CHAPTER II
ELECTRICAL CONDUCTIVITY OF IMPURE ACENAPHTHENE

2.1 INTRODUCTION

Semi-conducting properties in large number of high resistivity organic solids have been reported. The conduction phenomena in these groups of solids have been explained with the help of approximate theories developed by Rose\textsuperscript{175,177} and others\textsuperscript{215,216} based on concentration of traps and their energy distribution. Mechanisms such as tunnelling\textsuperscript{217,218}, Schottky emission\textsuperscript{219}, field and thermal ionization\textsuperscript{171(d)} of traps and impurities, avalanche multiplication\textsuperscript{220} etc. have also been proposed recently to explain the observed electron transfer behaviour in high resistivity films sandwiched between metal electrodes. The situation at present is that no universally accepted theory exists to explain the true conductivity of these solids. This may, perhaps, be ascribed to the difficulties encountered in providing an adequate interpretation of effects known experimentally and to the variety and complexity of polarization phenomena. A brief review of factors which affect the electrical conductivity is presented below :-

2.2 FACTORS AFFECTING ELECTRICAL CONDUCTIVITY

(i) FIELD

A number of mechanisms have been employed to explain the increase of conductivity with externally applied
field strength. The variation of current through the sample with applied voltage has been found to be

\[ I \propto V^n \tag{2.1} \]

The value of \( n \) is 1 when the behaviour is ohmic. A value of \( n = 2 \) is given when a space charge limited current flows through a trap free insulator. Rose has shown how to work backward from an experimentally determined \( I - V \) characteristic to obtain the energy distribution of traps and their number. It has been shown by Riehl\(^{221}\) with the help of measurements of an organic substances that electrical conductivity is proportional to \( \exp(-B/T) \), where \( T \) is absolute temperature and \( B = 0.7, 0.75, 0.55 \) and 0.4 eV respectively. Electrical conductivity was found to increase with high fields but not the value of B. Hartshorn\(^{222}\), Popov\(^{223}\) and Liang\(^{224}\) also proposed theories to explain the variation of conductivity with field.

Very recently Pateriya\(^{225}\), Saraf\(^{226}\) and Agrawal\(^{227}\) have found that electrical conductivity increases with field for para-chloroaniline, pyrene and xanthene respectively. Bhatnagar and Shrivastava\(^{228}\) have found electronic conductivity super imposed on the ionic component at high fields in sugar-cane wax.

(ii) TEMPERATURE

The electrical conductivity characteristic is very much dependent on the temperature state of the organic substance. A rise in temperature tends to increase the current and conductivity. The electrical conductivity at
various temperatures obeys the exponential relation.

\[ \sigma = \sigma_c \exp \left( - \frac{E}{kT} \right) \quad \ldots \quad (2.2) \]

where \( \sigma \) - the conductivity measured, \( E \) - the activation energy of conduction, \( \sigma_c \) - pre-exponential factor, \( k \) - Boltzmann constant and \( T \) - the absolute temperature. If the logarithm of the conductivity is plotted against \( 1/T \), two regions, a high temperature region and the other low temperature region depending strongly upon the past history of the crystal, result. The high temperature region is independent of past history of the crystal, and involves a considerably larger activation energy. The complete conductivity curve is a superposition of two curves given by

\[ \sigma = \sigma_1 \exp \left( - \frac{E_1}{kT} \right) + \sigma_2 \exp \left( - \frac{E_2}{kT} \right) \quad (2.3) \]

where \( \sigma_1 \) and \( \sigma_2 \) are pre-exponential terms. Out of the two terms in equation (2.3) the first has a small coefficient and small activation energy and predominate at lower temperatures while the other has a larger coefficient and larger activation energy and is predominant at higher temperature.

Study of conductivity dependence on field and temperature sometimes reveals that the current-temperature and current-field curves obtained on increasing and decreasing of temperature or field are quite different and distinct, resulting into a sort of hysteresis loop. Hysteresis effect has been observed in case of paraffin
wax\textsuperscript{229}, carnauba wax\textsuperscript{230}, sugar cane wax\textsuperscript{228}, polyethylene\textsuperscript{33}

\textsuperscript{PC}\textsuperscript{221}, napthene\textsuperscript{184}, \beta - naphthol\textsuperscript{231}, xenthene\textsuperscript{227},
P-chloroaniline\textsuperscript{225} and Pyrene\textsuperscript{226}.

(iii) PRESSURE

Previously Eley et al.\textsuperscript{205,206} and Akamotu and Inokuchi\textsuperscript{232} implied the existence of limiting pressure above which the electrical conductivity did not change. Akamotu and Inokuchi (loc. cit.) found that the resistivity of iso-violanthrone powder decreases with pressure, i.e., conductivity increases with pressure and remains constant approximately above 80 atmospheres.

The pressure dependence of apparent dark conductivity has been described by many workers. Materials studied include quaterylene\textsuperscript{233} pentacene\textsuperscript{234,235}, anthracene violanthrone pyranthrone\textsuperscript{236,237}, ferrocene\textsuperscript{238}, benzo-phenone\textsuperscript{239} and many others\textsuperscript{240-249}.

It has been reported by many workers that increase in conductivity has been followed by a lowering of activation energy. Eley et al. (loc. cit.) attributed this to packing effects on powder specimen. Brown and Aftergut\textsuperscript{250} state that macroscopic voids are removed due to pressure. Activation energies at the highest pressure studies were found to be about one sixth of that of atmospheric value\textsuperscript{194}.

(iv) ELECTRODE MATERIAL

Reucroft\textsuperscript{251} studied the conductivity of anthracene monocryystals with different electrodes (sodium, silver,
indium) and found the identical results with respect to the magnitude of the conduction current and therefore concluded that the observed electrode barriers are independent of the work function of the individual metallic electrode employed. Electrolytic contacts in anthracene have been extensively studied by Kallmann and Pope\textsuperscript{141,252}, Silver\textsuperscript{253} and others\textsuperscript{254} who showed that the I - V relation with electrolytic contact is linear only above a certain critical voltage level. Eley et al.\textsuperscript{255} measured the conductivity of bovine plasma albumen with four electrode metals Cu, Pt, Al and In. Closely similar results were obtained in all cases. Bhatnagar and Srivastava\textsuperscript{256} have observed a measurable influence of the electrode materials of Zn, Cu and Al on the conductivity of Indian Sugarcan wax at 35° C.

(v) HUMIDITY EFFECT

Hartshorn\textsuperscript{222} and Whitehead\textsuperscript{257} have shown that moisture causes the conductivity to increase with field strength. Recently, the effect of hydrogen bonding on the conductivity of organic solids has been studied in the pellet form by Gravatt and Gross\textsuperscript{258}. Barker and Thomas reported that the moisture affects the conductivity in two ways (1) resulting in increase in the dielectric constant and therefore ions concentration by reducing the effective dissociation energy and (2) departure from ohm's law in high fields as a result of
activation perturbation even in the absence of thermal and chemical effects.

(vi) THICKNESS

O'Dwyer has reported the current voltage characteristic to be dependent on the thickness. According to Wright the current varies as inverse cube of thickness. Sharma has found a linear relationship between conductivity and thickness in sealing wax. Bashara and Dotty have found existence of space charge limited current which increased with thickness.

(vii) IMPURITY CONTENT

The electrical conductivity of organic compound is extremely sensitive to the presence of impurities. The conductivity itself could be used as a measure of purity provided that the absolute value for a given material were known. The studies of the effect of purification on the semiconduction of Imidazole were carried out by Brown and Aftergut and they found that the presence of two slopes in log $\sigma$ versus $1/T$ plot was indicative of an impure specimen since further purification gave rise to single slope. Recently similar effect for sample 1,5- diamino-naphthalene has been reported by Srivastava and Agrawal. Pick and Wiseman showed that for naphthalene the activation energy depend on the presence of impurities. Effect of known impurities on electrical properties of hydrocarbons have been investigated by
Northrop and Simpson\textsuperscript{265,266}. Okamoto and coworkers\textsuperscript{267} observed a change in conductivity properties of hydrocarbons, which were purified by different methods.

2.3 PRESENT EXPERIMENTAL TECHNIQUE

The present investigations consist of the study of the steady state dark conductivity in impure acenaphthene. The degree of accuracy of conductivity depends on the accuracy of measuring current, voltage, temperature, contact resistance from the surface and dimension of the sample with various other perturbing parameters. The whole process can be divided into different parts which are discussed below.

(i) PREPARATION OF SAMPLE

Most of the organic materials are available only in the powder form as such the studies on them usually carried out are either in the powder form or in the compressed pellet form. The present experimental studies were done in the form of pellets prepared from the microcrystalline powder, by uniform compression. In the present case the specimen was prepared by packing the acenaphthene powder in a well cleaned cylindrical cavity and pressing it hard by a clean cylindrical piston under uniform compression. A good number of pellets were prepared under similar condition keeping all the parameters such as pressure etc. to be constant. Each pellet had a thickness of 0.65 mm and 4.45 sq. cm. area of cross-section.
Acenaphthene powder used was supplied by Fluka A G, Buchs S G, made in Switzerland.

(ii) TEST CELL AND ELECTRODE ASSEMBLY

In order to minimize the surface conduction and effect of the fringing of the field at the edge a three terminal guarded electrode system is used. The electrode assembly in the present investigation is made on the two optically plane glass slabs. The glass slabs are cleaned with benzene. A square silver foil of 5 sq.mm. area of cross-section is pasted on one of the glass slabs and the guarded electrode area of cross-section 4.45 sq.cm. with guard ring is fixed to the other glass slab. The protruding strips of the electrodes out of the glass slabs are used as electrical connections during current measurement. The spacing between guarded electrode and guard ring was kept to be 0.05 cm. uniformly in all the sides.

The effective area of the circular electrodes are determined by the formula

$$r = \frac{r_1 + r_2}{2} - \frac{2d}{n} \log \left[ \cosh \left( \frac{r_2-r_1}{4d} \right) \right] \ldots (2.3)$$

where $r_1$ and $r_2$ are the radii of guarded electrode and guard ring.

(iii) VOLTAGE SOURCE

The current flowing through the semiconductors is of the order $10^{-13}$ to $10^3$ amperes approximately and
therefore the stability of the voltage supplied by the source is most important for current measurement. In the present case ten 90 volt dry batteries no. 700-D Mini-Max supplied by Eveready India were used as a D.C. field source.

(iv) TEMPERATURE CONTROL

Temperature is most important factor in the measurement of conductivity of semiconductors and dielectrics as change in temperature affect the conductivity considerably. In order to have a controlled temperature for experiments the test cell is kept in a thermo-stat giving different desired temperature from room temperature to 250° C within the accuracy of ±1° C. The thermostat used in the present investigation is supplied by M/s. Tempo. Industrial Corporation Bombay, India.

(v) CURRENT MEASURING INSTRUMENT

Keithley Electrometer Model 600B.

Keithley electrometer model 600B supplied by Keithley instruments U.S.A. is completely solid state ultrastable microvolt electrometer with imput resistance greater than 10^{16} ohms. Using the built in high-megohm shunt resisters, the electrometer becomes one of the most sensitive ammeter. The electrometer has twenty two ranges from 10^{-15} amp. full scale to 3 \times 10^{-5} amp. and can directly resolve 5 \times 10^{-17} amp. across its 10^{12} ohm resistor. A large amount of negative feedback is used for
Circuit Diagram for Conductivity Measurement

A - Guarded Electrode
B - Electrometer Amplifier
C - Lower Electrode
E - Metal Box
F - Shielded Wires
G - Guardring
stability and accuracy. Speed and sensitivity are fully compatible with mass spectrometer, Microvoltmeter, Infrared absorption spectrometer and photo-multipliers, etc.

By placing its 20 PF ± 0.25% guarded capacitor in the feedback loop the model 600 becomes a coulombmetry current integrator. As a coulommbmeter it can detect charge as low as 5 x 10⁻¹⁶ coulomb. As a current integration it can resolve 10⁻¹⁷ ampere.

(vi) DETAILS OF PROCEDURE

The accuracy of the measurement of the conductivity depends on the state of the thermal equilibrium inside the sample. At room temperature inside, the sample shows poor reproducibility of I-V characteristics due to non equilibrium of temperature inside the sample. Thus in the present case in order to have a thermal equilibrium the whole conductivity cell in a metal box was kept in the thermo-stat at a desired constant temperature for five hours. The D.C. field is applied after 5 hours duration needed for thermal equilibrium. Smith and Rose²¹⁵ reported that a longer waiting time was needed at lower temperatures when the current was relatively low. In view of this preliminary experiments were performed at lower temperatures to arrive at this suitable time of 5 hours required for thermal equilibrium and was kept to be the same for measurements at higher temperatures. Current was measured as a function of (a) field at constant temperatures and (b) temperature at constant fields.
(a) Variation of current with field

In this part of investigation the current was measured at a fixed temperature by varying the potential difference across the sample between 90 volt and 900 volt in steps of 90 volt. Different series of such measurements were made by changing the fixed temperature in steps of $10^\circ C$ between $40^\circ C$ to $70^\circ C$ and in steps of $5^\circ C$ between $70^\circ C$ to $90^\circ C$. For each fixed temperature a new specimen was used and the current was measured both by increasing and decreasing the potential difference.

(b) Variation of current with temperature

To study the variation of current with temperature, the field was kept constant and the temperature was varied from $40^\circ C$ to $90^\circ C$ initially in steps of $10^\circ C$ and then in steps of $5^\circ C$. Freshly prepared sample was used for each set of field. The value of the field was varied from $1.45 \text{ KV/cm}$ to $14.50 \text{ KV/cm}$ in steps of $1.45 \text{ KV/cm}$. The current was recorded in the increasing and decreasing side of temperatures.

2.4 DETAILS OF THE CALCULATIONS

The recorded values of the current measurement taken at constant temperature with field variation are plotted on a log-log graph and are shown in fig. 2.5. The $I - V$ characteristic curves suggest an important relation between current and applied potential. The current and applied voltage follow a power law of the type

$$I = KV^m \quad \ldots \quad (2.4)$$
The degree of linear relationship between \( \log I \) and \( \log V \) was determined by the power \( 'm' \) and correlation coefficient \( 'r' \).

(i) CALCULATION FOR POWER \( 'm' \)

Present calculation for power \( 'm' \) is most simple and is based on the relation \( I = kV^m \). Taking a logarithm of the equation to the base \( e \), we get

\[
\log I = m \log V + \log k \quad \ldots \ (2.5)
\]

where supposing \( \log I = Y, \log V = X \) and \( \log k = C \)
Equation reduces to \( Y = mX + C \quad \ldots \ (2.6) \)

which is a equation of straight line to a set of points in the plane \( XY \). Now the power \( 'm' \) can be calculated by the following relationship

\[
m = \frac{\sum X \sum Y - n \sum XY}{(\sum X)^2 - n \sum X^2} \quad \ldots \ (2.7)
\]

(ii) CORRELATION COEFFICIENT

Correlation coefficient represents the relationship between two variables \( X \) and \( Y \) in which, with the change in the value of one variable the value of other variable also changes. For variables showing approximate linear relationship, the degree of linearity can be measured from the correlation coefficient \( r \), which can be calculated from the formula

\[
r = \frac{n \sum XY - \sum X \sum Y}{\sqrt{[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]}} \quad \ldots \ (2.8)
\]
In this formula \( r \) is based on a set of 'n' points in the XY plane. The magnitude of \( r \) determines the nature of relationship, whereas coefficient \( r \) tells us as to whether \( Y \) tends to increase or decrease with the value of \( X \). The nature of \( r \) shows that (1) \( r \) must satisfy the inequality \(-1 \leq r \leq +1\) and (2) the value of \( r \) will be equal to \( \pm 1 \) if the points of the scatter diagram lie on a straight line.

(iii) ACTIVATION ENERGY

Exponential relationship between conduction and inverse temperature of the type.

\[
\langle \rho \rangle = A e^{-E/kT}
\]

where \( k \) is Boltzmann constant and \( E \) is known as activation energy is governed in the each straight portion of the graph. A resolution between the conductivities corresponding to high and low temperature regions seems to have taken place in each case. Activation energy \( E_2 \) corresponding to high temperature straight line and \( E_1 \) corresponding to low temperature straight line are calculated from their slopes in each case.

Activation energy \( E_1 \) and \( E_2 \) corresponding to low and high temperature regions have been calculated from the semi-log graphs by using the formula

\[
E = \frac{(\log \rho_2 - \log \rho_1) \times k}{1/T_2 - 1/T_1} \quad \ldots (2.9)
\]

where \( k \) is the Boltzmann constant.
2.5 RESULTS

The results of the studies of variation of dark current and dark conductivity with field and temperature for impureacenaphthene sample are shown in fig. 2.1 to 2.16.

(A) Variation of current and conductivity with field :-

The I - V characteristics at different temperatures for impure samples are represented in figures 2.1 to 2.4. The following conclusion can be drawn from these curves.

(1) The value of current flowing through the sample of impureacenaphthene varied from $10^{-12}$ to $10^{-7}$ ampere while the variation in electrical conductivity was found to be in the range of $10^{-16}$ to $10^{-12}$ ohm$^{-1}$ cm$^{-1}$.

(2) At all temperatures the value of current, while increasing the field was always greater than that while field decreasing.

(3) Characteristics of current-voltage an a log-log graph are shown in figure (2.5). The I - V characteristics at $40^\circ$ C is a single straight line and at all higher temperatures, than $40^\circ$ C is marked by two distinct regions. In the two voltage region the current varies linearly with voltage, while at higher voltage, the current follows a faster increase. No sharp knee is observed separating two regions.
Figure 2.1 to Current - Voltage Characteristics

TEMP.
50°C

40°C

CURRENT IN AMPS X 10^-11

FIELD IN kV/cm
Fig. 2.2 Current - Voltage Characteristics
Fig. 2.4 Current - Voltage Characteristics
Fig. 2.5 Log I - Log V Characteristics
The value of power 'm' was calculated in all cases for both regions of the curves. The values are shown tabulated in the table no. 2.2.

(a) Values of power 'm' for high field region were found to be always greater than that for low field region.

(b) The power 'm' being nearly one in low field region at all the temperatures in both the cases of increasing and decreasing temperature, show an agreement with ohm's law. In the higher field region the value of 'm' is greater than one and thus the ohm's law does not appear to hold good.

(c) Values of 'm' for all temperatures except the lowest temperature of 40°C are greater for the curves obtained by increasing the field than those for the curves while decreasing the field.

(4) Correlation coefficient has been calculated to determine linearity of the curves of I- V plot. In almost all cases, the values of correlation coefficient lie in the neighbourhood of 1.00 and as shown in table (2.2). This strong linear relationship shows that a power law $I \propto V^m$ is followed.

(5) Schottky plot has been obtained on a semilog graph between $E^\frac{1}{2}$ and J and is shown in fig. 2.6. At higher field region the Schottky emission can be very well seen from the straight line portions of the curves obtained. The
Fig. 2.6 Log I vs. $E^{1/2}$ (Schottky type plot)
deviation from this is very clear in the fields less than 4.35 kV/cm.

(6) Log \( J/v^2 \) versus 1/V (Fowler - Nordheim) plots are shown in figure 2.7. These plots are approximately linear for higher fields.

(7) The variation of conductivity with field has been investigated by plotting log \( \sigma \) versus field for all temperatures and is shown in figure 2.8. The conclusions obtained are:

(a) For temperatures 40°C, 50°C, 60°C and 90°C at all field region conductivity does not change.

(b) For temperature 70°C to 85°C at lower field region from 1.45 kV/cm. to 8.70 kV/cm. conductivity remains same and than increases very slowly with the increase in the field beyond 8.7 kV/cm.

(B) Variation of current and conductivity with temperature

Result of variation of current density with increasing and decreasing of temperature are shown in fig. 2.9 to 2.13. The important conclusions are:

(1) At all fields the current temperature curve does not repeat itself when the temperature is decreased indicating a hysteresis effect. During cooling the current is always lower than that obtained during heating.
Fig. 2.7 Log $J/V^2$ vs. $1/V$ (Fowler - Nordheim type plot)
Fig. 2.6 Variation of conductivity with field (log σ vs. E)
Fig. 2.9 Current Temperature Characteristics
Fig. 2.10 Current Temperature Characteristics
Fig. 2.02 Current Temperature Characteristics
Fig. 2.13 Current-Temperature Characteristics
(2) It is clear that the slope of each curve is higher in high temperature region, i.e., 70°C to 90°C than that for low temperature region (40°C to 70°C), showing a rapid change of current density in high temperature region than that in low temperature region.

(3) Richardson Schottky type plots log $J/T^2$ versus $1/T$ are shown in figure 2.14. Two straight line curves, with different slopes are clearly observed at every field. The slope in low temperature region is less than that for high temperature region. A sharp knee separates these two regions. An important conclusion observed from these plots is that the sharp knee transition temperature value decreases as field increases from 1.45 kV/cm to 14.50 kV/cm.

(4) Variation of conductivity with temperature at different fields (log $\sigma$ vs. $1/T$) are shown in figure 2.15, to

(a) Each curve corresponding to all the fields show two straight lines, one corresponding to low temperature region (40°C to 60°C) and other to higher temperature region (60°C to 90°C).

(b) The conductivity varies rapidly in high temperature region as compared to low temperature region. No sharp knee (transition temperature) is observed separating these two regions.

(5) Activation energy has been calculated from the slopes of the straight portions of the curves shown in figure
Fig. 2.14 Log $J/T^2$ vs. $1/T$ (Richardson plot)
Fig. 2.15 Plot of log $\sigma$ vs. $1/T$
2.16. The values are given in table no. 2.1.

The variation of activation energy with field in the two regions is shown in graph figure 2.16. It is observed that activation energy corresponding to high temperature region is greater than that corresponding to low temperature region. The variation of activation energy $E$, corresponding to low temperature region (40°C-60°C) with field is 0.88 eV to 0.99 eV and corresponding to high temperature region (60°C - 90°C), $E_2$ varies from 1.78 eV to 1.88 eV.

<table>
<thead>
<tr>
<th>Field kV/cm</th>
<th>Activation energy low temperature region (40°C-60°C) $E_1$(eV)</th>
<th>Activation energy high temperature region (60°C to 90°C) $E_2$(eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.45</td>
<td>0.88</td>
<td>1.78</td>
</tr>
<tr>
<td>2.90</td>
<td>0.91</td>
<td>1.78</td>
</tr>
<tr>
<td>4.35</td>
<td>0.94</td>
<td>1.79</td>
</tr>
<tr>
<td>5.80</td>
<td>0.96</td>
<td>1.78</td>
</tr>
<tr>
<td>7.25</td>
<td>0.96</td>
<td>1.81</td>
</tr>
<tr>
<td>8.70</td>
<td>0.96</td>
<td>1.84</td>
</tr>
<tr>
<td>10.15</td>
<td>0.96</td>
<td>1.83</td>
</tr>
<tr>
<td>11.60</td>
<td>0.98</td>
<td>1.88</td>
</tr>
<tr>
<td>13.05</td>
<td>1.00</td>
<td>1.87</td>
</tr>
<tr>
<td>14.50</td>
<td>0.99</td>
<td>1.87</td>
</tr>
</tbody>
</table>
Fig. 2.16 Variation of activation energy with field

E₂ = TEMP. 70°C to 85°C
E₁ = TEMP. 40°C to 60°C
### TABLE 2.2

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Power 'm' region corresponding to lower field</th>
<th>Power 'm' region corresponding to higher field.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increasing</td>
<td>Decreasing</td>
</tr>
<tr>
<td>40</td>
<td>0.8985</td>
<td>0.9893</td>
</tr>
<tr>
<td>50</td>
<td>0.9657</td>
<td>0.8331</td>
</tr>
<tr>
<td>60</td>
<td>0.9945</td>
<td>0.9038</td>
</tr>
<tr>
<td>70</td>
<td>1.0812</td>
<td>0.9413</td>
</tr>
<tr>
<td>75</td>
<td>1.1206</td>
<td>0.9528</td>
</tr>
<tr>
<td>80</td>
<td>1.0618</td>
<td>0.9465</td>
</tr>
<tr>
<td>85</td>
<td>1.0032</td>
<td>1.0610</td>
</tr>
<tr>
<td>90</td>
<td>0.9717</td>
<td>0.9332</td>
</tr>
</tbody>
</table>

### TABLE 2.3

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Value of 'r' for lower field region</th>
<th>Value of 'r' for higher field region</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>50</td>
<td>1.00</td>
<td>1.02</td>
</tr>
<tr>
<td>60</td>
<td>1.00</td>
<td>1.03</td>
</tr>
<tr>
<td>70</td>
<td>1.00</td>
<td>0.99</td>
</tr>
<tr>
<td>75</td>
<td>1.00</td>
<td>0.993</td>
</tr>
<tr>
<td>80</td>
<td>0.9934</td>
<td>0.9969</td>
</tr>
<tr>
<td>85</td>
<td>1.01</td>
<td>1.008</td>
</tr>
<tr>
<td>90</td>
<td>1.00</td>
<td>0.9991</td>
</tr>
</tbody>
</table>