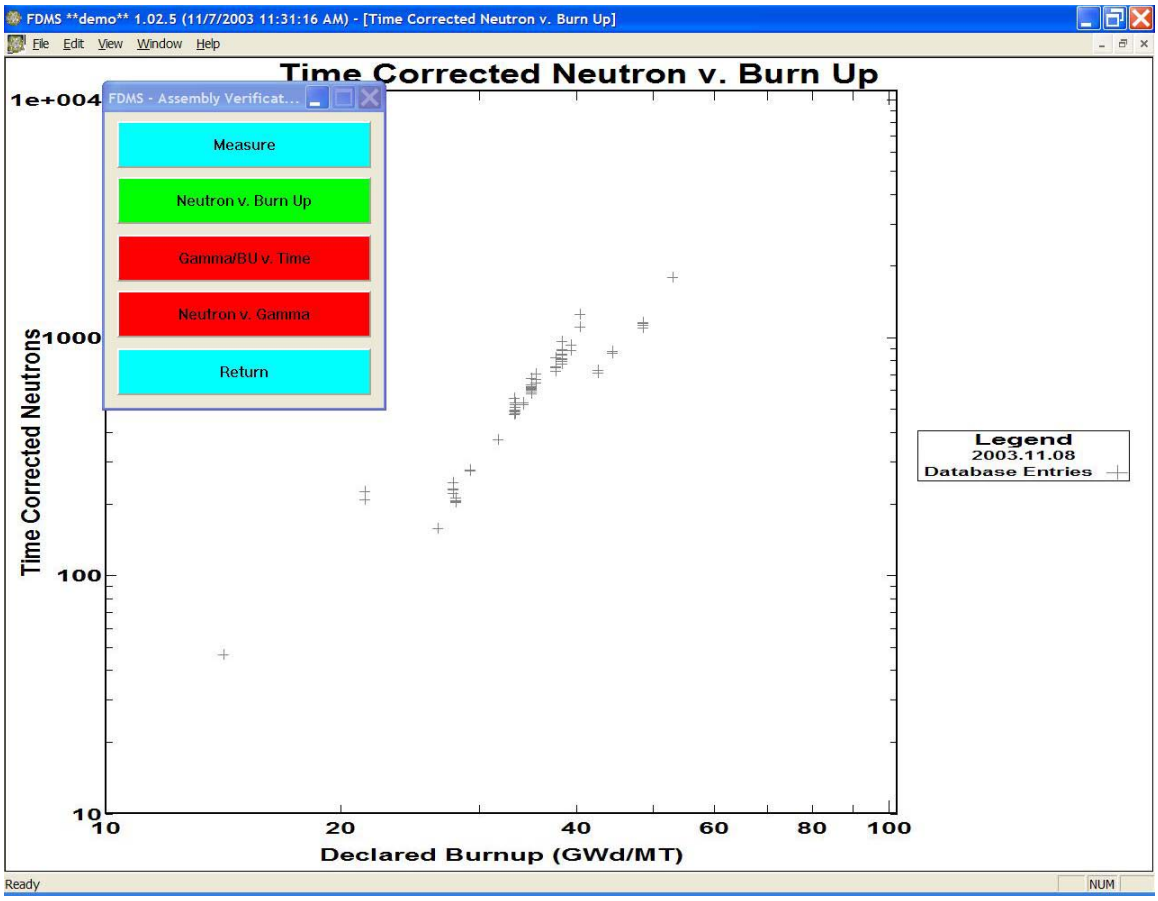


If the return button in the “FDMS - Cycle Verification” is pressed then the user is returned to the “FDMS – Verify” window shown earlier.

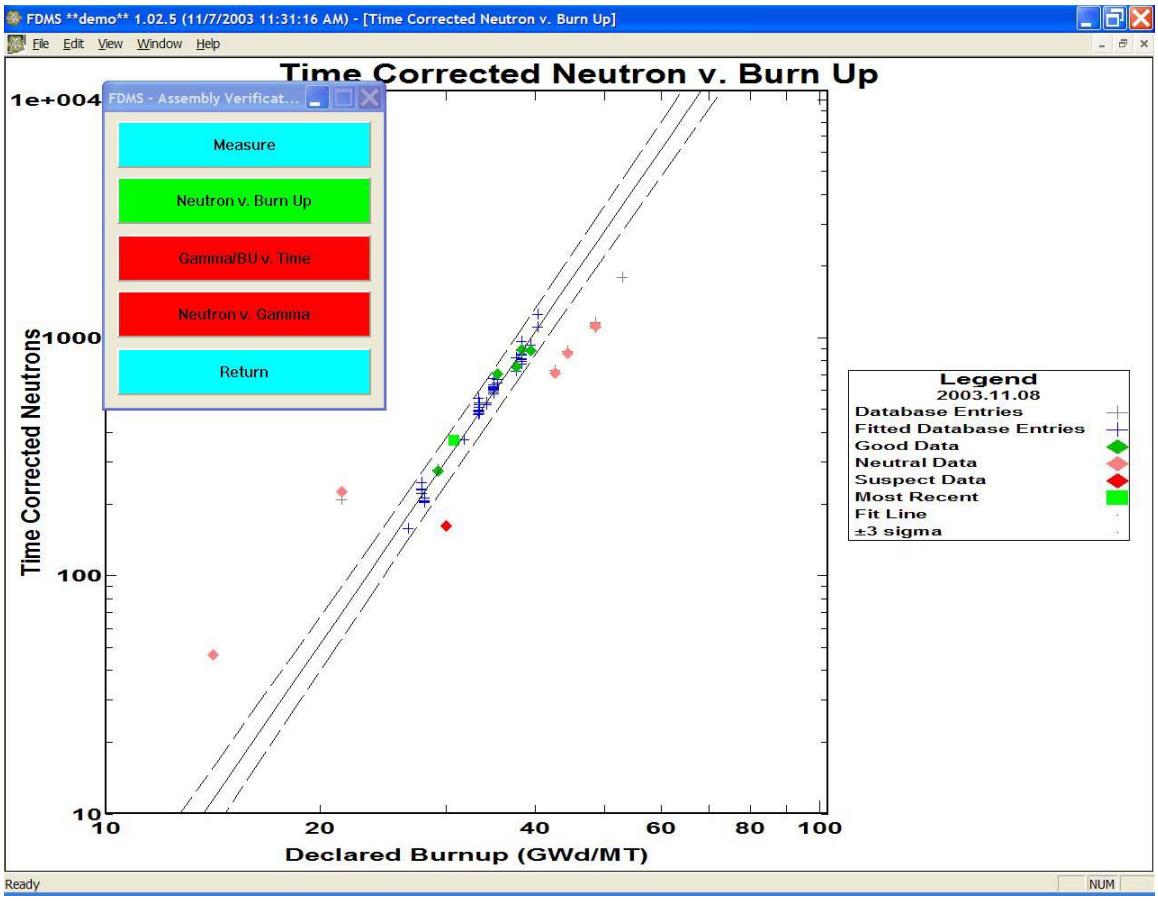
If the “Assembly Verification” button is clicked on, then the “FDMS – Assembly Verification” window is opened as shown below.



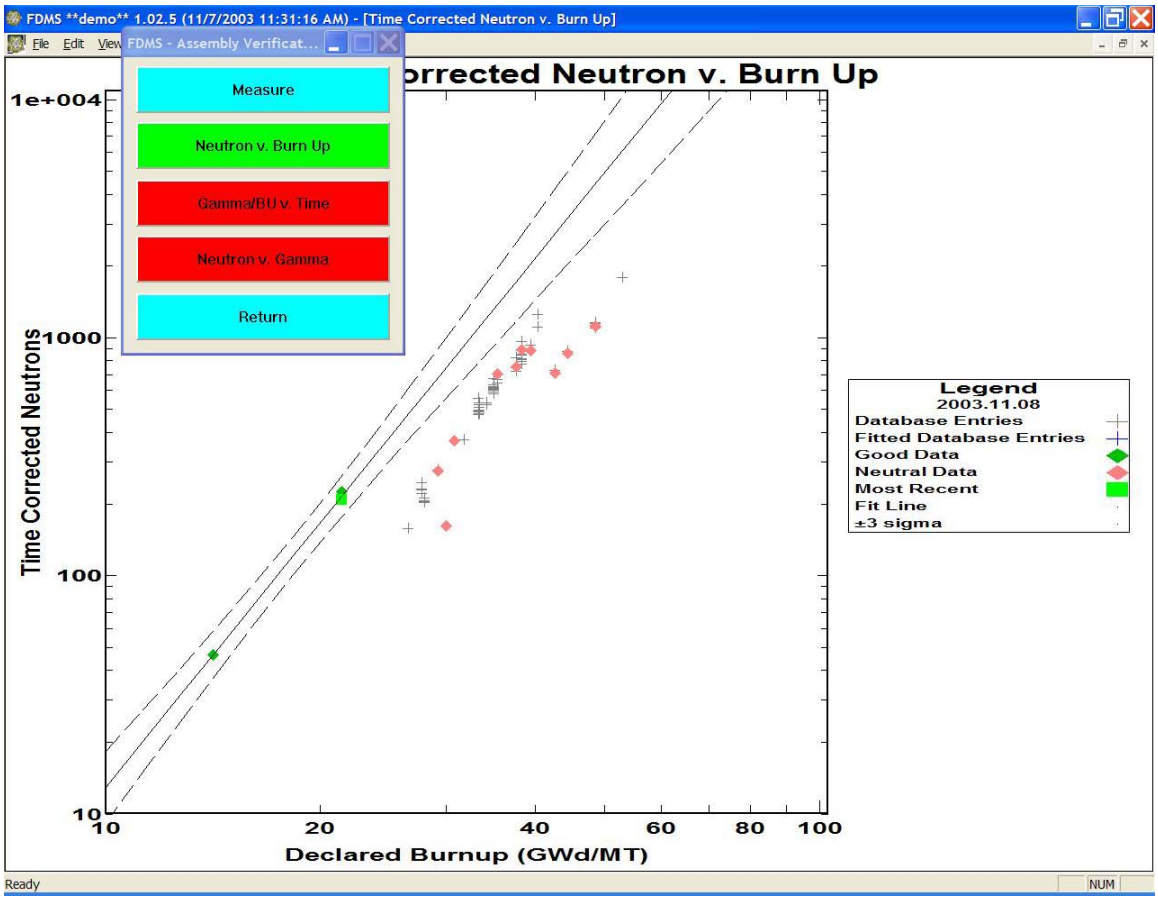
Three analysis options are available: Neutron v. Burn up; Gamma/BU v. Time; and Neutron v. Gamma. All are initially turned off. If the Neutron v. Burn up option is selected then the corresponding button turns green and the “Time Corrected Neutron v. Burn Up” window opens as shown below.



The displayed data points are all the type=2 measurements from the DB file. If the measurement option is selected then measurements are performed in the method described above, but the analysis performed is different. An example of a Neutron v. Burn Up plot, after several measurements, is shown below.

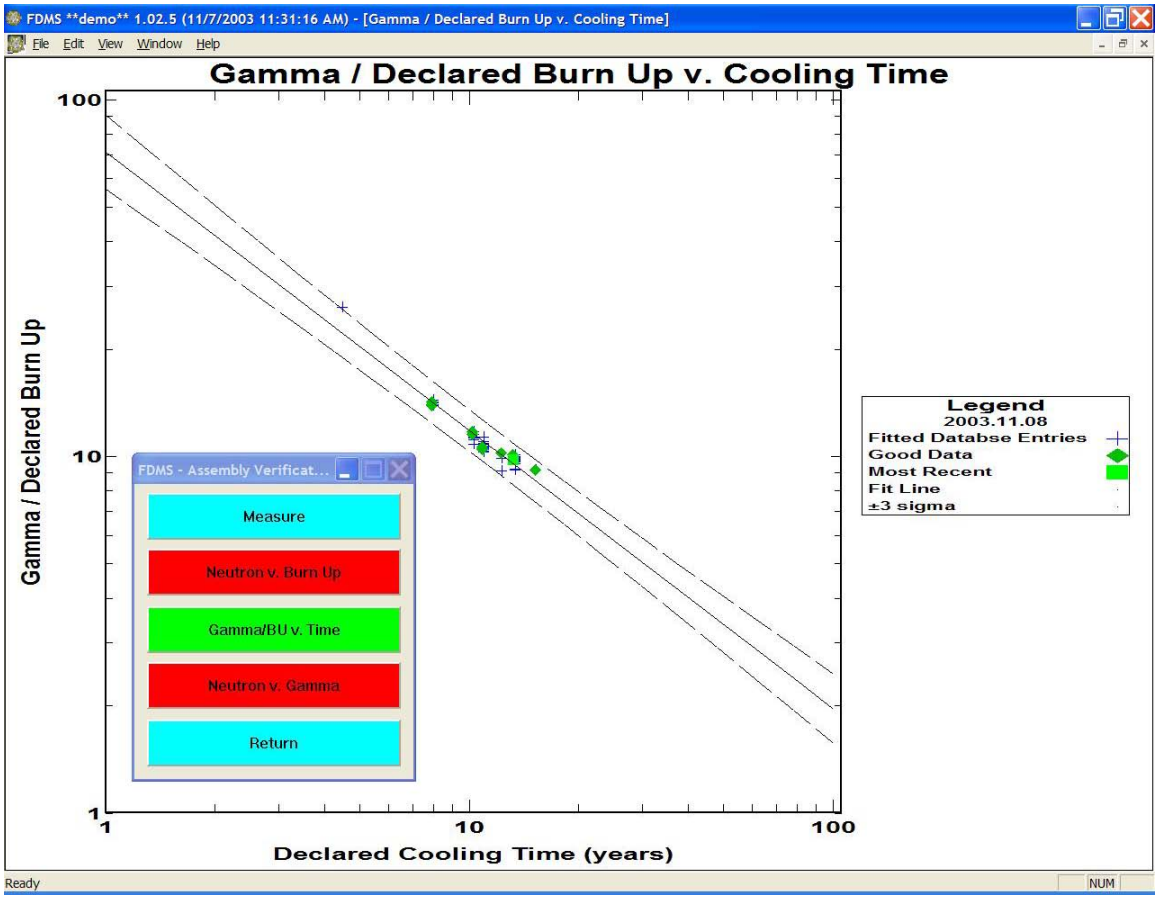


Notice that eight classes of objects are displayed in the plot (see the legend). The most recent measurement is shown by the square at a Burn Up of ~30 GWd/MT and a Time Corrected Neutrons of ~300 (1/s). In this case the most recent measurement was of an assembly with an initial ^{235}U enrichment of 2.9%, and DELTA_ENRICHMENT parameter was set to 0.15%. The fitted database entries are those with enrichments from 2.75% to 3.05%. The database entries with enrichments beyond this range are displayed with gray crosses. The measurements of assemblies with enrichments in the 2.75% to 3.05% range are assigned the labels “good” or “suspect” by comparing them to the fit made to the “fitted” database entries. The solid line shows a standard linear regression fit, while the dashed lines show the corresponding 3-sigma confidence limits. The measurements that lie inside the 3-sigma limits are “good” and displayed in green. The measurements outside these limits are “suspect” and are displayed in red. Measurement on assemblies with enrichments more than DELTA_ENRICHMENT from the enrichment of the most recently measured assembly are assigned the label “neutral” and plotted in salmon (I think this should be changed to orange). The “neutral” points in the above plot are from measurement of assemblies with an enrichment of 1.78%, and a second set of measurements of assemblies with enrichment of 3.72 and 3.87%. If the next measurement is of another assembly with an enrichment of 1.78% then the generated Neutrons v. Burn Up plot is shown below.



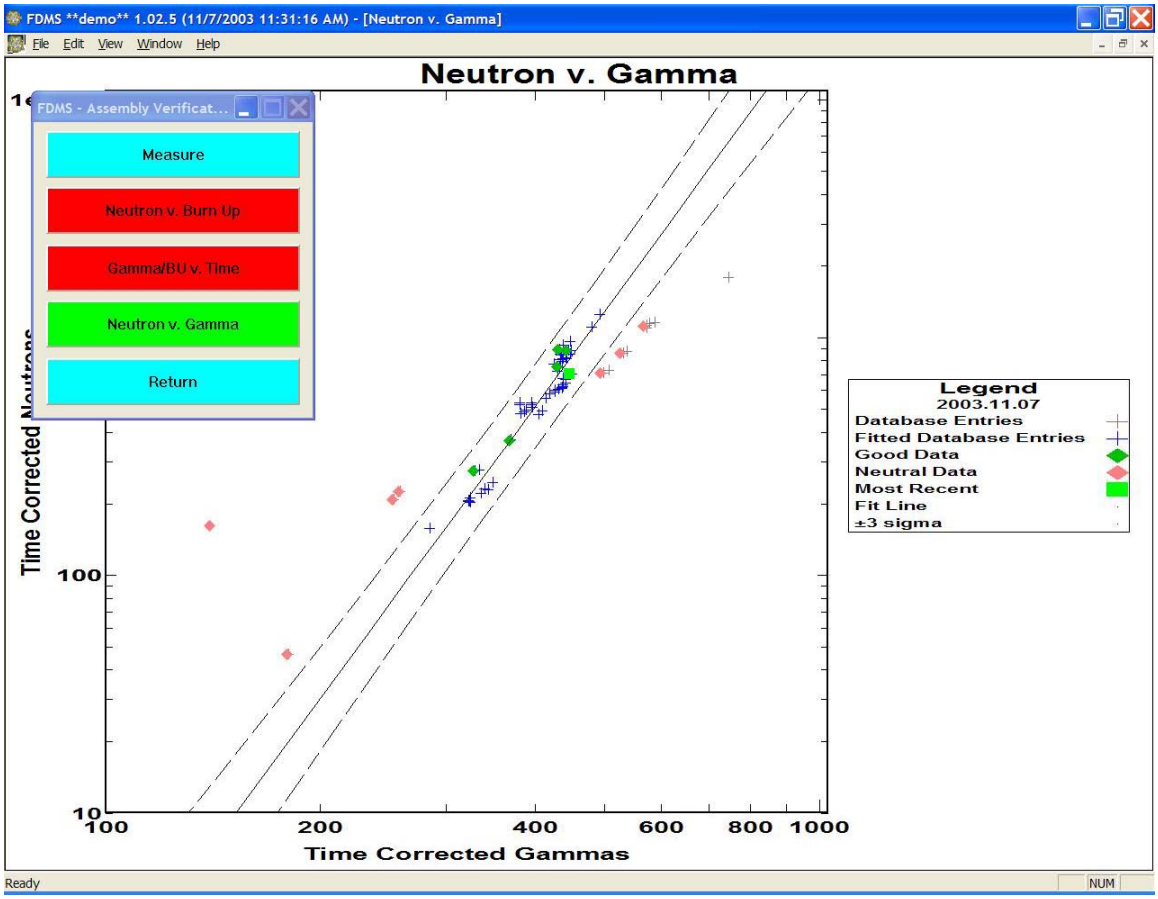
This new most recent point is compared to the DB entries with enrichments that are within 0.15% of 1.78%. The most recent measurement is the left of center point and has been assigned the status “good” and is displayed by a green square. What was previously the “neutral” point at a burn up of ~21 GWd/MT has an enrichment within 0.15% of 1.78% and can thus be compared to the new fitted database entries. Its status has been changed from “neutral” to “good”. The other measurements were of assemblies with enrichments of ~2.9%. These cannot be compared to the new fitted database entries and are thus assigned the status “neutral”.

An example of a Gamma/BU versus Cooling-time plot is shown below.



This type of test is relatively insensitive to the assembly enrichments and thus all database entries can be simultaneously fitted, without reference to the enrichment.

An example of a Neutron v. Gamma plot is shown below.



This type of test is sensitive to the assembly enrichment and, despite time corrections to both the neutron and gamma data, this test is also very sensitive to the cooling time. However, it is possible that for assemblies with similar enrichments and the same cooling times, this test may meet the requirements for a partial defect measurement. In the example shown above the parameters DELTA_ENRICHMENT and DELTA_COOLING time were set to 0.15% and 0.2 years, respectively. The large number of “neutral” points is because many of the previous measurements have (in this case) either enrichments more than 0.15% away from that of the most recent assembly, or cooling time more than 0.2 years different from that of the most recent assembly. However, the 3-sigma limits for this test are significantly narrower than in the other two tests.

The user may choose to turn on any combination of the assembly verification tests. With more than one of the tests on, measurement points are only assigned the status “good” if the measurement points pass all “on” tests. The status “suspect” is assigned to a measurement point if it fails a single “on” test. If a point is labeled “neutral” in any of the “on” tests then it will be “neutral” in all tests.

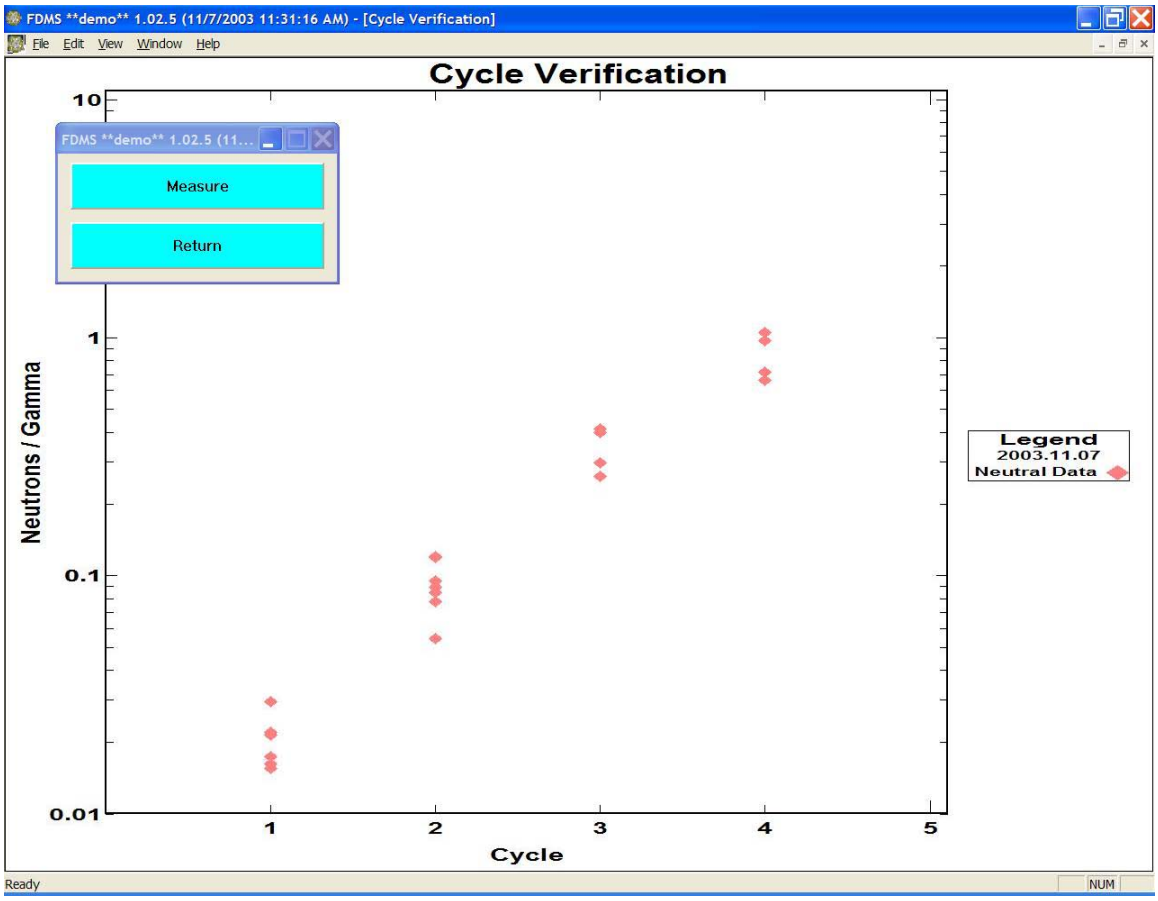
There can be anomalous results associated with small DB files. For example, if only one or two DB entries can be compared to a “most recent measurement” then strange results

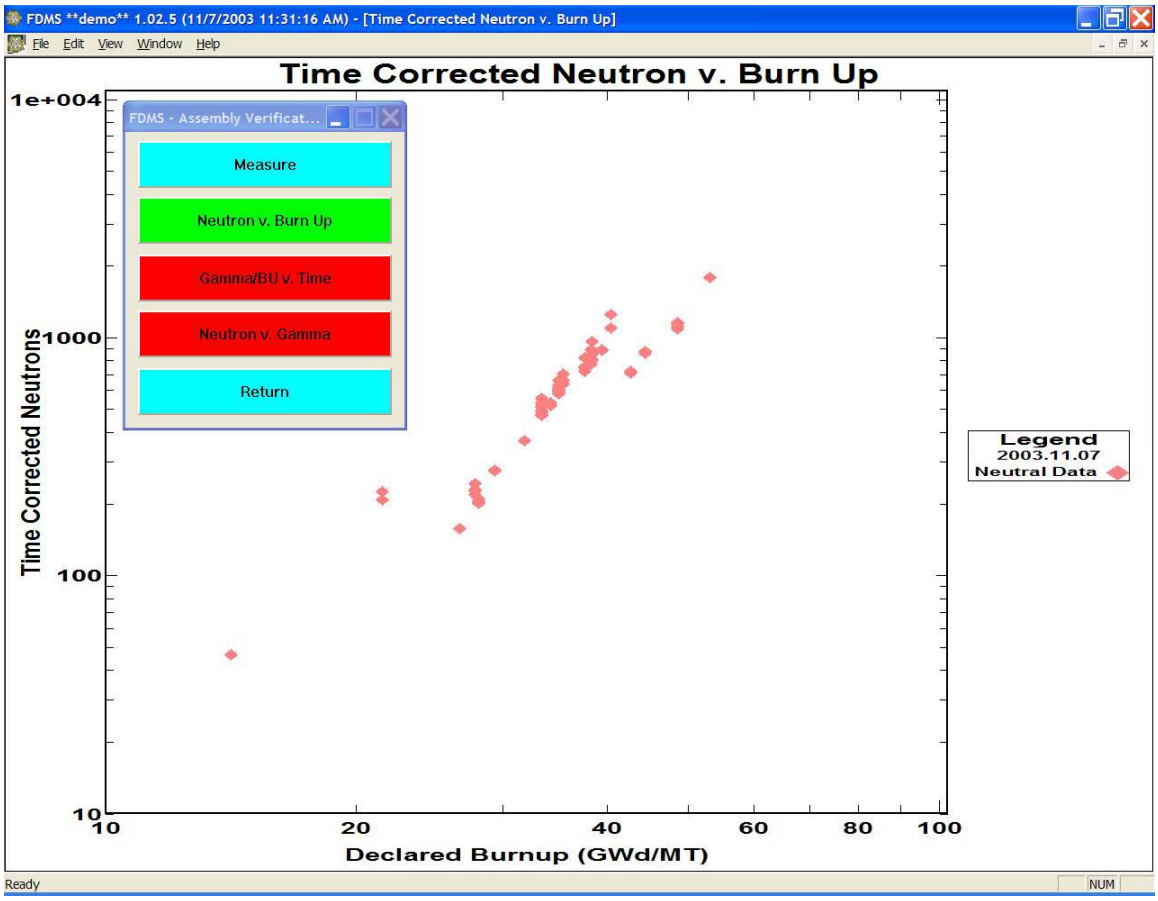
can be obtained because of problems in getting linear fits, with confidence limits, to data sets containing less than three points. At the present time, users should avoid cases where new measurements will be compared to less than three DB entries. If this is done, the user should ignore the strange plot(s) and move on to the next measurement. This problem will be fixed.

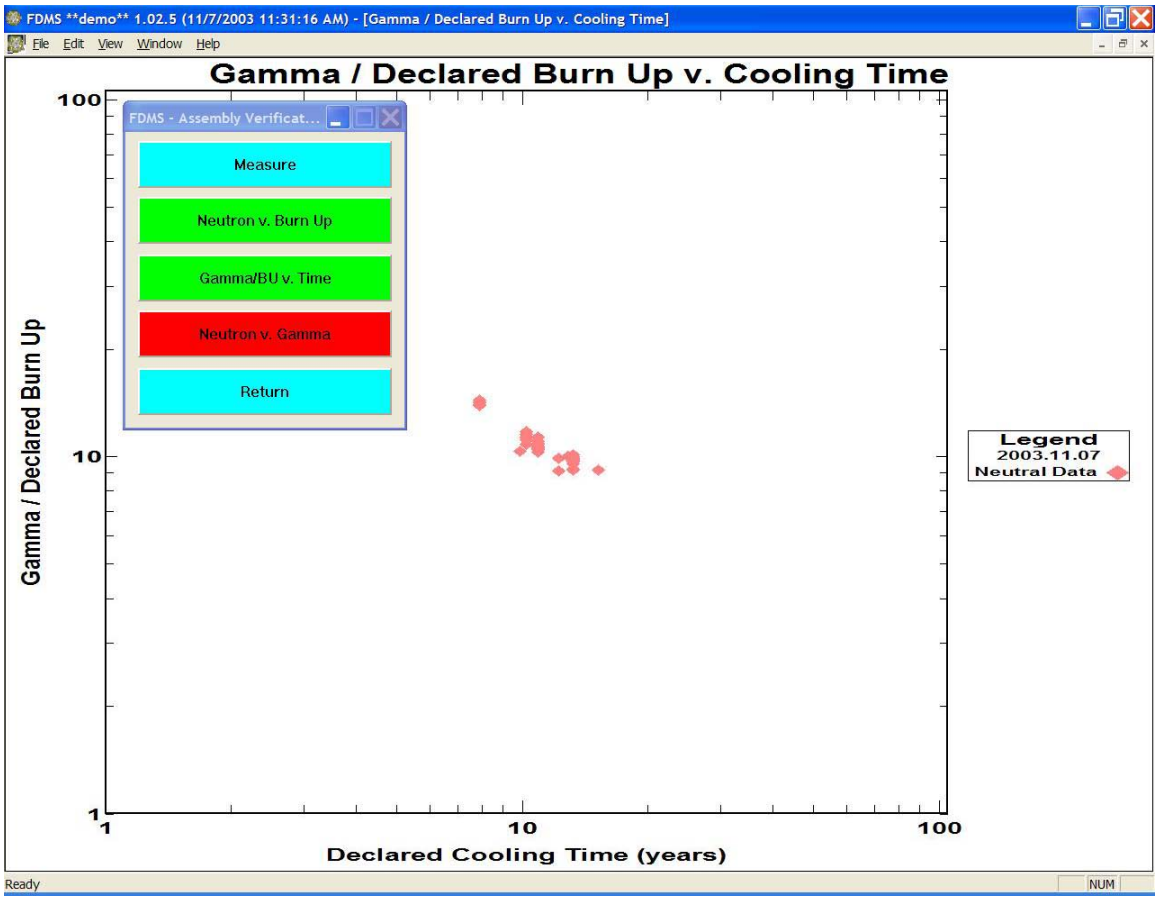
Using the software without any initial DB entries

It may be necessary to perform measurements without any initial DB entries; this is, make new measurements without comparing them to past measurements. This can be done, but the DB file must exist and contain the single line of header information as described in the “Database (DB) file” section. With no existing DB entries, the software labels all measurement points “neutral”.

If all the assemblies in the original MP file, sent in the software package, are selected and measured with the demo version of the software then the corresponding Neutrons/Gamma v. Cooling Time, Neutrons v. Burn UP, and the Gamma/Bu v. Cooling Time plots are as shown below. The Neutron v. Gamma plot can be selected but the results may look strange. LANL needs to check to see what the time corrected gamma values are in this case, because the time correction for the gammas is determined using a fit to the DB entries and because none exist we are unclear what is being displayed. This will be sorted out later.


FDMS **demo** 1.02.5 (11/7/2003 11:31:16 AM) - [Cycle Verification]
File Edit View Window Help
Cycle Verification
FDMS **demo** 1.02.5 (11...
Measure
Return
10
1
0.1
0.01
Neutrons / Gamma
1
2
3
4
5
Cycle
Legend
2003.11.07
Neutral Data
Ready
NUM


FDMS **demo** 1.02.5 (11/7/2003 11:31:16 AM) - [Time Corrected Neutron v. Burn Up]
File Edit View Window Help
Time Corrected Neutron v. Burn Up
FDMS - Assembly Verificat...
Measure
Neutron v. Burn Up
Gamma/BU v. Time
Neutron v. Gamma
Return
1e+004
1000
100
10
Time Corrected Neutrons
10
20
40
60
80
100
Declared Burnup (GWd/MT)
Legend
2003.11.07
Neutral Data
Ready
NUM

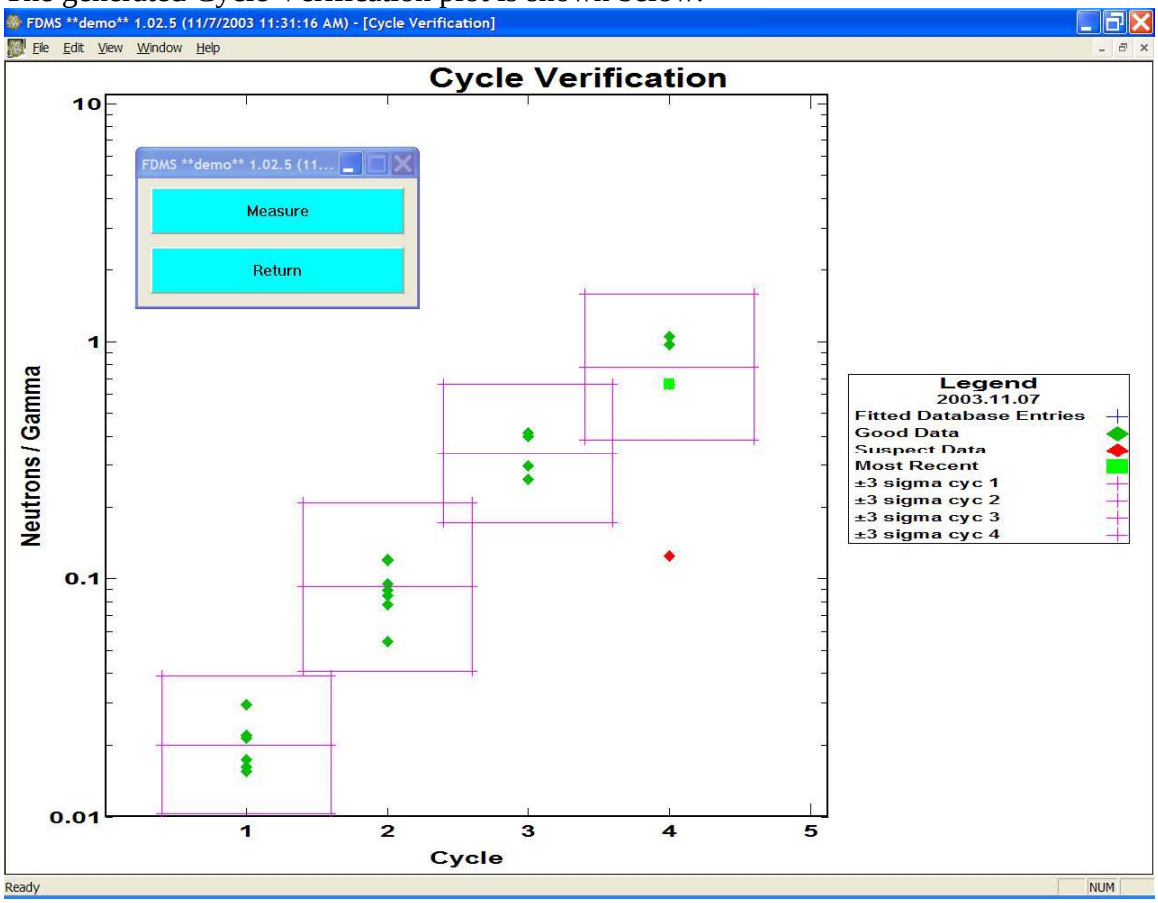


Analysis of new measurements without a DB file containing previous measurements

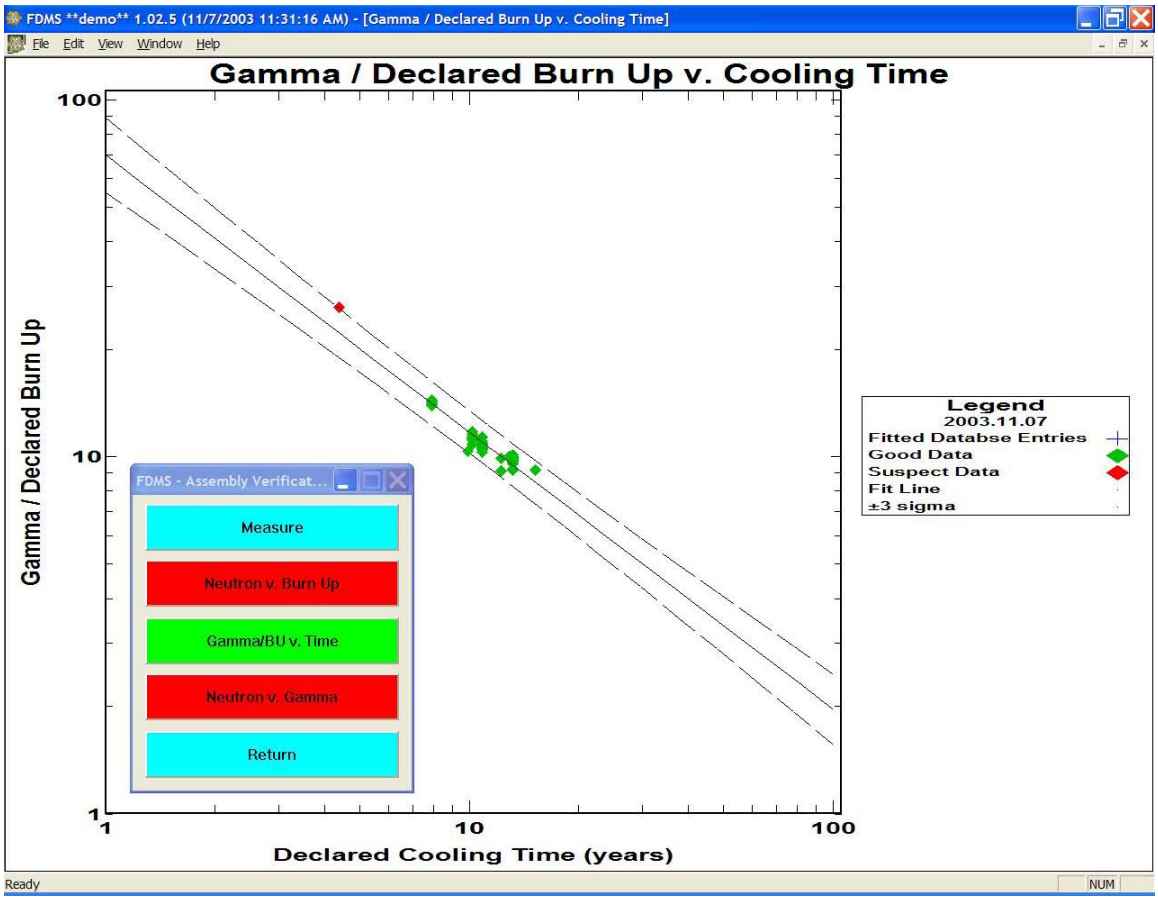
The FDMS software is presently configured such that the standard analysis mode is as follows: new measurements of assemblies declared in the MP file are compared to previous measurements of similar assemblies, from the same or a similar facility, measured by the same or similarly calibrated fork detector, stored in the DB file. However, if no previous measurements exist then a self-consistency check can be performed by comparing a collection of new measurements to themselves. To do this, first remove any non-measured items from the MP file and save a new version of the MP file containing only measured items. This creates a DB file that matches the MP file. These changes and file creations can be performed using Excel. When saving new *.csv files remember to answer “yes” when asked the question “to keep this format, which leaves out incompatible features, click yes”. After the MP file has been edited, and the new DB file created, execute the demo version of the FDMS software. In this way the user can force the software to re-read the new measurement results from the MP file and then force the software to compare these measurements to themselves. The DB file should only contain “good” data and thus any obviously questionable data should be removed from the DB file. We have applied this procedure to the data displayed in the plots in the last section. The lowest point with a cycle number of 4 was removed from the

“created DB file” because it is obviously inconsistent with the other cycle 4 measurements.

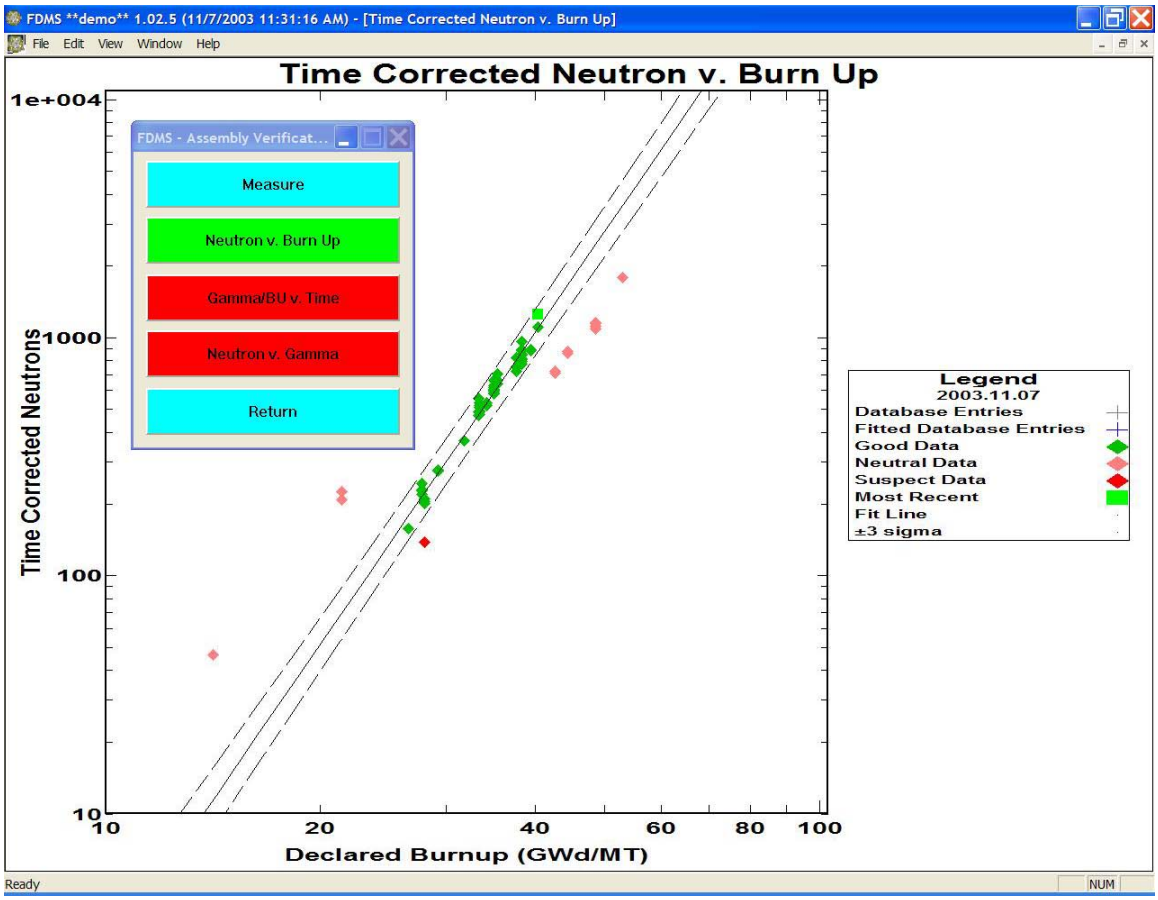
The generated Cycle Verification plot is shown below.



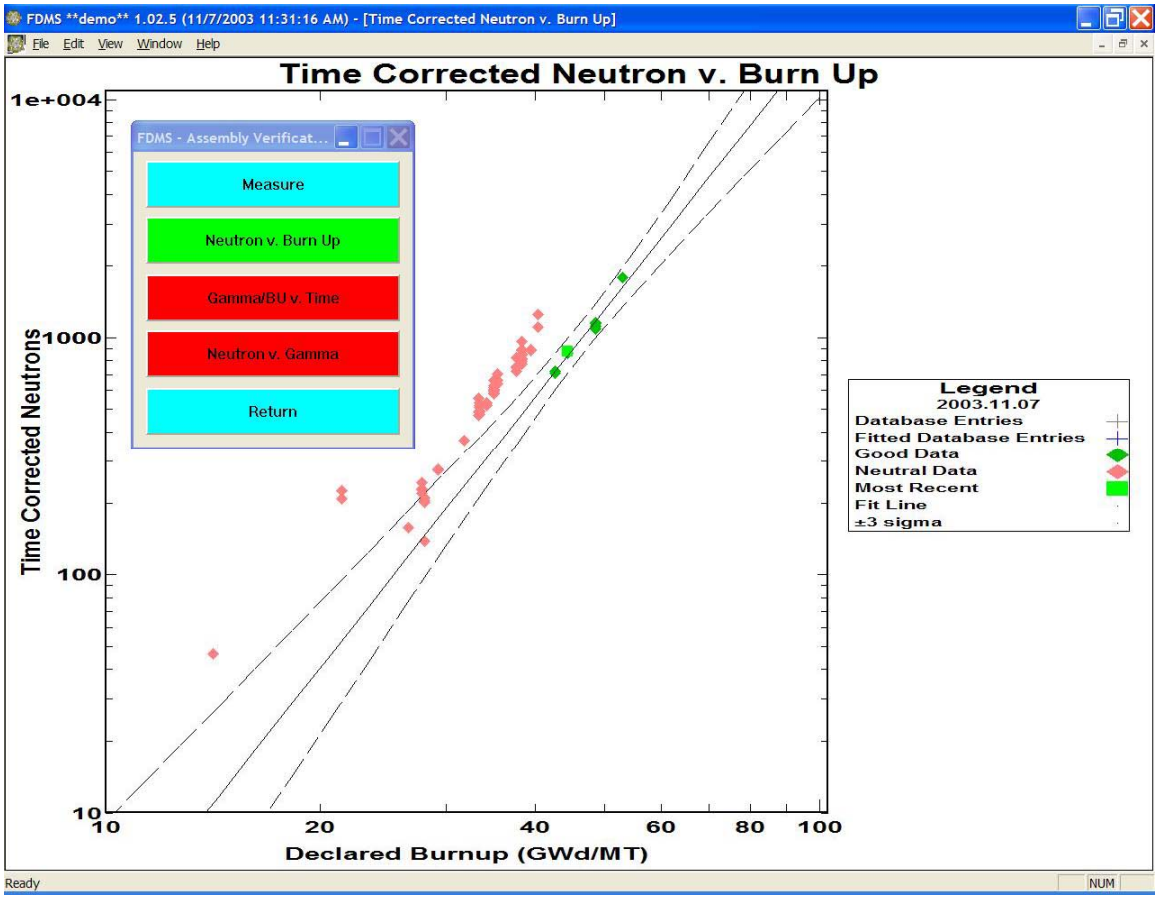
The Gamma / Declared Burn Up v. Cooling Time plot is generated without the need to make any fake measurements with the software because the Gamma / Burn up v. Cooling Time test is performed without reference to the assembly enrichment. This plot of the discussed data set is shown below.


FDMS **demo** 1.02.5 (11/7/2003 11:31:16 AM) - [Gamma / Declared Burn Up v. Cooling Time]
File Edit View Window Help
Gamma / Declared Burn Up v. Cooling Time
Gamma / Declared Burn Up
Declared Cooling Time (years)
100
10
1
1
10
100
Legend
2003.11.07
Fitted Databse Entries
Good Data
Suspect Data
Fit Line
±3 sigma
FDMS - Assembly Verificat...
Measure
Neutron v. Burn Up
Gamma/BU v. Time
Neutron v. Gamma
Return
Ready
NUM

The Neutron v. Burn Up, and Neutron v. Gamma plots require a most recent point before the software can determine which measurements in the DB file are to be compared to the measurements in the MP file. Remember that making fake (demonstration/training) measurements with the demo software will not change the measured data in the MP file. To generate the plot shown below, a 2.9% assembly was chosen from the MP file, and measured. Notice that one of the other 2.9% assembly measurements has been labeled "suspect" and is displayed by a red diamond. The measurements of the ~1.8% and ~3.8% enriched assemblies have been labeled "neutral" and are displayed on both sides of the 2.9% enrichment measurements.

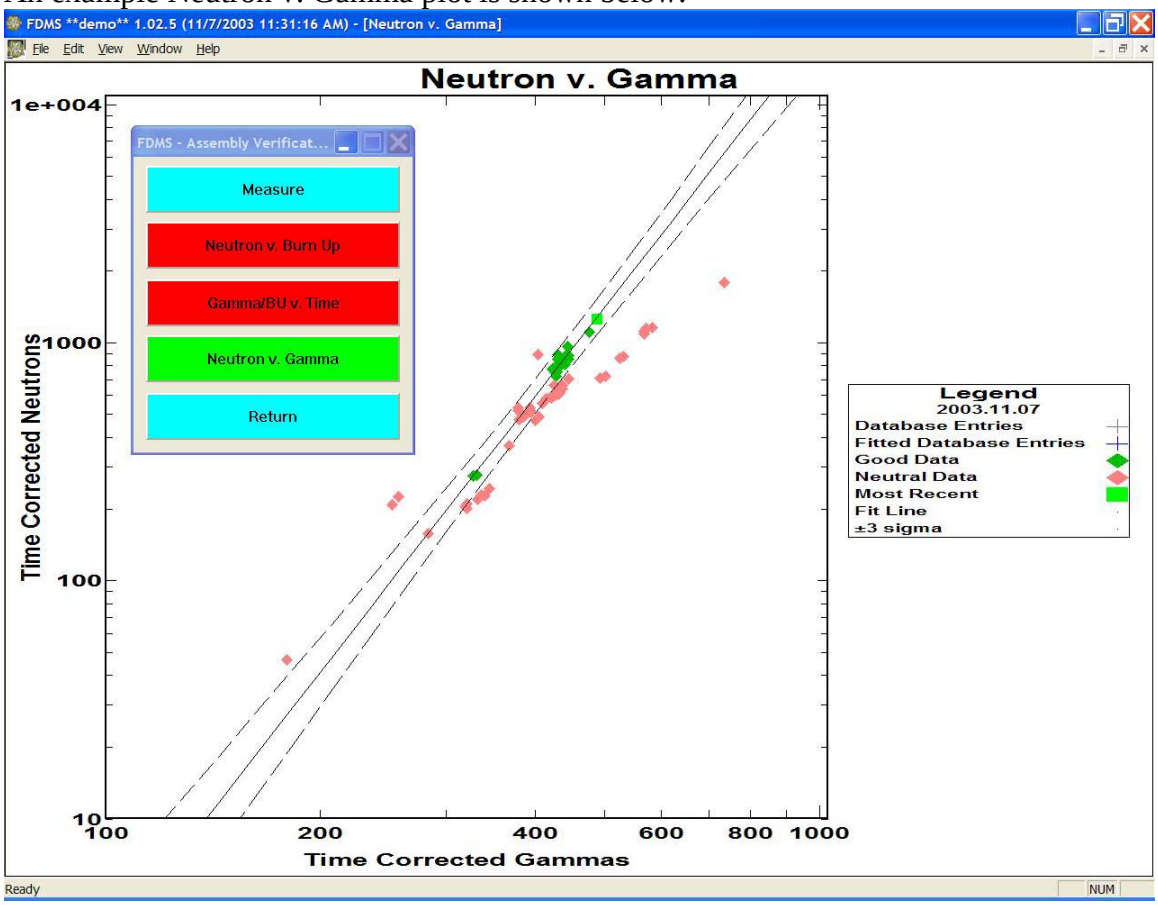


To analyze the measurements of the ~3.8% enriched assemblies, a demo measurement of one of the ~3.8% enriched items must be made. If this is done, then the generated plot is shown below.



All of these ~3.8% enriched measurements have been labeled “good”. Notice that the ~1.8% and ~2.9% enriched measurements are now the “neutral” points.

An example Neutron v. Gamma plot is shown below.



Please remember that the Neutron v. Gamma test requires points with enrichments and cooling times close to the corresponding values of the most recent measurement. In the example shown above the parameters DELTA_ENRICHMENT and DELTA_COOLING time were set to 0.15% and 0.2 years, respectively. The large number of “neutral” points is because many of the measurements have (in this case) either enrichments more than 0.15% away from that of the most recent assembly, or cooling time more than 0.2 years different from that of the most recent assembly. Wider ranges of enrichments and cooling times will produce a broadening of the 3-sigma limits and will weaken this test. Without research into more complex time and enrichment corrections, the Neutron v. Gamma plots are only likely to meet the requirements for a partial defect test if this analysis technique is limited to assemblies discharged at the same core re-fueling (i.e. very similar discharge dates) and with similar enrichments.

New features:

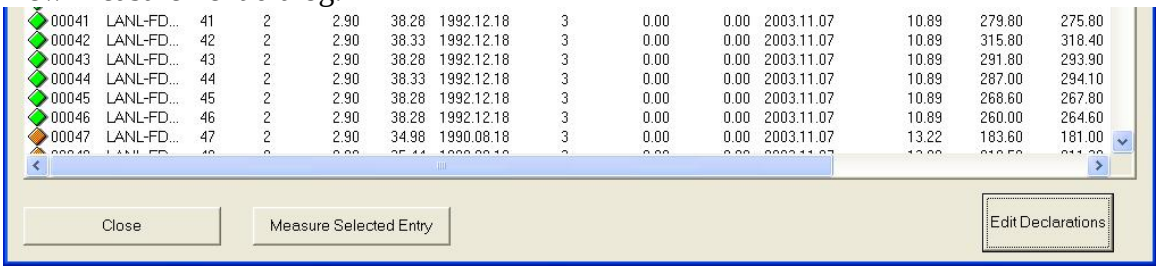
1. Editing, creating and removing a measurement plan entry.

The measurement dialog now allows a measurementplan entry to be edited from within the FDMS application. New entries can be created, entries may be deleted, and a small subset of information for an existing entry may be changed. This table (below)

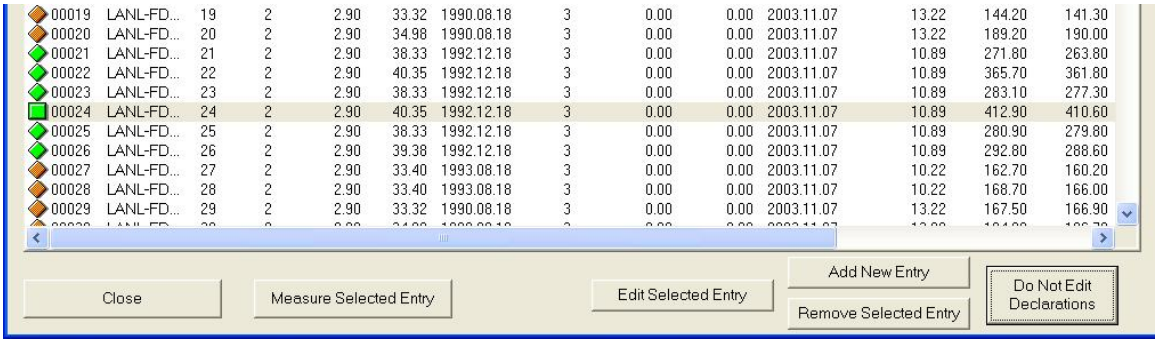
summarizes the 6 editable pieces of information per entry, with associated constraints on their values.

Name	Type or unitary value	Low range	High range	Example
Facility	Alphanumeric	Empty	32 characters	X22-F; Unit H
Assembly ID	Alphanumeric	Empty	32 characters	77B-1:30
Enrichment %	%	0.0	100.0	3.28
Burn Up	GWd / MT	0.0	100.0	31.08
Discharge Date	Year, month, day	January 1, 1950	February 18, 2038	2003.11.07
Cycle Number	Single digit	1	10	3

These new operations are available by selecting the “Edit Declarations” button on the New Measurement dialog.



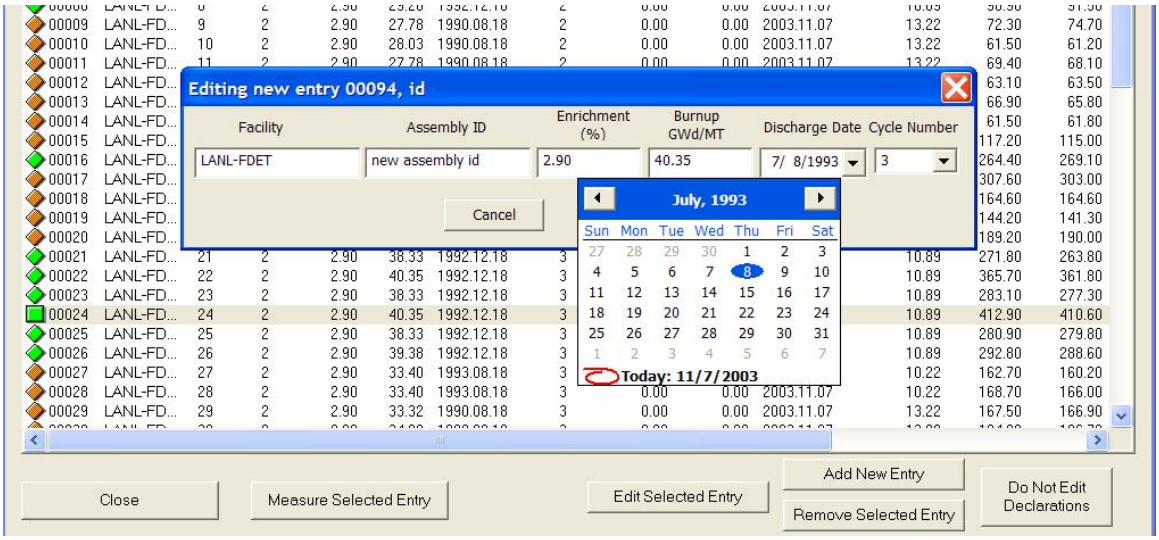
The “Edit Selected Entry”, “Add New Entry” and Remove Selected Entry” buttons appear.



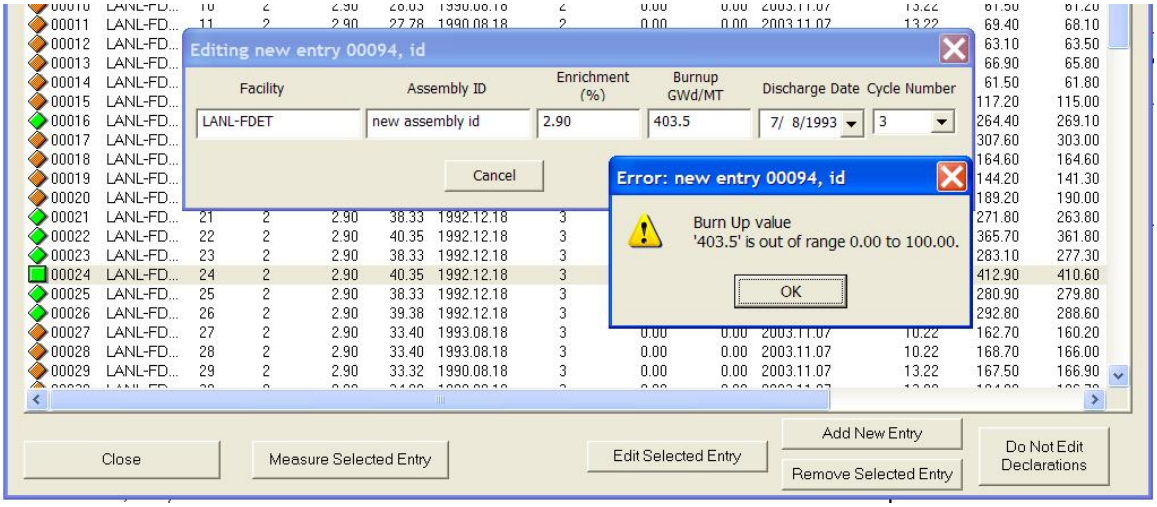
Add New Entry

To add a new entry, select a row that you would like to use as a source for data, and then press “Add New Entry”. A new row for the new entry is inserted into the list, and a dialog appears with 6 fields that can be edited for the new row.

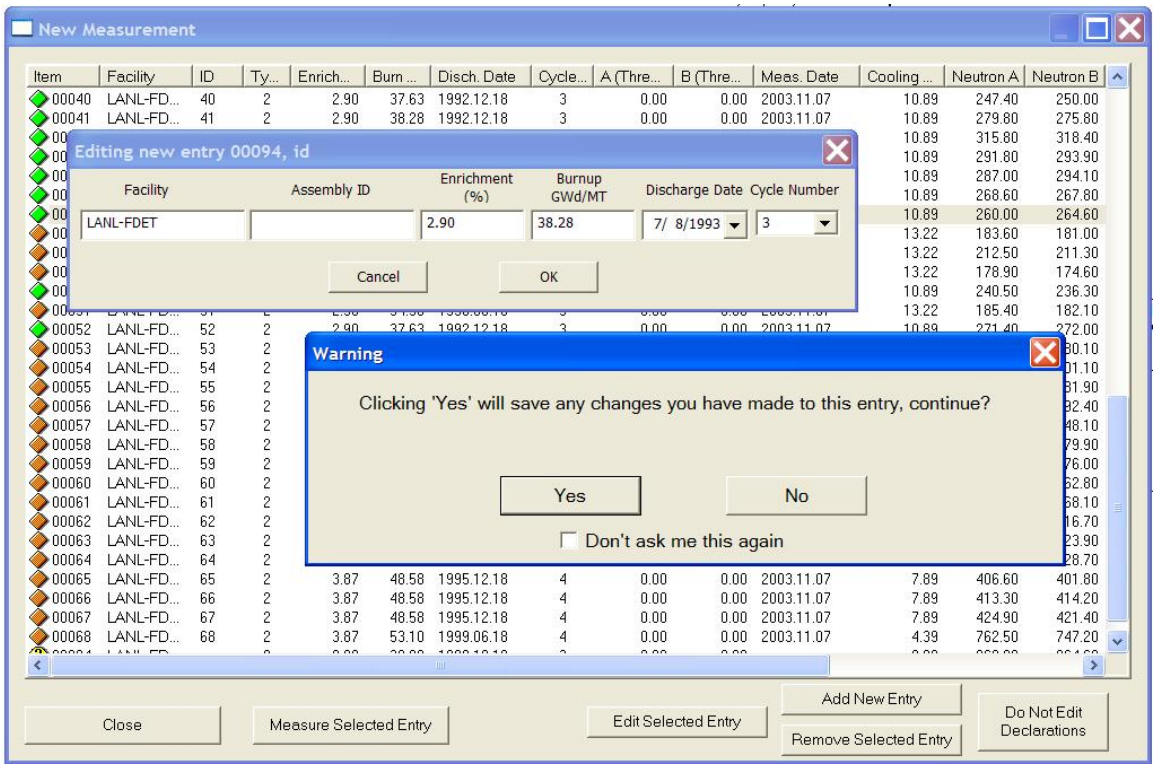
Useful data from the source entry will be copied to the new entry for your convenience. Values that must be measured or computed will initially be set to 0. A default unique Item ID is created for the new entry. You will then edit the 6 data items for the new entry with the Edit Entry dialog, (below). The example below shows a new entry edit dialog, with an assembly ID already entered by the user (‘new assembly id’), and the Discharge Date calendar tool active, choosing a new Discharge Date for this entry.



Each field will constrain your entry to values that are allowed. Below is an example of an error message that can occur when a range for Burn Up is exceeded. Clicking OK to a range entry warning reverts the offending value back to the previous acceptable value.

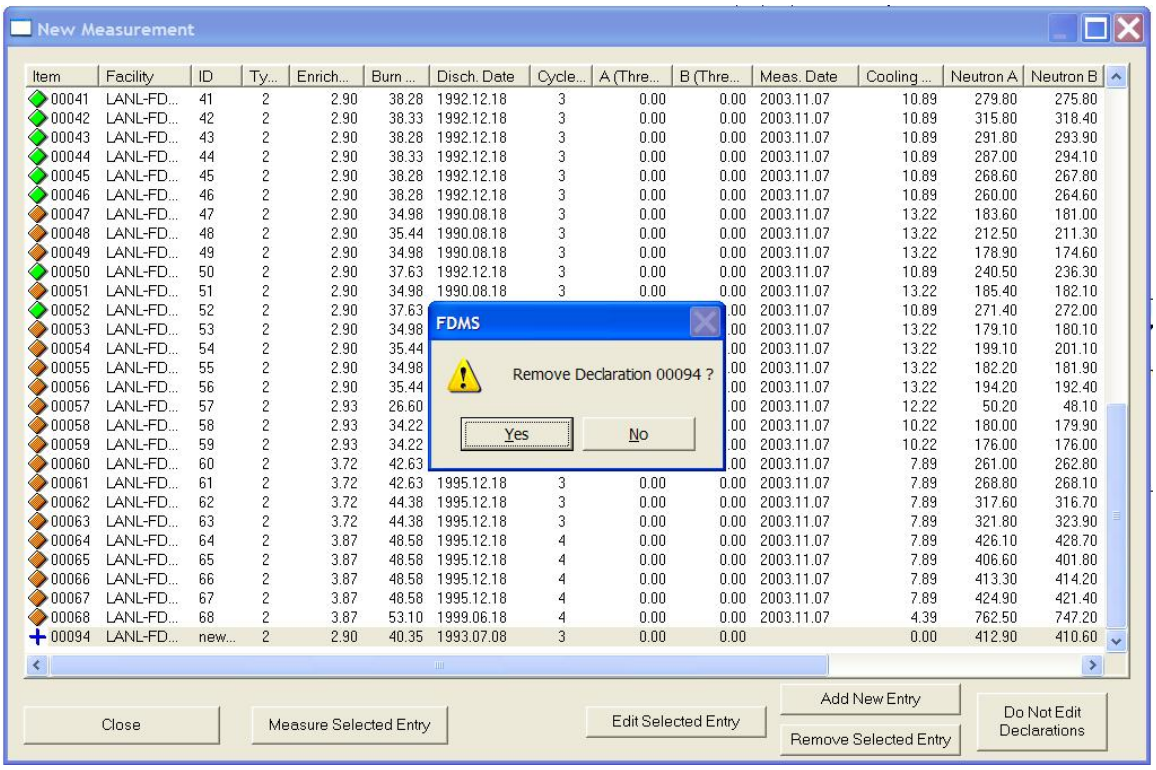


When you are ready to save your changes, click OK, and a confirmation dialog will be presented, choose “Yes” to save the changes you have made to the new entry.



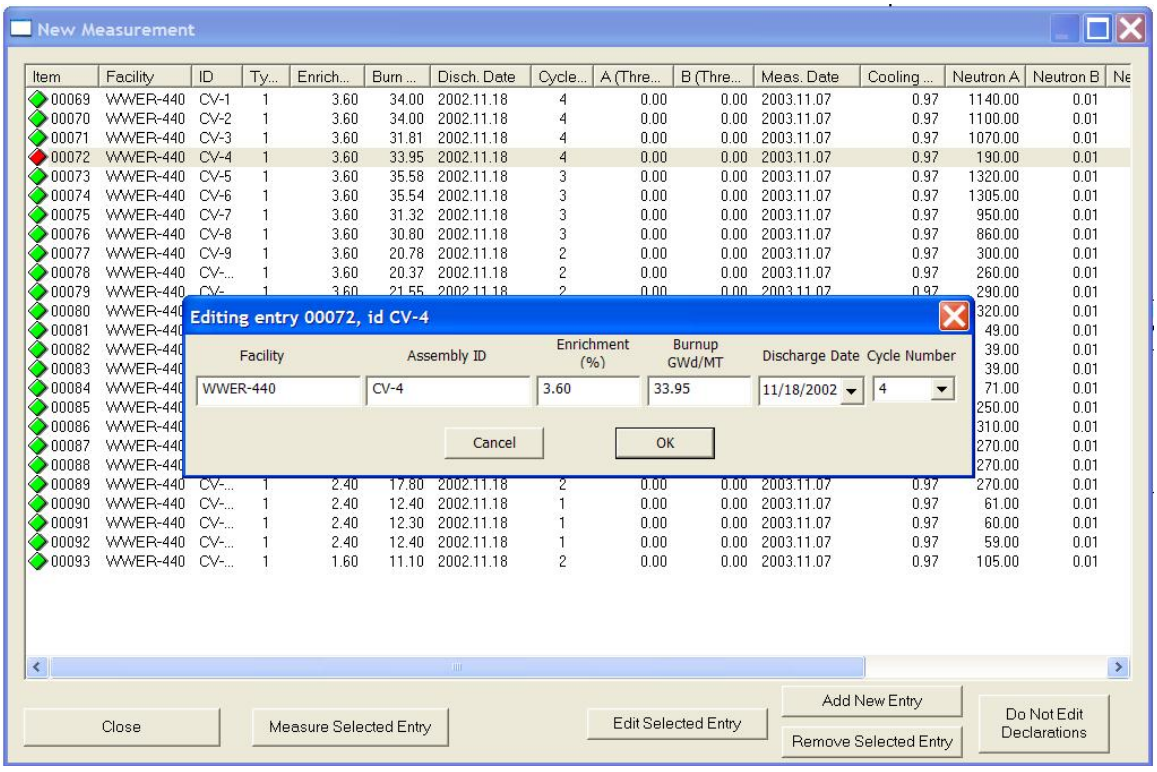
Remove Selected Entry

To remove an entry, select a row that you would like to remove, and then press “Remove Selected Entry”. A confirmation dialog is presented. Click “Yes” to delete the entry from the measurement plan.



Edit Selected Entry

To edit an existing entry, select the entry that you would like to edit, and then press “Edit Selected Entry”. The edit dialog is presented; you can modify the values and then save them, for more information, see the editing details in the “Add New Entry” description above.

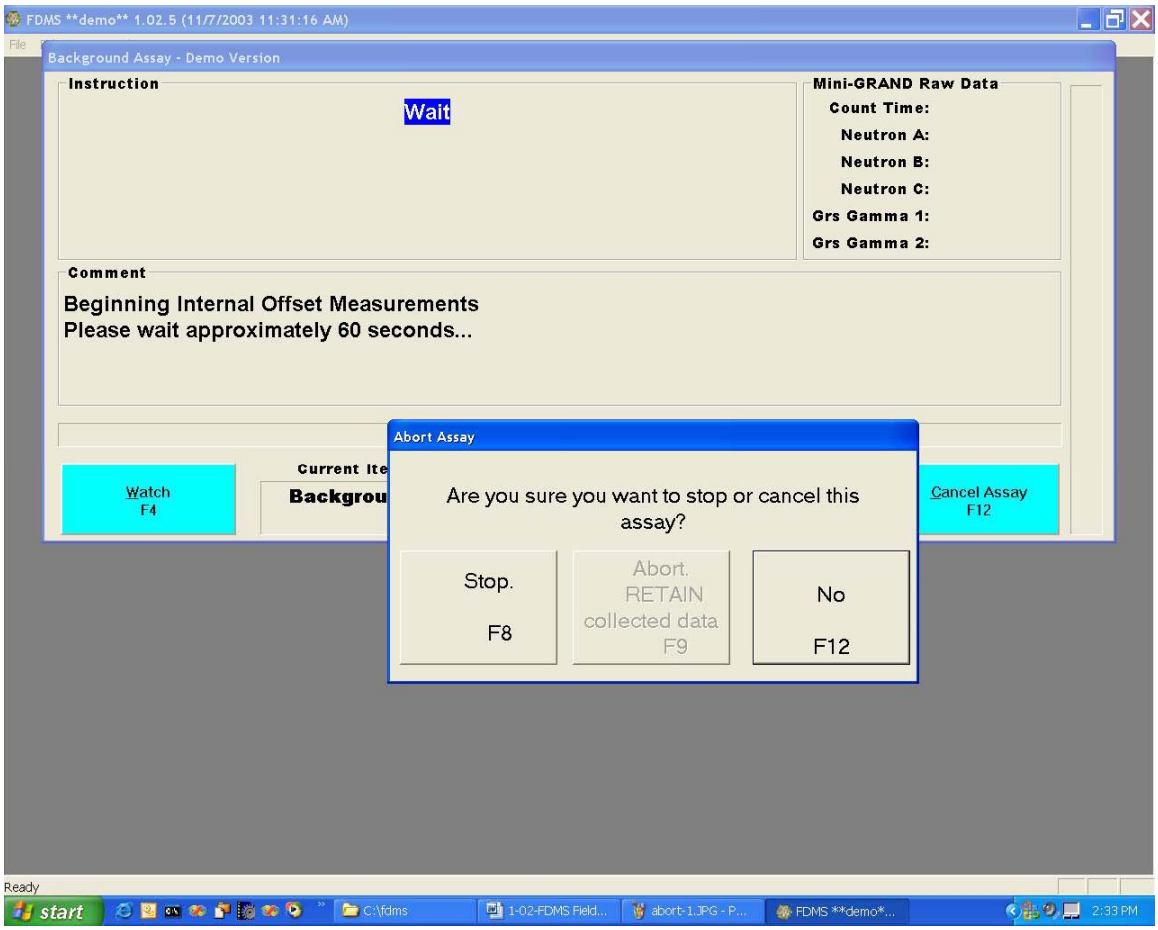


2. Aborting an incomplete attended measurement.

Upon commencement of a background or standard measurement, the measurement may be terminated early by selecting the Cancel button. If some data has been collected during the measurement, it may be retained.

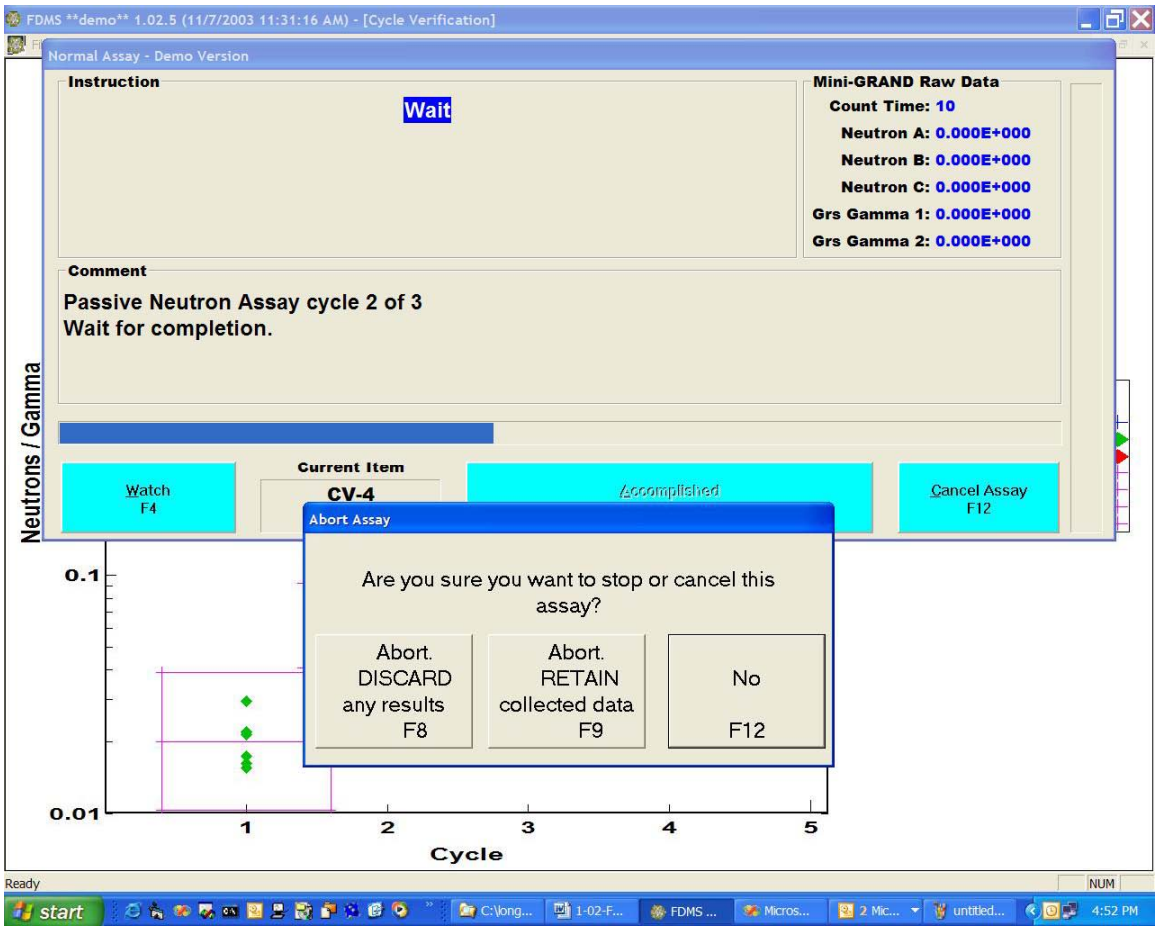
If the FDMS has not started the measurement cycle yet, (see the background assay example below), there will be no data available. The Abort Assay dialog will ask "Are you sure that you want to stop or cancel this assay?". Two choices are presented:

- Stopping the measurement by selecting the "STOP" button.
- Continuing with the measurement by selecting the "NO" button.



If the FDMS has not started the measurement cycle yet, (see the standard assay example below), there will be no data available. The Abort Assay dialog will ask “Are you sure that you want to stop or cancel this assay?”; Three choices are presented:

- “Abort, DISCARD any results”. Stops the measurement, discards any data collected.
- “Abort, RETAIN collected data”. Stops the measurement at the end of he current cycle, preserving the collected data as the measurement results.
- “No”. Continue with the measurement.

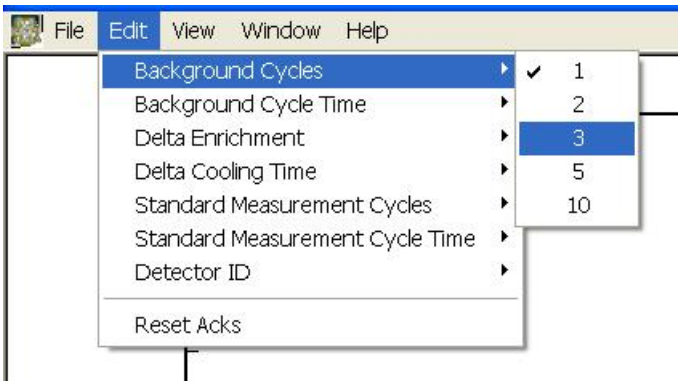


3. Changing measurement and analysis parameters from the FDMS menu.

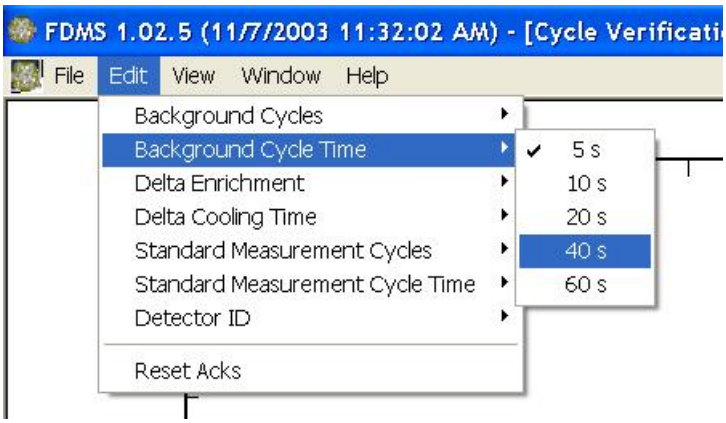
Some parameters may be changed with the FDMS application menus. 7 configuration parameters are available for modification from the main FDMS menu. Changing a parameter from the FDMS menu sets the new value active in FDMS, until FDMS is closed or shut down. You have the option, offered at program closing time, to save the changes permanently in the FDMS configuration file.

5 parameters modify measurement parameters.

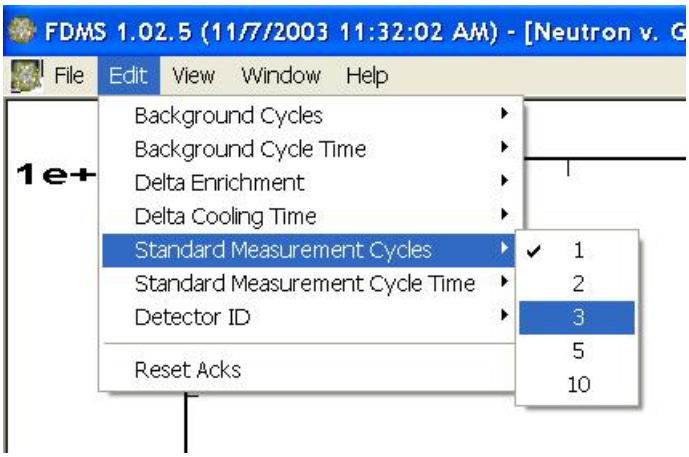
Background Cycles, set the value of the **BGCYCLES** configuration parameter (see the section entitled “Initialization (INI) file” (above) for details of this configuration value.) To provide an initial list of values for the menu, use the **BGCYCLES_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **BGCYCLES_CHOICE**=1,2,3,5,10



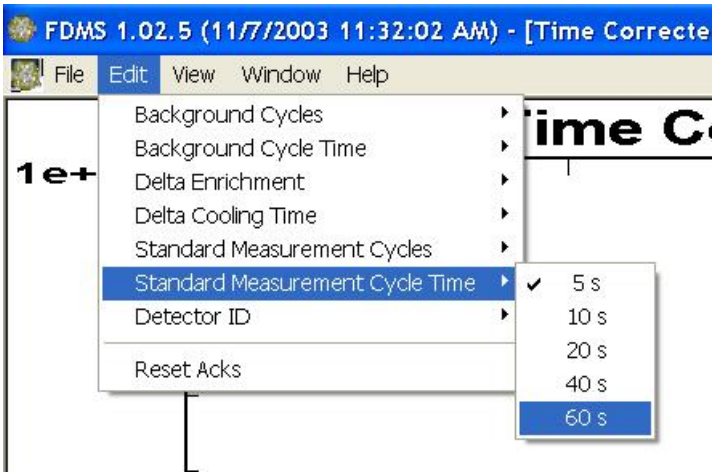
Background Cycle Time, sets the value of the BGCYCLETIME configuration parameter (see the section entitled "Initialization (INI) file" (above) for details of this configuration value.) To provide an initial list of values for the menu, use the **BGCYCLETIME_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **BGCYCLETIME_CHOICE**=5,10,20,40,60



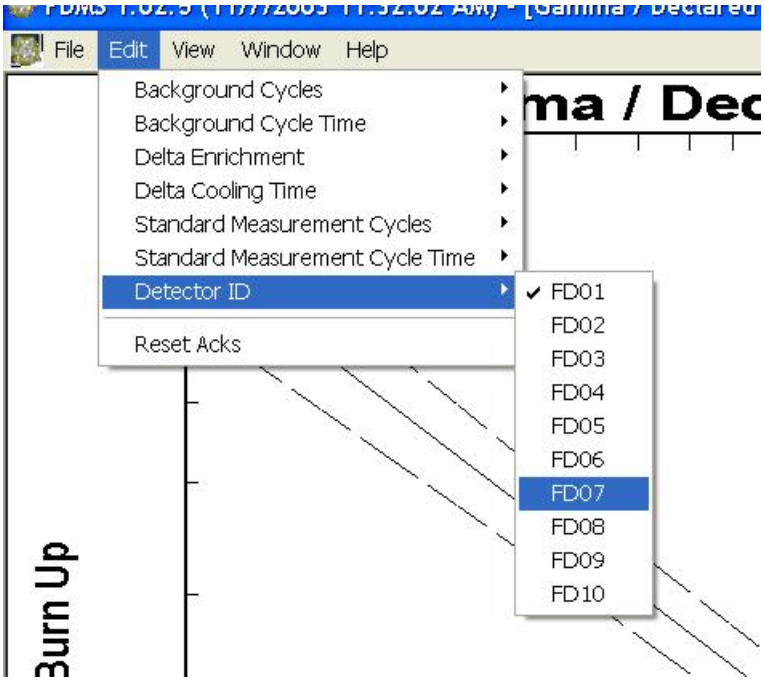
Standard Measurement Cycles, sets the value of the **CYCLES** configuration parameter (see the section entitled "Initialization (INI) file" (above) for details of this configuration value.) To provide an initial list of values for the menu, use the **CYCLES_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **CYCLES_CHOICE** =1,2,3,5,10



Standard Measurement Cycle Time, sets the value of the **CYCLETIME** configuration parameter (see the section entitled "Initialization (INI) file" (above) for details of this configuration value.) To provide an initial list of values for the menu, use the **CYCLETIME_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **CYCLETIME_CHOICE**=5,10,20,40,60

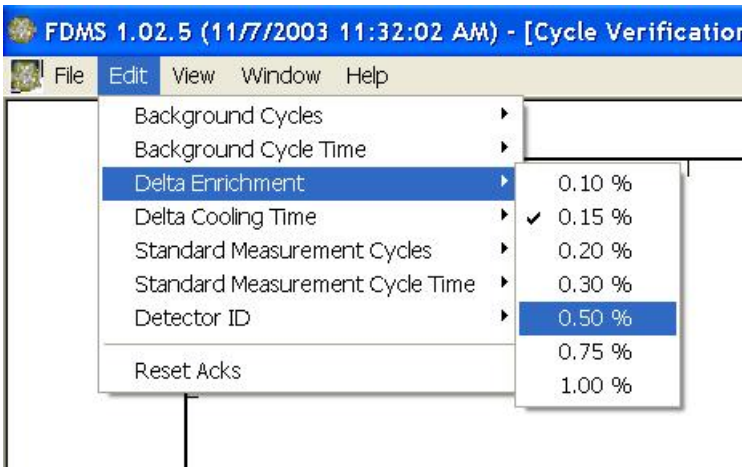


Detector ID, sets the value of the **DETECTOR_ ID** configuration parameter. This value is assigned to each new measurement and stored in the measurementplan file with the measurement results. To provide an initial list of values for the menu, use the **DETECTOR_ID_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **DETECTOR_ID_CHOICE**=FD01, FD02,FD03,FD04,FD05,FD06,FD07



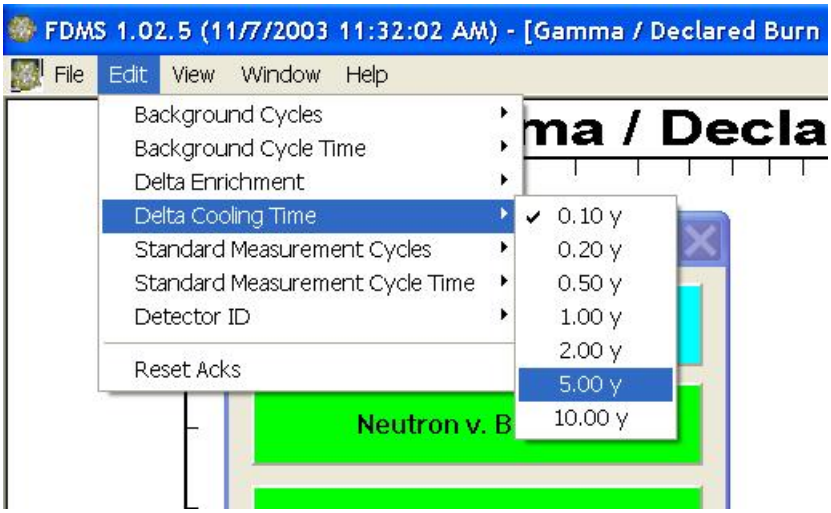
2 Parameters modify post measurement analysis values

Delta Enrichment, sets the value of the **DELTA_ENRICHMENT** configuration parameter (see the section entitled “Initialization (INI) file” (above) for details of this configuration value.) To provide an initial list of values for the menu, use the **DELTA_ENRICHMENT_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **DELTA_ENRICHMENT_CHOICE** =0.1,0.2,0.3,0.5,0.75,1.0

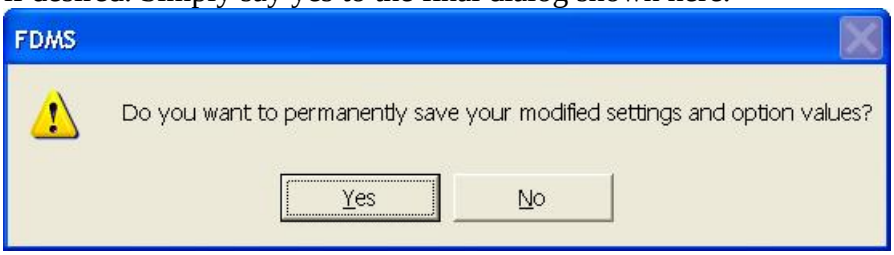


Delta Cooling Time sets the value of the **DELTA_COOLINGTIME** configuration parameter (see the section entitled “Initialization (INI) file” (above) for details of this

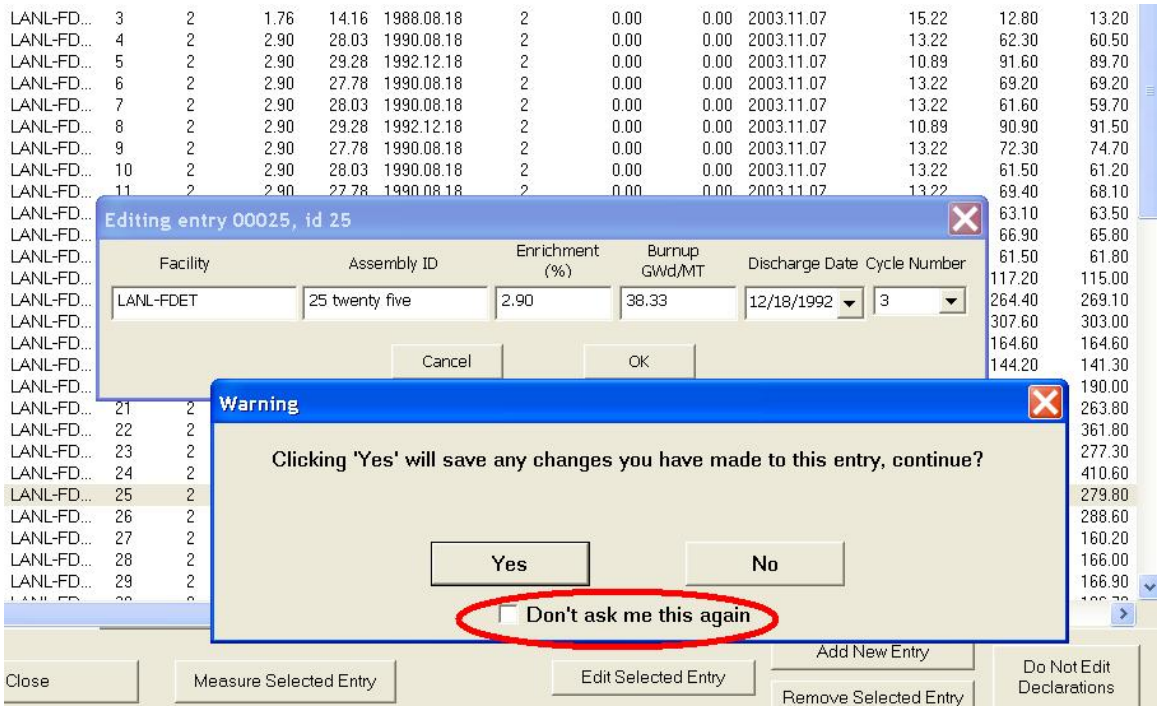
configuration value.) To provide an initial list of values for the menu, use the **DELTA_ COOLINGTIME_CHOICE** configuration parameter. Supply a comma delimited list of values, i.e. **DELTA_COOLINGTIME_CHOICE** =0.1,0.2,0.5,1.0,2.0,5.0,10.0



On program exit, any value changed during the FDMS session can be saved permanently, if desired. Simply say yes to the final dialog shown here.



A final feature: When an edit change is made to a measurement plan entry, either by changing an editable value, or creating a new entry, any change you have made to the values must be confirmed by you before the changes are saved to the measurement plan. Each confirmation dialog has a “Don’t ask me again” check box. Checking this box will avoid displaying the confirmation dialog for each change made, streamlining extensive edit sessions. The confirmation dialogs can be restored by selecting the “Reset Acks” (see above, under DELTA COOLING TIME, for example) menu item on the FDMS edit menu.


Editing entry 00025, id 25
Facility
Assembly ID
Enrichment (%)
Burnup GWd/MT
Discharge Date
Cycle Number
LANL-FDET
25 twenty five
2.90
38.33
12/18/1992
3
Cancel
OK
Warning
Clicking 'Yes' will save any changes you have made to this entry, continue?
Yes
No
Don't ask me this again
Close
Measure Selected Entry
Edit Selected Entry
Add New Entry
Remove Selected Entry
Do Not Edit Declarations