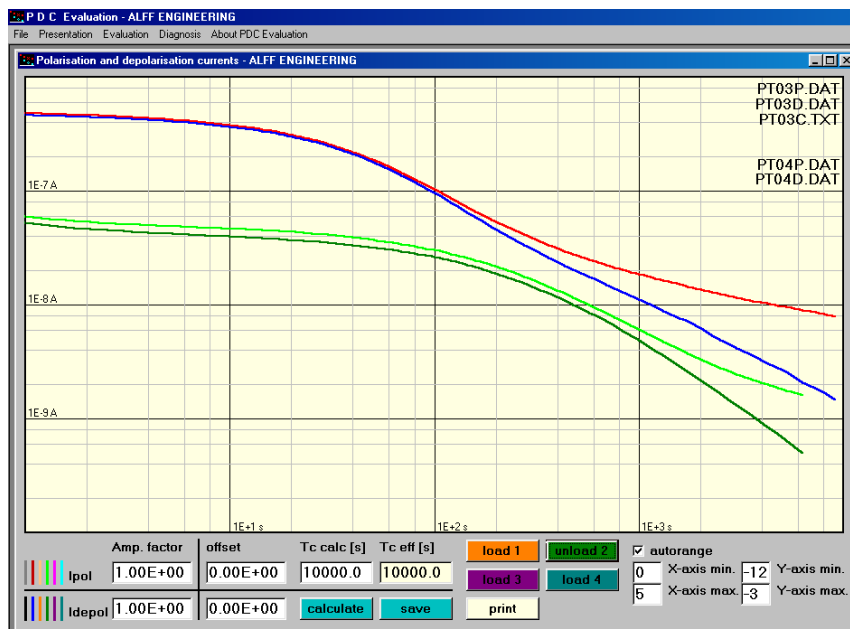


P D C-Evaluation

Polarisation and Depolarisation Current Evaluation Program

Version 3.0 – June 2000



User's Guide
(for the Standard Version)

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1 Introduction

The program *PDC-Evaluation* is for postprocessing relaxation currents as measured with the **PDC-ANALYSER-1MOD**. A standard version of this program comes preinstalled with each instrument. This program runs under windows 9x and all the features and function keys of the operating system can be used.

2 Structure of the program

When starting this program, an empty main window is shown. Several "sub" windows can now be opened from the menu commands of the *main* window permitting different kind of presentations, evaluations, and diagnosis.

The menu bar of the *main* window contains the following pull down menus and commands:

- *File* menu
- *Presentation* menu
- *Evaluation* menu
- *Diagnosis* menu
- *About PDC Evaluation* command

2.1 File menu

- The **Load** command permits to load the necessary data for evaluation from registered polarisation file *p.dat, depolarisation file *d.dat, and comment file *c.txt of a measurement performed with the **PDC-ANALYSER-1MOD**. Always start your *PDC-Evaluation* session by first choosing the data to analyse.
- The **Exit** command quits the *PDC-Evaluation* program.

2.2 Presentation menu

- The **PDC View** command permits to access a simple view program, *PDC view*, useful for graphic presentation of a set of measured relaxation currents with the same name prefix. For more explanation concerning this tool see section 3.2.
- The **Export graphic** command open a graphic tool permitting the presentation of measured relaxation current, calculated complex capacitance, $\tan\delta$, recovery voltage or polarisation spectrum curves in a compact graphic ready to print, to save in a bitmap file (*.bmp) or to export in other programs as (MS Word) by clipboard. For more explanation concerning this tool see section 3.3.

2.3 Evaluation menu

- The **Complex capacitance** command opens a window, where the equivalent circuits from polarisation and depolarisation currents can be determined and quantities as complex capacitance (real part C' and imaginary part C'') and $\tan\delta$ in a frequency range of 10^{-5} to 10^2 can be calculated and presented. For more explanation concerning this tool refer to section 3.4.
- The **Pol. and depol. currents** command gives access to the *Polarisation and depolarisation currents* window. This tool permits to manipulate mathematically loaded currents as multiplying with a factor and adding an offset value. It permits also a graphic comparison of resulting currents with other currents. For more explanation concerning this tool see section 3.5.
- The **Polarisation index** command open the *Polarisation index* window. In this window, it is possible to calculate the polarisation index "PI" for different predefined time values according to established standards or to values freely chosen by the user. For more explanation concerning this tool see section 3.6.
- The **Polarisation spectrum** command open the *Polarisation spectrum* window permitting the determination of polarisation spectrum from the measured relaxation currents. For more explanation concerning this tool see section 3.7.
- The **Recovery voltage** command opens the *Recovery voltage* window, where time dependency of recovery voltage for different charging and discharging duration are evaluated from measured relaxation currents. For more explanation concerning this tool see section 3.8.
- The **Resistance** command gives access to a window, where resistances of investigated test objects can be determined from measured polarisation and depolarisation currents using two different definitions. For more explanation concerning this tool see section 3.9.

2.4 Diagnosis menu

From this menu it is possible to access to advanced tools, which permit a diagnosis (determination of ageing state, moisture content in pressboard, oil conductivity, etc) of oil-paper insulation in homogeneous systems as cables, instrument transformers and in multi-layer systems as power transformers. These tools are optional and not accessible in the standard version of this program. For more Information see the User's Guide for the Advanced Tools of the *PDC-Evaluation* program.

2.5 About PDC Evaluation command

- The **About PDC Evaluation** command lets access to a short information concerning this program.

3 Windows accessible in PDC-Evaluation (standard version)

3.1 Main window

The *main* window appears immediately after starting the program. From the menu bar of this window it is possible to open sub windows as "tools" for different kind of evaluations.

The data files necessary for evaluation of polarisation and depolarisation currents i.e. *p.dat, *d.dat and *c.txt, are loaded with the **Load** command in the *File* menu. It is just necessary to load the polarisation file *p.dat. The two other files *d.dat and *c.txt are loaded automatically. After loading the measured data, the corresponding polarisation and depolarisation current curves will be automatically presented in the *Pol. and depol. currents* window.

Important: By transferring data from a directory to an other keep the 3 files, *p.dat, *d.dat and *c.txt together.

This program *PDC-Evaluation* permits the evaluation of one measurement at a time. Loading new current data resets the program.

3.2 PDC View

The *PDC View* is a useful tool for presentation of individual polarisation and depolarisation currents with identical name prefix in a series of measurement. (example: xy01p.dat, xy02p.dat and xy03p.dat have an identical name prefix xy). This window is accessible from the *Presentation* menu of the *main* window.

The **open** command permits to choose a single polarisation current file *p.dat from a series of measurements. After that, all the measurements in that series are displayed in a list on the right side of the *PDC View* window.

To see the polarisation and depolarisation currents as well as the information concerning the measurements registered in comment file *c.txt, it is sufficient to click on the name of the desired measurement in the list.

Important: data loaded in *PDC View* are local and are not accessible to other sub windows "tools".

For comparison purposes, it is possible to display several current curves in the same graph. This can be done by unchecking the check box *single presentation*.

This tool permits to print a hardcopy protocol of a measurement on one A4 page consisting of a graph with the polarisation and depolarisation currents and a listing of the information stored in the comment file.

3.3 Export graphic

The *Export graphic* is a useful tool for the presentation of measured relaxation current, calculated complex capacitance, $\tan\delta$, recovery voltage or polarisation spectrum curves in a compact graphic ready to print, to save in a bitmap file (*.bmp) or to export in other programs as (MS Word) by clipboard.

Up to 10 curves with different colours can be presented in a graph by using the **load** commands. The X-values are taken from the first column of the loaded data files. The Y-values are taken from the second column. In case of data files with more than two columns as complex capacitance data files, (*.dsp files, see Appendix A), or polarisation spectrum data files, (*.psp files, see Appendix B), the column number, from which the Y-values must be taken, can be defined in the corresponding *Y* text box of each curve.

Titles for the curves, axes or graph can be defined by using the corresponding text boxes. To position a title in the graph, first, click the *text* option button in the *input* field, second, choose the title to be positioned by clicking its option button (at the right side of the text box), third, localised with the mouse pointer the desired position for the title in the graph and click the left button of the mouse.

Connection lines between curves and their titles can also be presented in the graph. To position a line in the graph, first, click the *line* option button in the *input* field, second, choose the line to be positioned by clicking its option button (at the right side of the text box), third, localised the line by defining its start point position respectively its end point position with the mouse pointer in the graph and by clicking the left respectively right button of the mouse.

The positioned lines or titles in a graph can also be removed. To delete a line respectively a title, first, click the *line* respectively *text* option button from the *input* field, second, choose the line or title to be deleted by clicking its option button, third, click the *delete line/text* button.

3.4 Complex capacitance

This tool permits the determination of two equivalent circuits, one from measured polarisation currents and one from depolarisation currents and the calculation of the complex capacitance C' and C'' and the dissipation factor $\tan\delta$, all in the frequency range of 10^{-5} to 10^2 Hz. The *Complex capacitance* window is accessible from *Evaluation* menu of the *main* window.

The determination of equivalent circuits from polarisation and depolarisation currents can be separately performed with the **fit** commands.

The values of charging voltage U_C , charging duration T_C and capacitance at 50 Hz $C_{50\text{Hz}}$ necessary for determination of equivalent circuits are taken from the comment file **c.txt*. If this comment file can not be found, the values of these quantities are set to 1. The original values can also be changed by typing new values into the corresponding text boxes.

Two different procedures can be used to determine the values of DC resistance R_0 . If the equivalent circuit is determined from polarisation current, R_0 is obtained from a DC component fitting. If the equivalent circuit is determined from depolarisation current, the DC resistance value is calculated from the difference of polarisation and depolarisation currents for the largest measured polarisation time. The values of DC resistance can also be set manually by unchecking the check box *calc. R0*.

The results of fitting with a sum (superposition) of exponential functions to the measured polarisation and depolarisation currents are presented in separate lists. These lists contain the time constants T_i , the amplitude values A_i , the amplitude values for infinite charging time A_i^* , the resistance values R_i and the capacitance values C_i (see figure 1).

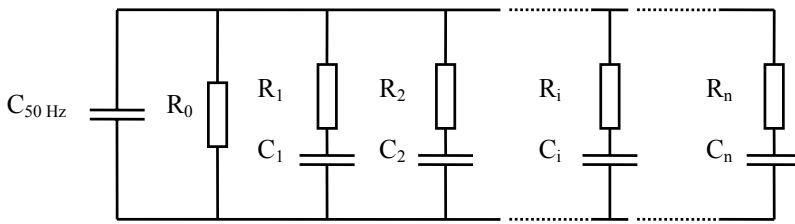


Figure 1: Equivalent circuit to model a linear dielectric

The **save** commands save the previously determined values of the equivalent circuits in a *.par file and the values of C' , C'' $\tan\delta$ in a *.dsp file.

An example of these output files is presented and further explained in Appendix A.

The generated files *.par file and *.dsp file are compatible to MS Excel program if their file extensions is changed manually to *.xls.

Calculated curves of complex capacitance respectively $\tan\delta$ can also be presented graphically, these graphs can be evoked by clicking the C' and C'' respectively $\tan\delta$ option buttons from *presentation* field.

The **load** command permits to superpose previously stored curves of C' , C'' , and $\tan\delta$ (from a chosen *.dsp file) with actually calculated curves for comparison purposes.

By using the **print** command, this tool generates a protocol with all the graphic results and the parameters of the equivalent circuits.

The *complex capacitance* tool determines the ratio of capacitance calculated at 0.0001 Hz to the capacitance measured at 50 Hz. This ratio is a significant value for quality assessment of insulation with homogeneous structure.

3.5 Pol. and depol. currents

This tool is useful to mathematically manipulate measured polarisation and depolarisation currents. The *Pol. and depol. currents* window is accessible from the *Evaluation* menu of the *main* window.

This tool permits to multiply the loaded currents with arbitrary factors chosen individually for polarisation and depolarisation parts and/or to add arbitrary offset currents. It also permits to simulate polarisation and depolarisation currents for theoretical charging durations $T_{c\text{ calc}}$ different from the original measurement duration $T_{c\text{ eff}}$.

The manipulated curves can be saved with the **save** command.

This tool permits also a graphic comparison between the manipulated curves and up to four additional polarisation and depolarisation current curves.

The graphic window with all these curves can be printed in a protocol by using the **print** command.

3.6 Polarisation index

This tool permits the determination of diverse polarisation index from measured polarisation currents. The *polarisation index* window is accessible from the *Evaluation* menu of the *main* window.

For the computation of the resistance and the polarisation index, the measured polarisation currents are first fitted with a smooth curve. This is a kind of post-filtering to eliminate or reduce the influence of noise and perturbations on the computed resistance and polarisation index values as

these are based on polarisation currents at times T_1 and T_2 . The fitting can be made even smoother by checking *smoother curve fitting*.

The values of T_1 and T_2 can be changed by choosing new positions with the mouse pointer in the graphic field and by clicking left for T_1 respectively right for T_2 . Values for T_1 and T_2 can also be entered by typing into the corresponding text boxes. Four combination for T_1 and T_2 can be predefined, they will be saved when terminating the program and reactivated at the next start of the *PDC Evaluation*.

The value of the charging voltage U_C , which is necessary for the determination of the resistance, is taken from comment file **c.txt*. If this comment file is missing, this value is set to a default value of 1 volt. The charging voltage used by the computation can manually be changed by typing the desired value into the corresponding text box.

This tool generates a graphic protocol with polarisation index values for predefined and for user chosen time instants T_1 and T_2 . The printout of the protocol is evoked by the **print** command.

3.7 Polarisation spectrum

This tool permits the determination of polarisation spectra from the measured polarisation and depolarisation currents basing on a linear model (an equivalent circuit) as presented in figure 1.

The determination of a polarisation spectrum from polarisation current or depolarisation current can be separately performed with the **calculate** commands.

The values of charging voltage U_C , charging duration T_C and capacitance at 50 Hz $C_{50\text{Hz}}$ necessary for determination of equivalent circuits are taken from the comment file **c.txt*. If this comment file can not be found, the values of these quantities are set to 1. The original values can also be changed by typing new values into the corresponding text boxes.

Two different procedures can be used to determine the values of DC resistance R_0 . If the equivalent circuit is determined from polarisation current, R_0 is obtained from a DC component fitting. If the equivalent circuit is determined from depolarisation current, the DC resistance value is calculated from the difference of polarisation and depolarisation currents for the largest measured polarisation time. The values of DC resistance can also be set manually by unchecking the check box *calc. R0*.

The values of the parameters for calculation of the polarisation spectrum i.e. the charging voltage $U_{c\text{ps}}$, the ratio of charging duration to discharging duration t_c/t_d , the end time of calculation of recovery voltages t_e , the first charging duration of the polarisation spectrum t_1 and the last charging duration of the polarisation spectrum t_2 can be changed by setting new values in the corresponding text boxes.

The results of polarisation spectrum calculated from the polarisation current or the depolarisation current i.e. the maxima of recovery voltage $U_{r\text{max}}$, the time to peak $t_{r\text{max}}$, and the initial slope S_r at the time $t = 0$ determined from individual recovery voltage curves in function of charging duration are presented in 2 separate lists

The **save** commands save the determined polarisation spectrum values in a **.psp* file.

An example of this output file is presented and further explained in Appendix B.

The generated **.psp* file is compatible to MS Excel program if its file extensions is changed manually to **.xls*.

The **load 1** to **load 4** commands permit to superpose previously stored polarisation spectrum curves with actually calculated curves for comparison purposes.

By using the **print** command, this tool generates a protocol with the graphic results, the parameters and the values of the calculated polarisation spectra.

3.8 Recovery voltage

In this tool, the time dependency of recovery voltage for different charging and discharging duration and excitation voltage levels are evaluated from measured relaxation currents, basing on a linear model (an equivalent circuit), see figure 1.

The determination of recovery voltage from the polarisation current or from the depolarisation current can be separately performed with the **calculate** commands.

The values of charging voltage U_C , charging duration T_C and capacitance at 50 Hz $C_{50\text{Hz}}$ necessary for determination of equivalent circuits are taken from the comment file **c.txt*. If this comment file can not be found, the values of these quantities are set to 1. The original values can also be changed by typing new values into the corresponding text boxes.

Two different procedures can be used to determine the values of DC resistance R_0 . If the equivalent circuit is determined from polarisation current, R_0 is obtained from a DC component fitting. If the equivalent circuit is determined from depolarisation current, the DC resistance value is calculated from the difference of polarisation and depolarisation currents for the largest measured polarisation time. The values of DC resistance can also be set manually by unchecking the check box *calc. R_0* .

The values of parameters for calculation of the recovery voltages i.e. the charging voltage $U_{c\text{rv}}$, the charging duration t_c , the discharging duration t_d and the end time of calculation of recovery voltages t_e can be changed by setting new values into the corresponding text boxes.

The resulting parameters of recovery voltages calculated from the polarisation current or the depolarisation current i.e. the maxima of recovery voltage $U_{r\text{max}}$, the time to peak $t_{r\text{max}}$, and the initial slope S_r at the time $t = 0$ are presented separately in this tool.

The **save** commands save the determined recovery voltage values from the polarisation current or from the depolarisation current in a **.rvm* file.

An example of this output file is presented and further explained in Appendix C.

The generated **.rvm* file is compatible to MS Excel program if its file extensions is changed manually to **.xls*.

The **load 1** to **load 4** commands permit to superpose previously stored recovery voltage curves with actually calculated curves for comparison purposes.

By using the **print** command, this tool generates a protocol with the graphic results and the calculation and resulting parameters of the determined recovery voltages.

3.9 Resistance

This tool permits the determination of the "DC" resistance from measured polarisation and depolarisation currents with two different definitions. The *Resistance* window is accessible from the *Evaluation* menu of the *main* window.

The resistance values are determined from fitted curves for the time T . The smoothing degree of the fitting can be changed by checking the check box *smoother curve fitting*.

The value of T can be changed by choosing a new position with the mouse pointer in the graphic field and by clicking on the left button of the mouse. New values for T can also be entered by typing them into the corresponding text box. Further, up to three different values for T can be entered by the user, they will be saved when terminating the program and reactivated at the next start of *PDC Evaluation*.

The value of the charging voltage U_C , necessary for the determination of the resistance, is taken from the comment file **c.txt*. If this comment file is missing, this value is set to 1. The value of the charging voltage can be changed by typing the desired value into the corresponding text box.

This tool generates a protocol with graphic results and with values of resistance for predefined and for user chosen times T by using the **print** command.

Further information concerning the DC resistance can be obtained by fitting the polarisation current with a sum of exponential functions plus a DC component. See also the comment on fitting techniques in 3.3 *Complex capacitance* tool.

4 Performing an Evaluation

To perform an evaluation, start the program *PDC Evaluation* and open a polarisation file **p.dat* with the **Load** command from the *File* menu of the *main* window. The depolarisation file **d.dat* and the comment file **c.txt* will be opened automatically in the background. These data are now available in all evaluation tools.

The *PDC view* from the *Presentation* menu is a useful tool for performing a quick search of desired data in a series of measurements. Files opened or loaded in *PDC view* are not used in other windows.

The names of loaded files are presented in the graphic area of all the evaluation tools. In case of an invalid file, its name will appear in red colour.

The desired evaluation tool can be started from evaluation menu.

In all graphic presentations, the range of the graph axis can be either determined automatically or set manually by checking the *autorange* check box. The ranges chosen for the screen representation also apply for the printed graphs.

Appendix A

In Appendix A.1 is presented one example of a parameter data file (*.par) and in Appendix A.2 is presented one example of a spectrum data file (*.dsp) generated from *Complex capacitance* evaluation tool.

In the following examples, the comments are written in *italic*. These comments are not included in the original files.

A.1 Format of the *.par file

From fist row to last but one row :

$T_i [s]$	$A_i [A]$	$A_i^* [A]$	$R_i [\Omega]$	$C_i [F]$
1.000000E+00	2.024160E-08	2.024160E-08	4.939332E+10	2.024565E-11
1.000000E+01	2.184677E-09	2.184677E-09	4.576420E+11	2.185114E-11
3.162278E+02	2.568437E-09	2.568438E-09	3.892639E+11	8.123737E-10
1.778279E+03	7.639517E-09	8.128031E-09	1.230064E+11	1.445680E-08
5.623413E+03	3.134806E-09	5.322335E-09	1.878499E+11	2.993567E-08

Last row:

$C_{50Hz} \times R_0 [s]$	$U_C / R_0 [A]$	$U_C / R_0 [A]$	$R_0 [\Omega]$	$C_{50Hz} [F]$
7.315220E+03	1.108426E-09	1.108426E-09	9.020000E+11	8.110000E-09

A.2 Format of the *.dsp file

<i>Frequency [Hz]</i>	<i>C' [F]</i>	<i>C'' [F]</i>	<i>tan δ</i>
1.000000E-05	3.967891E-08	2.769016E-08	6.978558E-01
1.100000E-05	3.943222E-08	2.613152E-08	6.626945E-01
1.200000E-05	3.917203E-08	2.489105E-08	6.354290E-01
1.300000E-05	3.890025E-08	2.389075E-08	6.141541E-01
1.400000E-05	3.861870E-08	2.307508E-08	5.975104E-01
1.500000E-05	3.832908E-08	2.240346E-08	5.845031E-01
.	.	.	.
.	.	.	.
.	.	.	.
9.500000E+01	8.110000E-09	6.832390E-14	8.424649E-06
9.600000E+01	8.110000E-09	6.761220E-14	8.336892E-06
9.700000E+01	8.110000E-09	6.691517E-14	8.250946E-06
9.800000E+01	8.110000E-09	6.623236E-14	8.166752E-06
9.900000E+01	8.110000E-09	6.556335E-14	8.084260E-06
1.000000E+02	8.110000E-09	6.490771E-14	8.003418E-06

Appendix B

In Appendix B.1 is presented one example of a polarisation spectrum data file (*.psp) generated from *Polarisation spectrum* evaluation tool.

In the following examples, the comments are written in *italic*. These comments are not included in the original files.

B.1 Format of the *.psp file

<i>tc [s]</i>	<i>Ur max [V]</i>	<i>Tr max [s]</i>	<i>Sr [V/s]</i>
1.000000E+00	1.535701E+00	3.550000E+01	1.275786E+00
2.000000E+00	1.873593E+00	1.416000E+02	8.958778E-01
5.000000E+00	3.582952E+00	5.867000E+02	4.419135E-01
1.000000E+01	6.499475E+00	6.978000E+02	2.934013E-01
2.000000E+01	1.214790E+01	7.596000E+02	2.087525E-01
5.000000E+01	2.825190E+01	8.020000E+02	1.852978E-01
1.000000E+02	5.265834E+01	8.232000E+02	2.614841E-01
2.000000E+02	9.308646E+01	8.541000E+02	4.355877E-01
5.000000E+02	1.664553E+02	9.648000E+02	7.415045E-01
1.000000E+03	2.092069E+02	1.228600E+03	8.559131E-01
2.000000E+03	2.072668E+02	1.746400E+03	7.319924E-01

Appendix C

In Appendix C.1 is presented one example of a recovery voltage data file (*.rvm) generated from *Recovery voltage* evaluation tool.

In the following examples, the comments are written in *italic*. These comments are not included in the original files.

C.1 Format of the *.rvm file

<i>t [s]</i>	<i>Ur [V]</i>		
1.000000E-01	4.355877E-02	9.200000E+02	9.298444E+01
2.000000E-01	8.708159E-02	9.400000E+02	9.291981E+01
3.000000E-01	1.305705E-01	9.600000E+02	9.284203E+01
4.000000E-01	1.740271E-01	9.800000E+02	9.275223E+01
5.000000E-01	2.174531E-01	1.000000E+03	9.265165E+01
6.000000E-01	2.608495E-01		
7.000000E-01	3.042176E-01		
8.000000E-01	3.475582E-01		
9.000000E-01	3.908721E-01		
1.000000E+00	4.341600E-01		
1.200000E+00	5.206600E-01		
1.400000E+00	6.070623E-01		
1.600000E+00	6.933699E-01		
1.800000E+00	7.795851E-01		
2.000000E+00	8.657097E-01		
.	.		
.	.		
.	.		
9.000000E+00	3.828438E+00		
9.200000E+00	3.911690E+00		
9.400001E+00	3.994866E+00		
9.600000E+00	4.077967E+00		
9.800000E+00	4.160993E+00		
1.000000E+01	4.243945E+00		
1.200000E+01	5.069394E+00		
1.400000E+01	5.887537E+00		
1.600000E+01	6.698491E+00		
1.800000E+01	7.502357E+00		
2.000000E+01	8.299229E+00		
.	.		
.	.		
.	.		
9.000000E+01	3.228103E+01		
9.200000E+01	3.286601E+01		
9.400000E+01	3.344600E+01		
9.600000E+01	3.402101E+01		
9.800000E+01	3.459111E+01		
1.000000E+02	3.515630E+01		
1.200000E+02	4.054797E+01		
1.400000E+02	4.549241E+01		
1.600000E+02	5.002452E+01		
1.800000E+02	5.417653E+01		
2.000000E+02	5.797812E+01		
.	.		
.	.		
.	.		
9.000000E+02	9.303455E+01		