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Issue A

Application Note

Conversion of vacuum pressure units

EDWARDS

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VTC October 1992

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1 INTRODUCTION

Users of vacuum equipment around the world employ a variety of vacuum pressure units. The graphs and conversion factors in this document will help you to convert from one pressure unit to another. In addition, we include in this document definitions of the different vacuum measurement scales.

2 VACUUM MEASUREMENT SCALES

2.1 Absolute and gauge measurement scales

The word 'vacuum' is derived from the Latin word 'vacuus' which means empty. The origin of the word vacuum therefore suggests an ideal vacuum, a perfect vacuum or an absolute zero pressure. In practice, absolute zero pressure is never realised but it provides a convenient reference pressure for vacuum measurements. When vacuum pressures are referenced to absolute zero pressure, we describe them as being made on an 'absolute measurement scale'.

Atmospheric (or barometric) pressure is the local pressure, which can be expressed in any of the pressure units. Standard atmospheric pressure (1 atmosphere) is 760 mm Hg, 29.92 in Hg or 1013.25 mbar. When vacuum pressures are referenced to atmospheric pressure, we describe them as being made on a 'gauge measurement scale'.

To convert accurately between a gauge measurement and absolute measurement, you must know the atmospheric pressure on the day of the measurement. Alternatively, you can make an approximate conversion between these scales by using standard atmospheric pressure instead of the local atmospheric pressure in the conversion.

2.2 Absolute pressure

Absolute pressure is the total pressure measured with reference to absolute zero pressure. On the absolute pressure scale, the following vacuum pressure values all correspond to absolute zero pressure:

- 0 mm Hg = 0 in Hg = 0 mbar = 0 Torr

We recommend that you use absolute pressures because the measurement is referenced to an absolute and unchanging pressure.

2.3 Gauge pressure

Gauge pressure is the pressure measured above the local atmospheric (barometric) pressure.

So, for example, 2.1 bar gauge is equivalent to 3.1 bar absolute if the local pressure is exactly 1 bar absolute.

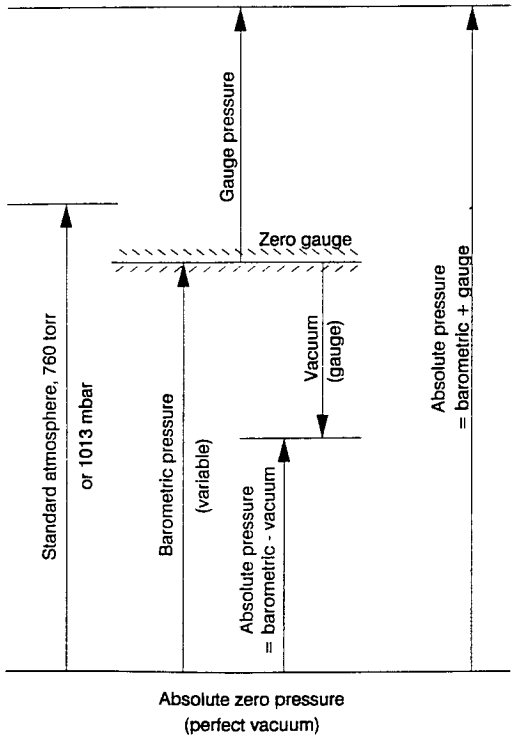


Figure 1 - Representation of vacuum pressure measurement scales

2.4 Gauge vacuum or vacuum (gauge)

Gauge vacuum is the pressure measured below the local atmospheric (barometric) pressure. Note that atmospheric pressure, which varies from day to day is used as the reference for gauge vacuum measurements.

So, for example, a vacuum of 25 in Hg gauge is equivalent to 5 in Hg absolute when the local atmospheric pressure is 30 in Hg.

The gauge vacuum scale is mainly used as an engineering scale. When mm Hg or in water are the units used, gauge pressure corresponds to the height of a column of mercury or water (respectively) which is supported by 1 atmosphere, as shown in Figure 2. A vacuum pressure of 0 therefore corresponds to a pressure of 1 atmosphere in the vacuum system.

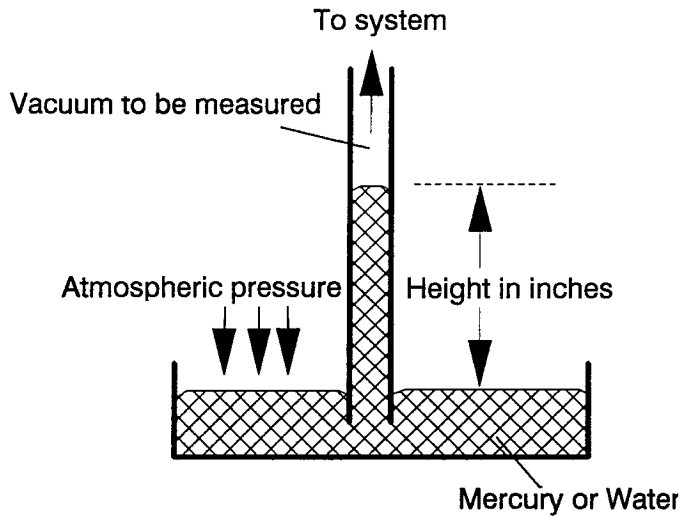


Figure 2 - Representation of a gauge vacuum measurement

Since local atmospheric pressure is approximately 30 in Hg (in fact, 1 standard atmosphere is 29.92 in Hg), when the gauge vacuum pressure is 30 in Hg there is a 'good' vacuum in the system. Note that, because atmospheric pressure varies from day to day, the gauge vacuum for a 'good' vacuum will vary from about 29 in Hg to about 31 in Hg.

The equation to convert from gauge vacuum pressure to absolute pressure is as follows:

absolute pressure = local atmospheric pressure - gauge vacuum pressure

All of the pressures must be in the same units. For example, if the gauge vacuum pressure is 25.4 in Hg and the local atmospheric pressure is 29.1 in Hg, the absolute pressure is (29.1 - 25.4) = 3.7 in Hg. You can convert to other pressure units with the conversion factors given in Section 4 of this publication.

The above example shows the importance of knowing the local atmospheric pressure when you convert between gauge vacuum pressure and absolute pressure. If you assume that atmospheric pressure is one standard atmosphere (29.92 in Hg), the absolute pressure would be (29.92 - 25.4) = 4.52 in Hg which represents an error of 22%.

2.5 Percentage vacuum

This scale is similar to the gauge vacuum scale described in Section 2.4. Percentage vacuum is the amount of gas removed from the system expressed as a percentage of the amount of gas normally in the system, at local atmospheric pressure. Again atmospheric pressure, which varies from day to day is used as the reference for this scale of measurement.

So, for example, a percentage vacuum of 80% (which means that 80% of the system gas has been removed) is equivalent to 6 in Hg absolute when the local atmospheric pressure is 30 in Hg.

You can convert to other pressure units with the conversion factors given in Section 4 of this publication.

3 VACUUM MEASUREMENT UNITS

3.1 Pressure and the pascal

The definition of pressure is

pressure = force per unit area

The SI (International System of Units) unit of force is the newton; the newton is defined as that force, which when applied to a mass of 1 kilogram (1 kg), gives it an acceleration of 1 meter per second per second (1 ms^{-2}).

The SI unit of pressure (and stress) is the pascal (Pa), which was adopted internationally in 1972. The pascal is equivalent to 1 newton per square meter (1 Nm^{-2}).

3.2 Vacuum pressure units

The names and abbreviations for the various vacuum pressure units referred to in this document are shown in Table 1 below.

Pressure unit name	Abbreviation
pascal	Pa
bar	bar
atmosphere	at
torr	Torr
millimetres of mercury	mm Hg
inches of mercury	in Hg
inches of water	in H_2O
percentage vacuum	% vac
pounds per square inch	psi

Table 1 - Vacuum pressure unit names and abbreviations

As described overleaf, the pascal is the SI unit of pressure. However, the mbar is commonly the preferred unit, where

- 1 mbar = 100 Pa = 1 hPa

The mbar is not related to the pascal by the preferred factor of 10^3, but it is used by the majority of European vacuum manufacturers.

Other commonly used vacuum pressure units are the Torr and the mm Hg which are often assumed to be exactly equivalent units of measurement. However, there is a slight difference in the definition of these units. The Torr is equal to the mm Hg within one part in 7 million. But, unless you need the most accurate conversion, you can assume that these units are equivalent and that:

- 1 mm Hg = 1 Torr

The term "micron of Hg" is sometimes used. In this case:

- 1 μ Hg = 1 mtorr

Other names and abbreviations are formed by combining these units with the decimal multiplication factors described in Section 3.3.

3.3 Decimal multiples of vacuum pressure units

Decimal multiples of vacuum pressure units can be formed with prefixes, some of which are listed in Table 2.

Prefix	Symbol	Multiplication factor
mega	M	10^6 or 1 000 000
kilo	k	10^3 or 1000
hecto	h	10^2 or 100
deca	da	10^1 or 10
deci	d	10^{-1} or 0.1
centi	c	10^{-2} or 0.01
milli	m	10^{-3} or 0.001
micro	μ	10^{-6} or 0.000 001
nano	n	10^{-9} or 0.000 000 001
pico	p	10^{-12} or 0.000 000 000 001

Table 2 - Decimal multiplication factors

Some examples of using these multiplication factors are shown overleaf:

- 1 millibar = 1 mbar = 1×10^{-3} bar = 0.001 bar
- 1 hectopascal = 1 hPa = 1×10^{2} Pa = 100 Pa
- 1 kilopascal = 1 kPa = 1×10^{3} Pa = 1000 Pa
- 1 milliTorr = 1 mTorr = 1×10^{-3} Torr = 0.001 Torr

Note that only one of the multiplication factors is used at one time, so 1000 kPa is not referred to as 1 kilokilopascal but as 1 megapascal.

4 UNIT CONVERSION FACTORS AND GRAPHS

Use the conversion factors in Table 3 to convert between the different units of vacuum pressure measurement. Note that we assume that mercury is at 0°C and that water is at 4°C; at other temperatures, the conversion factors will be slightly different but this change is usually negligibly in most vacuum processes and measurements.

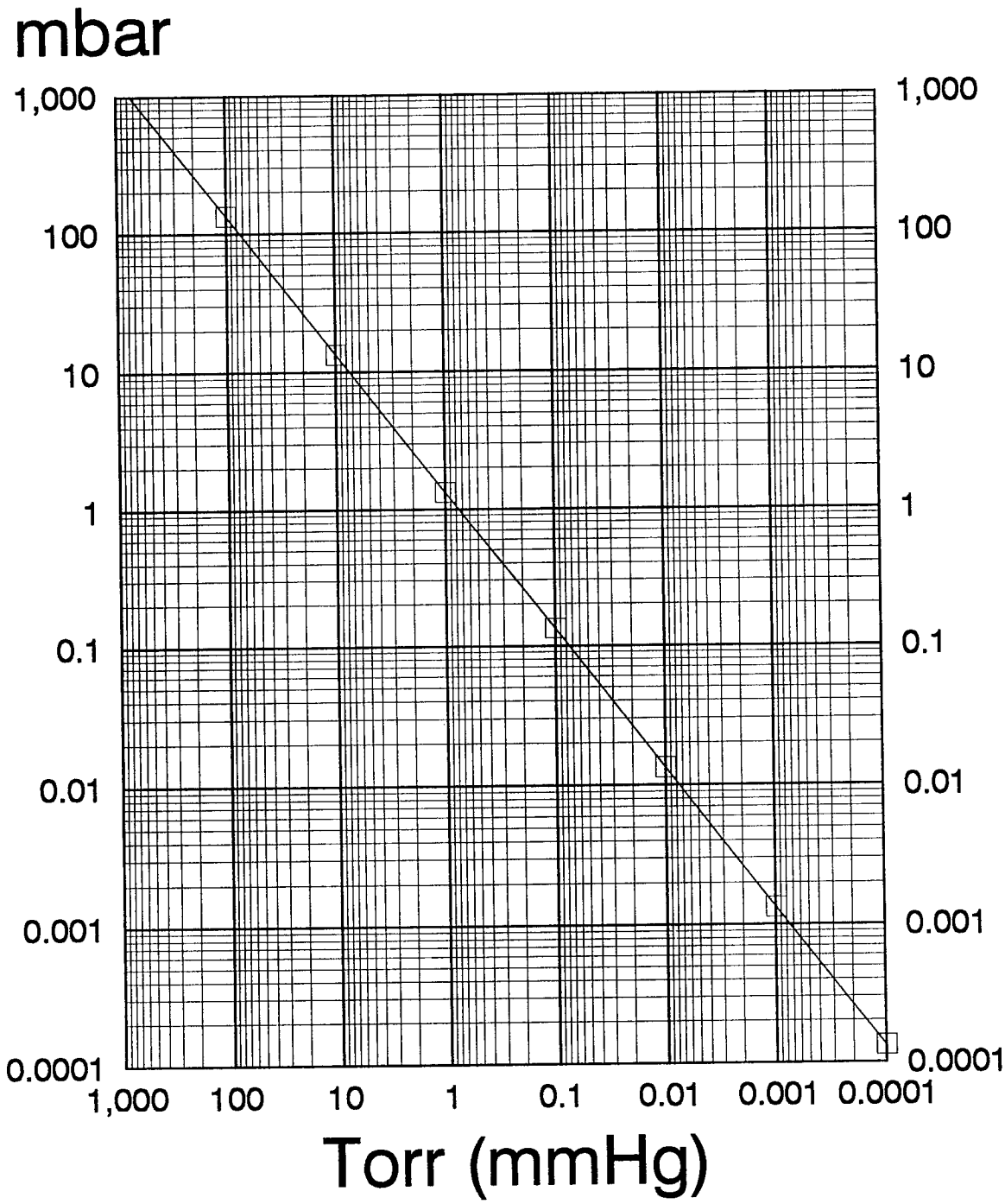
Use the procedure below to convert between units:

1. In Table 3, find the row with the unit you want to convert from in the left-hand column.
2. Look along this row until you get to the the column with the unit you want to convert to.
3. Multiply your vacuum pressure measurement by this conversion factor.

For example, to convert 120 mbar to Torr: pressure in Torr = $120 \times 7.50062 \times 10^{-1}$ = 90.003 Torr.

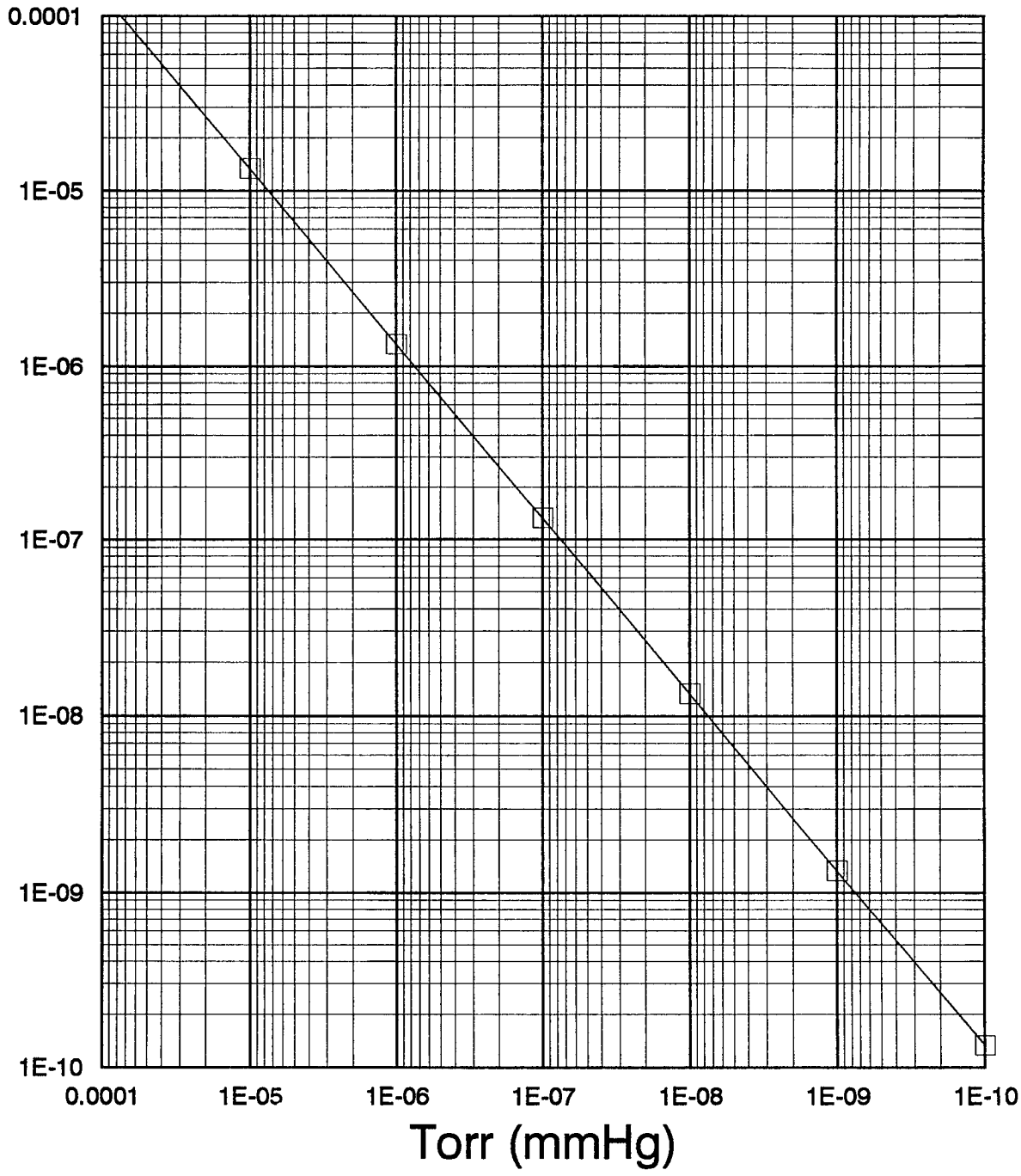
	mbar	Pa	at (standard)	Torr (mm Hg)	µm Hg (micron)	in Hg	in H_2O	psi	kPa	MPa	bar	hbar
1 mbar =	1	1×10^{2}	9.86923×10^{-4}	7.50062×10^{-1}	7.50062×10^{2}	2.95300×10^{-2}	4.01463×10^{-1}	1.45038×10^{-2}	1×10^{-1}	1×10^{-4}	1×10^{-3}	1×10^{-5}
1 Pa =	1×10^{-2}	1	9.86923×10^{-6}	7.50062×10^{-3}	7.50062	2.95300×10^{-4}	4.01463×10^{-3}	1.45038×10^{-4}	1×10^{-3}	1×10^{-6}	1×10^{-5}	1×10^{-7}
1 at =	1.01325×10^{3}	1.01325×10^{5}	1	7.6×10^{2}	7.60000×10^{5}	2.99213×10^{1}	4.06782×10^{2}	1.46959×10^{1}	1.01325×10^{2}	1.01325×10^{-1}	1.01325	1.01325×10^{-2}
1 Torr =	1.33322	1.33322×10^{2}	1.31579×10^{-3}	1	1.00000×10^{3}	3.93701×10^{-2}	5.35240×10^{-1}	1.93368×10^{-2}	1.33322×10^{-1}	1.33322×10^{-4}	1.33322×10^{-3}	1.33322×10^{-5}
1 µm Hg =	1.33322×10^{-3}	1.33322×10^{-1}	1.31579×10^{-6}	1.00000×10^{-3}	1	3.93701×10^{-5}	5.35240×10^{-4}	1.93368×10^{-5}	1.33322×10^{-4}	1.33322×10^{-7}	1.33322×10^{-6}	1.33322×10^{-8}
1 in Hg =	3.38639×10^{1}	3.38639×10^{3}	3.34211×10^{-2}	2.54000×10^{1}	2.54×10^{4}	1	1.35951×10^{1}	4.91154×10^{-1}	3.38639	3.38639×10^{-3}	3.38639×10^{-2}	3.38639×10^{-4}
1 in H_2O =	2.49089	2.49089×10^{2}	2.45832×10^{-3}	1.86832	1.86832×10^{3}	7.35559×10^{-2}	1	3.61273×10^{-2}	2.49089×10^{-1}	2.49089×10^{-4}	2.49089×10^{-3}	2.49089×10^{-5}
1 psi =	6.89476×10^{1}	6.89746×10^{3}	6.80460×10^{-2}	5.17149×10^{1}	5.17149×10^{4}	2.03602	2.76799×10^{1}	1	6.89476	6.89476×10^{-3}	6.89476×10^{-2}	6.89476×10^{-4}
1 kPa =	10	1×10^{3}	9.86923×10^{-3}	7.50062	7.50062×10^{3}	2.95300×10^{-1}	4.01463	1.45038×10^{-1}	1	1×10^{-3}	1×10^{-2}	1×10^{-4}
1 MPa =	1×10^{4}	1×10^{6}	9.86923	7.50062×10^{3}	7.50062×10^{6}	2.95300×10^{2}	4.01463×10^{3}	1.45038×10^{2}	1×10^{3}	1	10	0.1
1 bar =	1×10^{3}	1×10^{5}	9.86923×10^{-1}	7.50062×10^{2}	7.50062×10^{5}	2.95300×101	4.01463×10^{2}	1.45038×10^{1}	100	0.1	1	1×10^{-2}
1 hbar =	1×10^{5}	1×10^{7}	9.86923×10^{1}	7.50062×10^{4}	7.50062×10^{7}	2.95300×10^{3}	4.01463×10^{4}	1.45038×10^{3}	1×10^{4}	10	100	1

Table 3 - Conversion factors for different vacuum pressure units



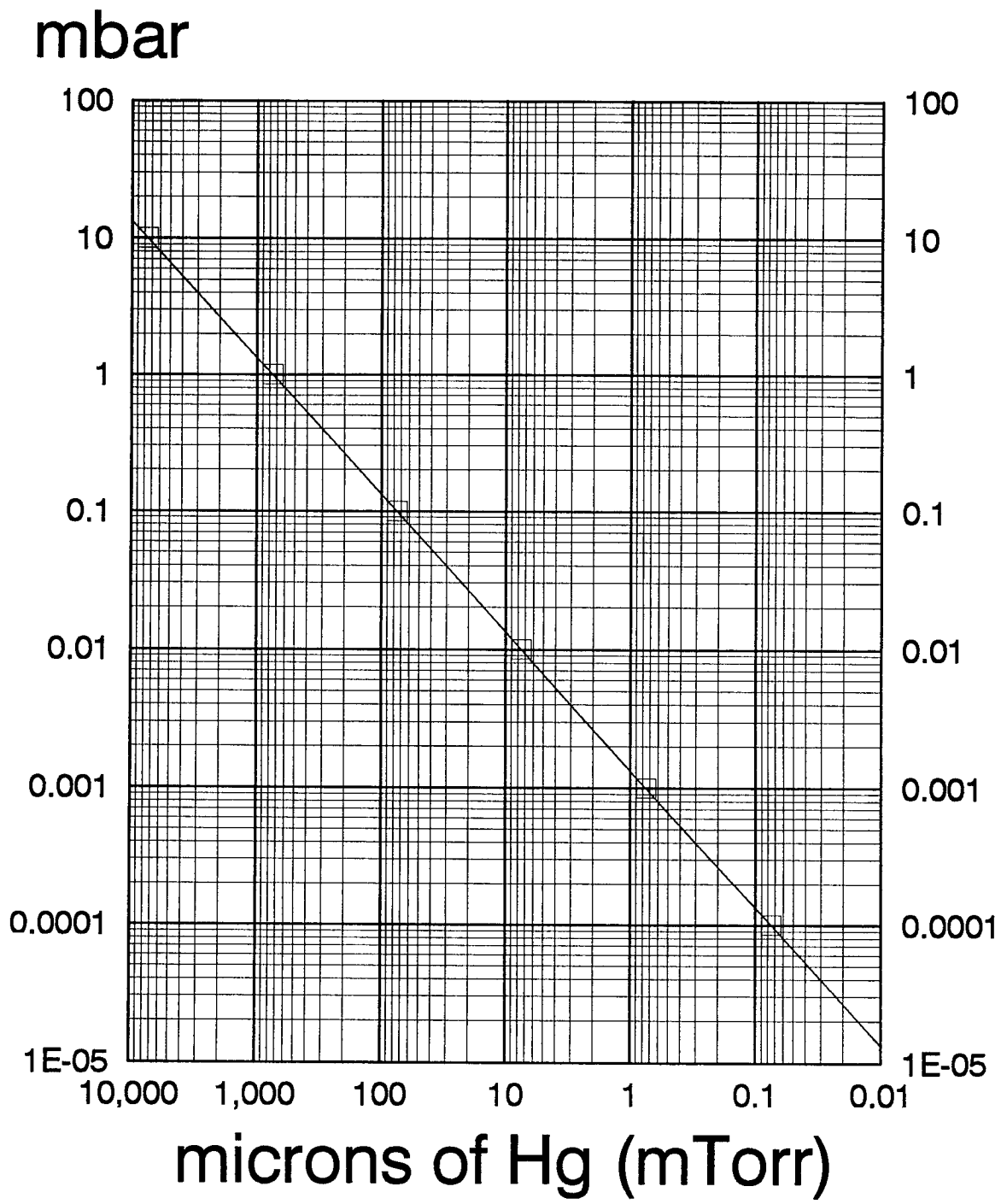
CONVERSION FACTOR: 1 mbar = 0.75 Torr

Figure 3 - Conversion graph: (1000 to 1 x 10^{-4}) mbar to Torr



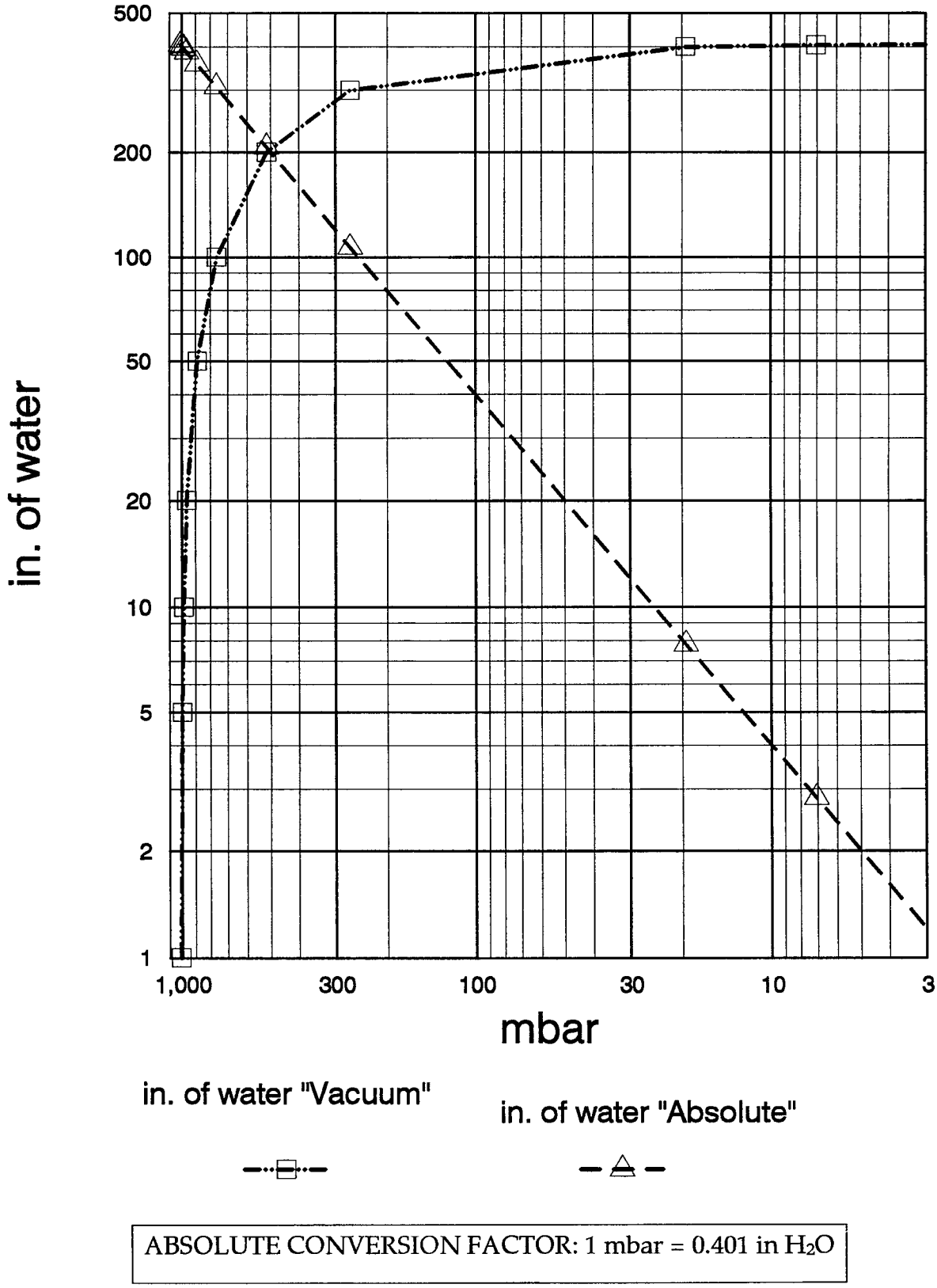
CONVERSION FACTOR: 1 mbar = 0.75 Torr

Figure 4 - Conversion graph: (1×10^{-4} to 1×10^{-10}) mbar to Torr



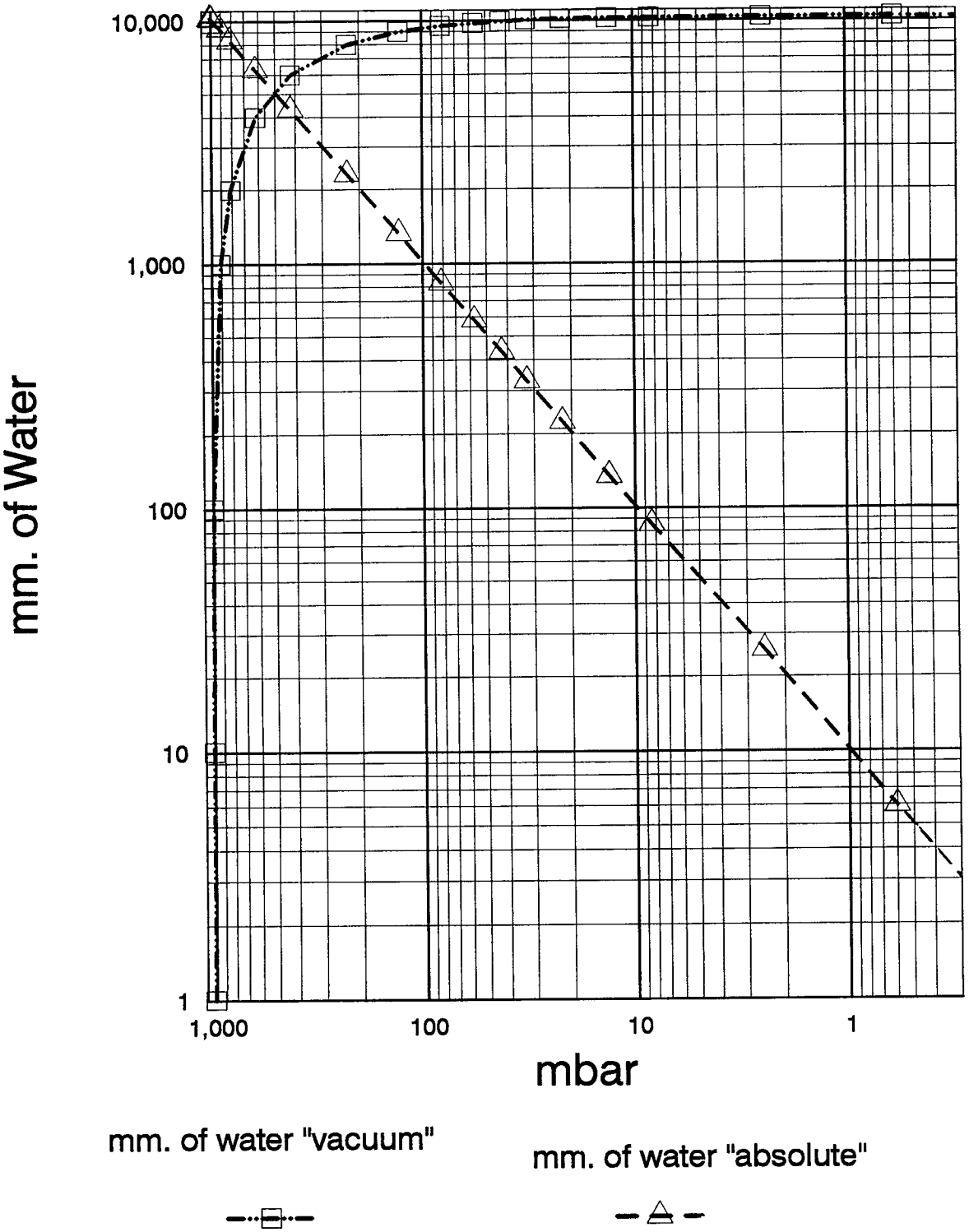
CONVERSION FACTOR: 1 mbar = 750 μm Hg

Figure 5 - Conversion graph: mbar to μm Hg (mTorr)



ABSOLUTE CONVERSION FACTOR: 1 mbar = 0.401 in H_2O

Figure 6 - Conversion graph: mbar to in H_2O



ABSOLUTE CONVERSION FACTOR: 1 mbar = 10.19 mm H_2O

Figure 7 - Conversion graph: mbar to mm H_2O

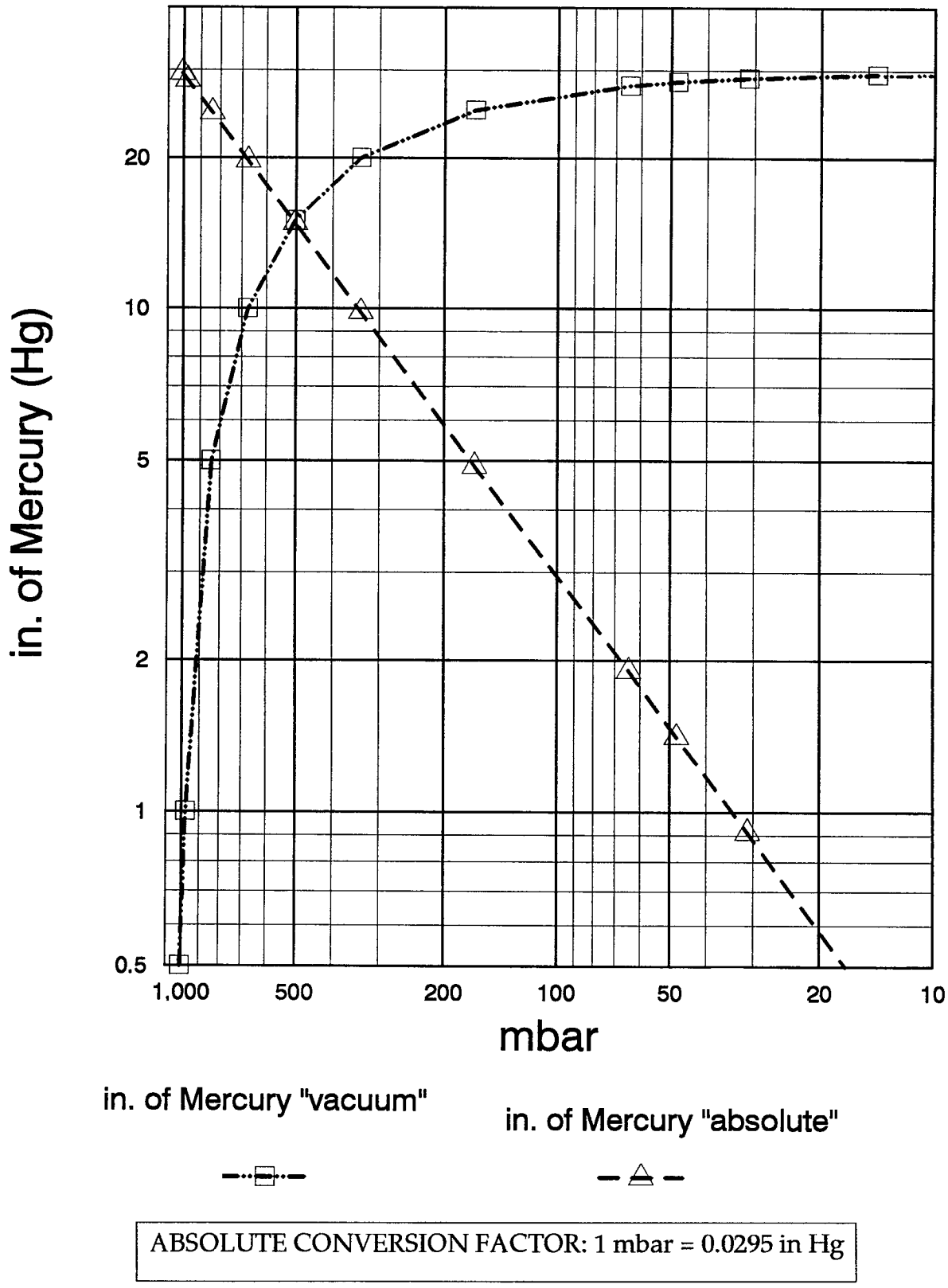


Figure 8 - Conversion graph: mbar to in Hg

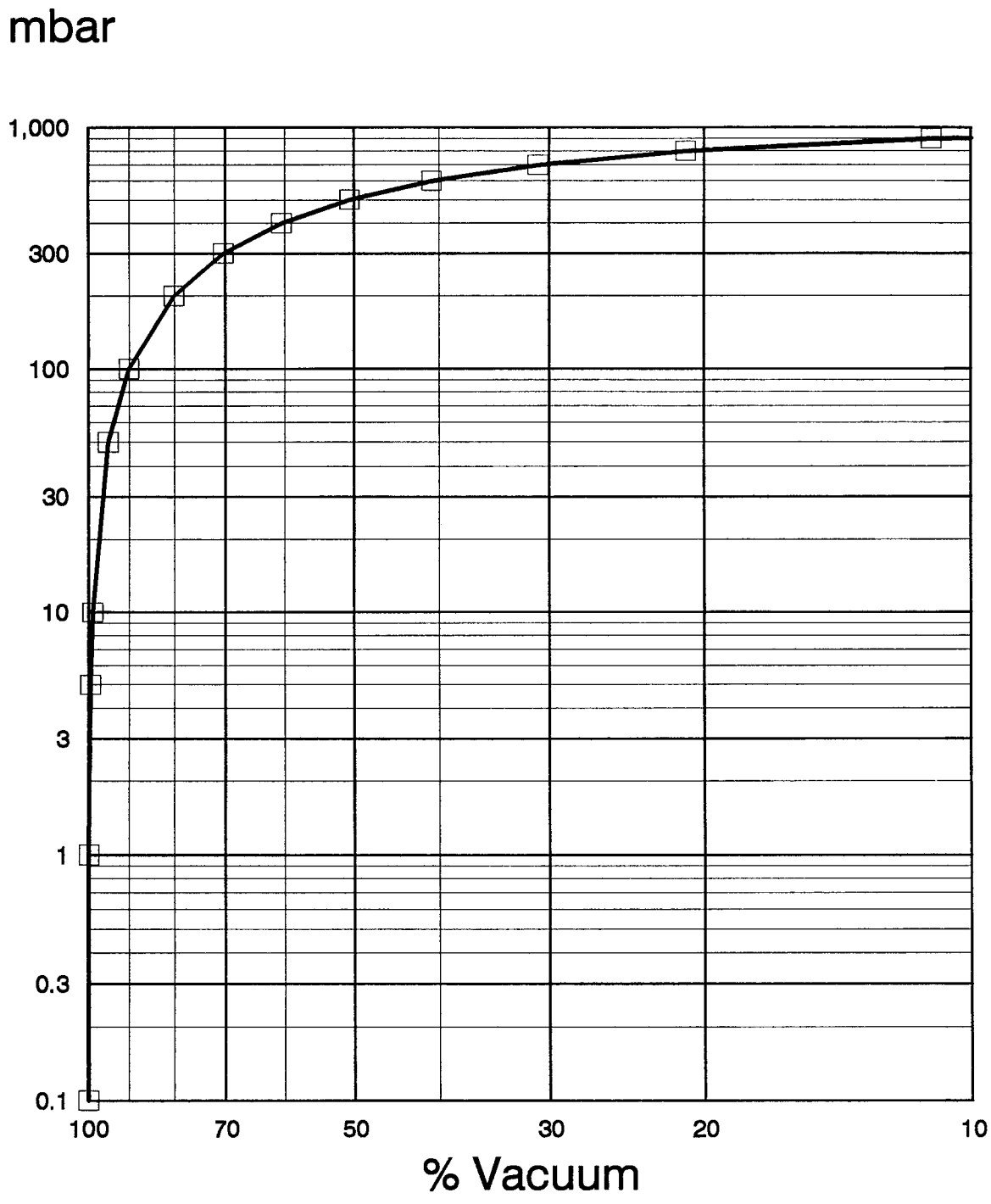


Figure 9 - Conversion graph: mbar to % vac

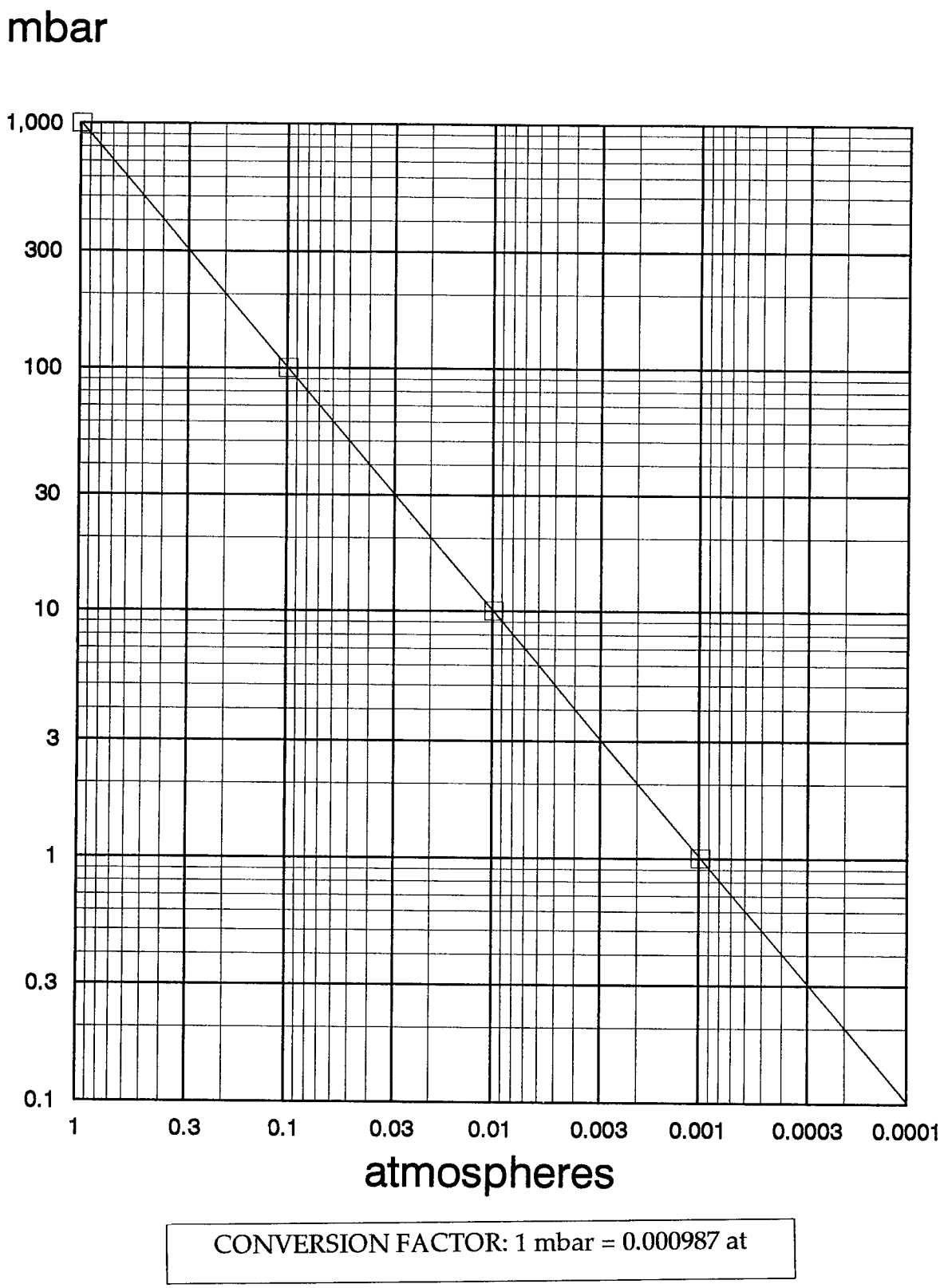
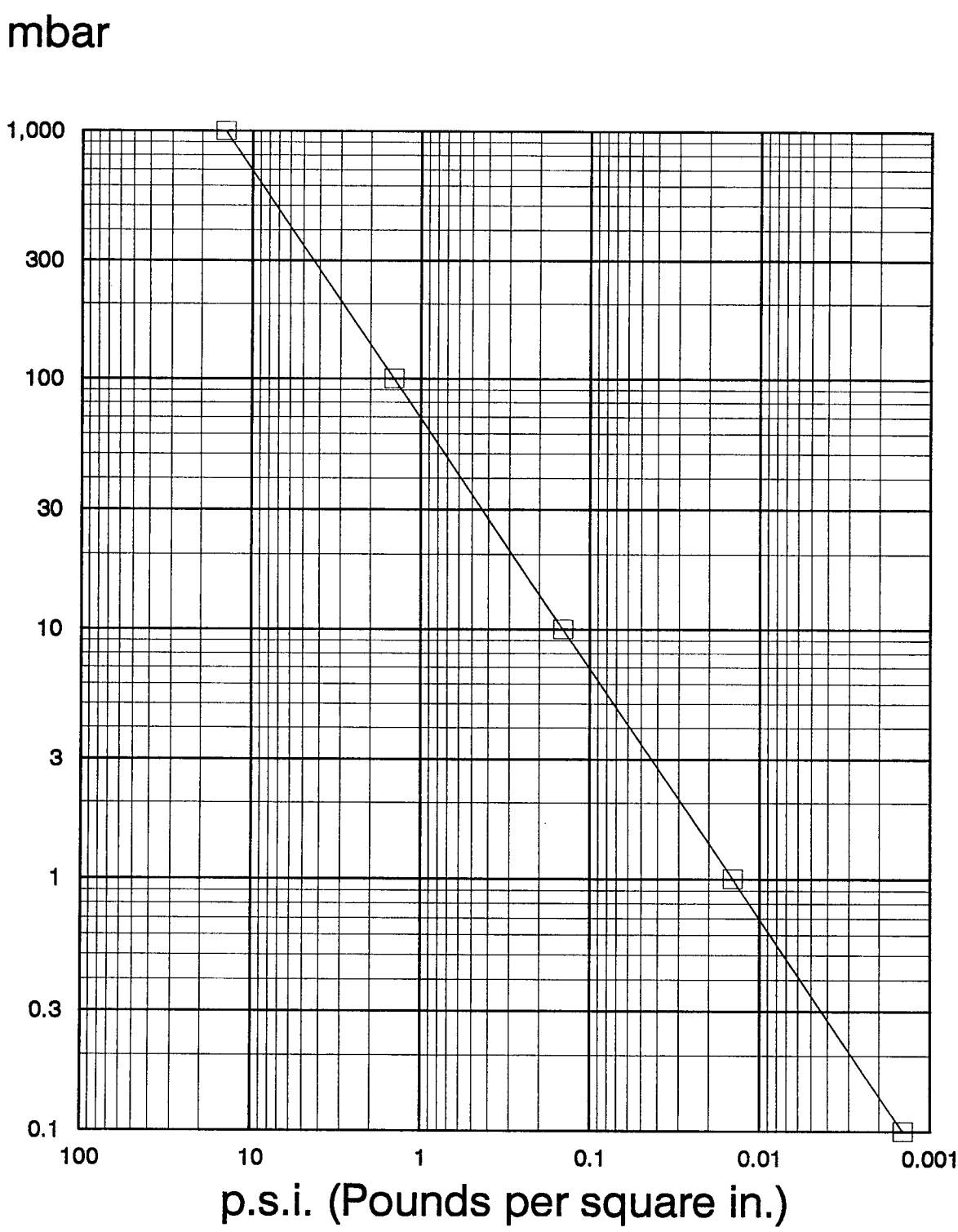
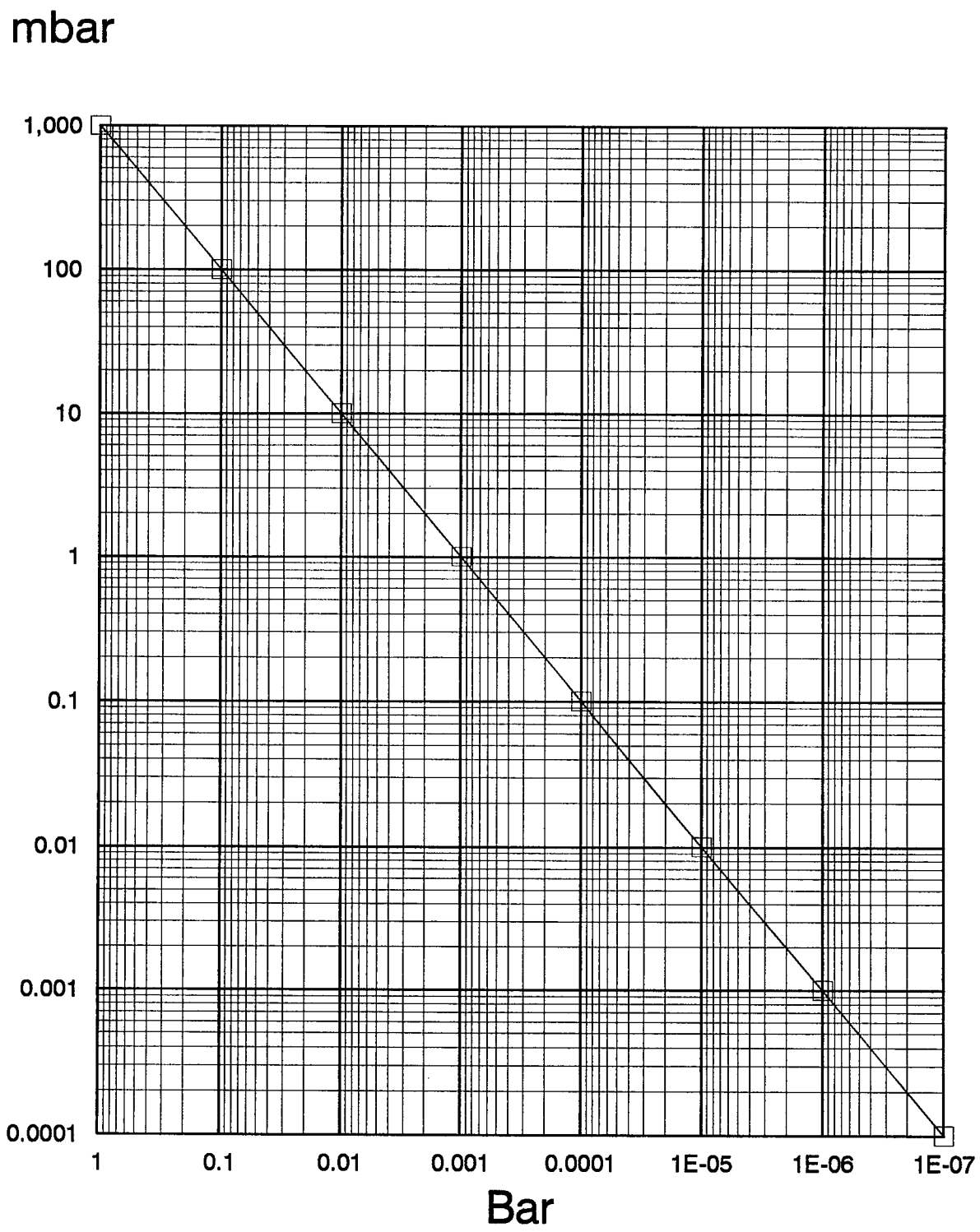


Figure 10 - Conversion graph: mbar to atmospheres



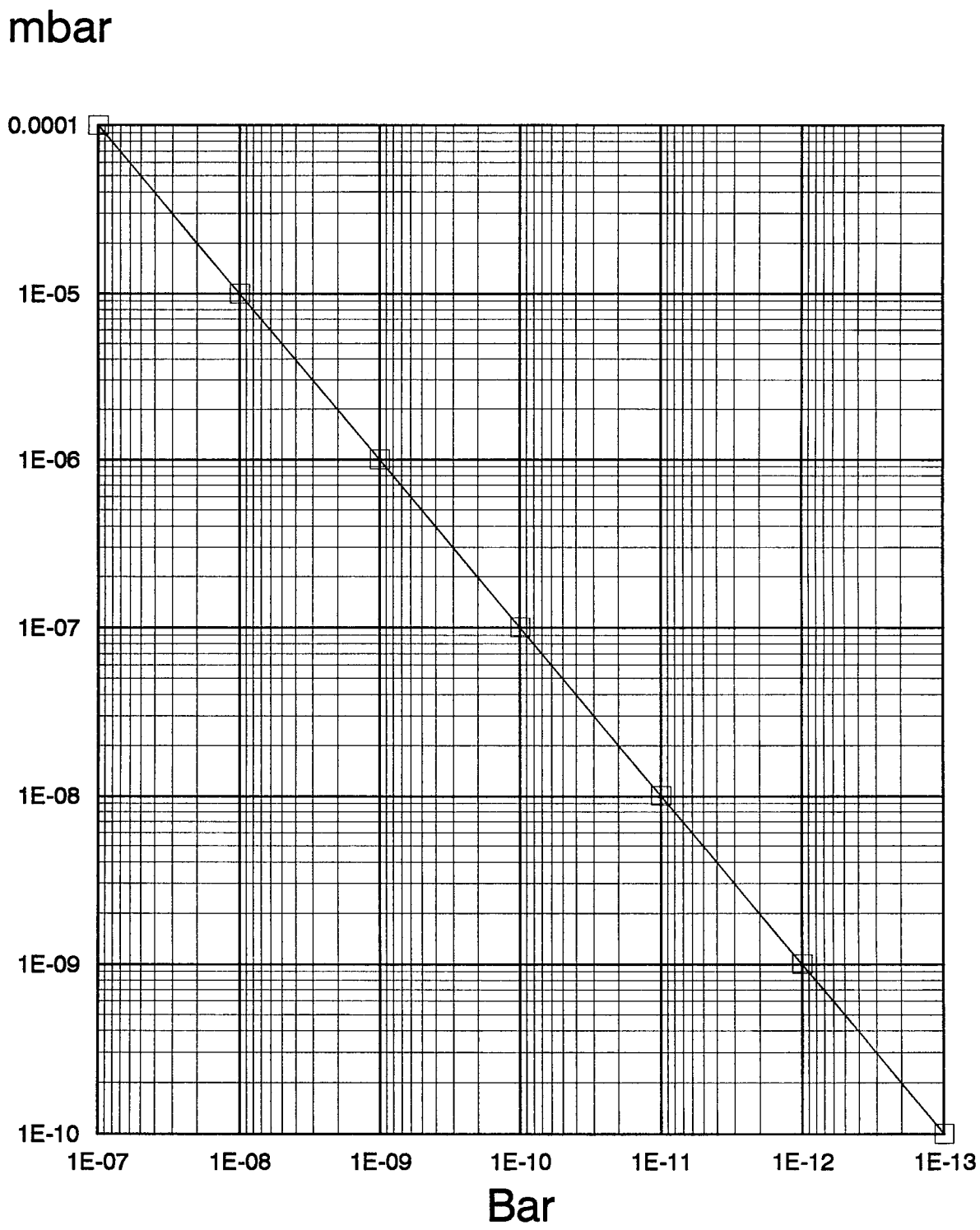
CONVERSION FACTOR: 1 mbar =0.0145 psi

Figure 11 - Conversion graph: mbar to psi



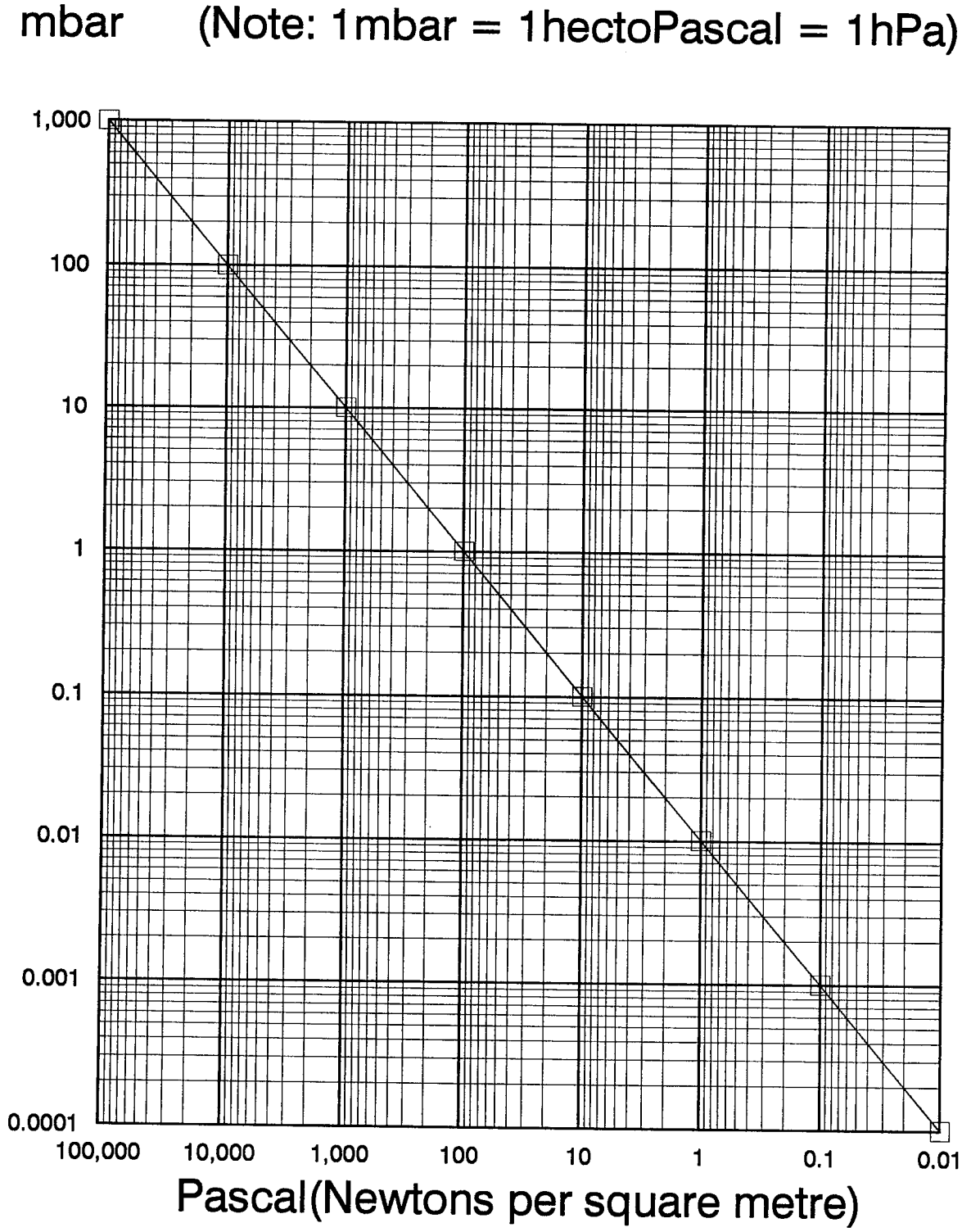
CONVERSION FACTOR: 1 mbar =0.001 bar

Figure 12 - Conversion graph: (1000 to 1 x 10^{-4}) mbar to bar



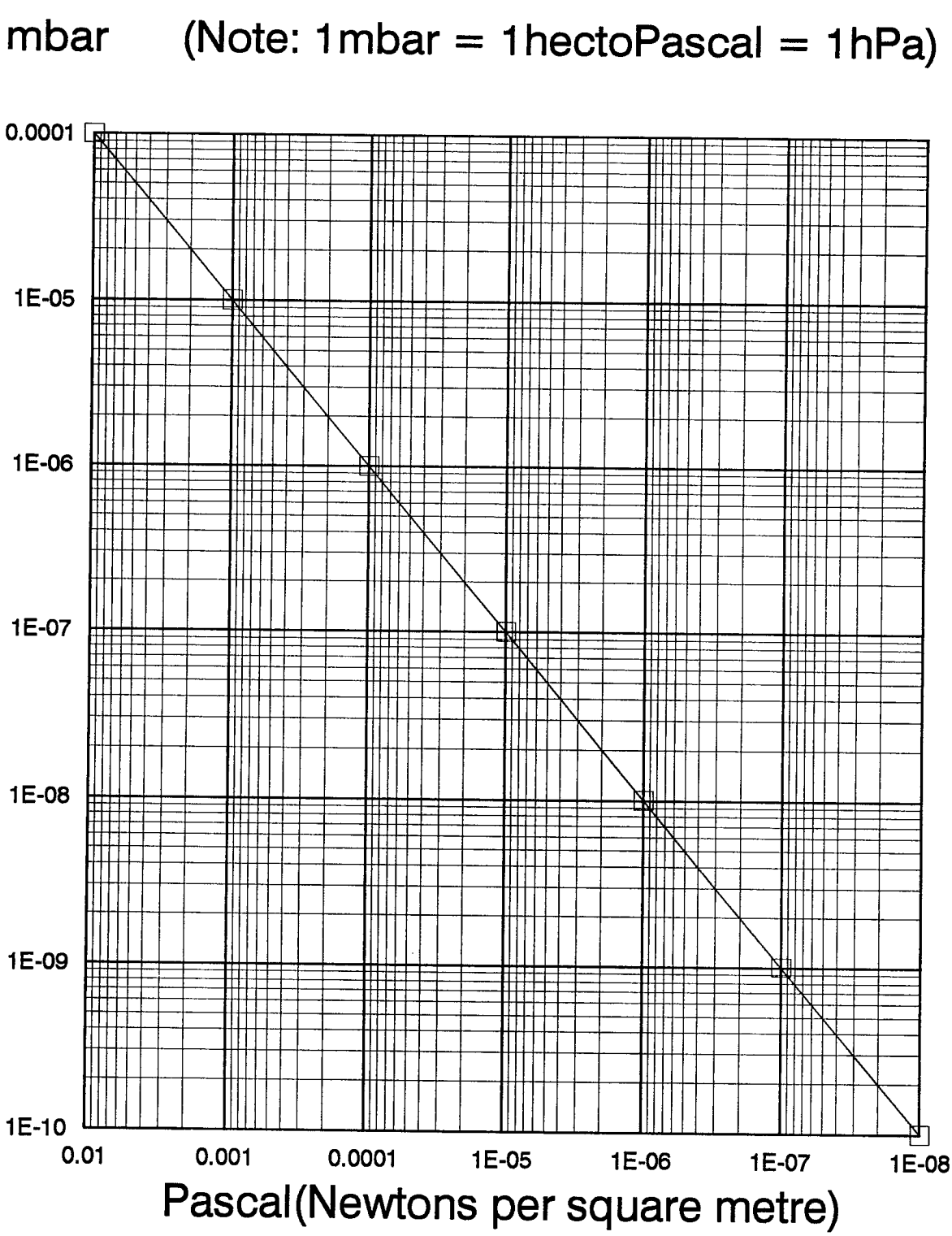
CONVERSION FACTOR: 1 mbar =0.001 bar

Figure 13 - Conversion graph: (1×10^{-4} to 1×10^{-10}) mbar to bar



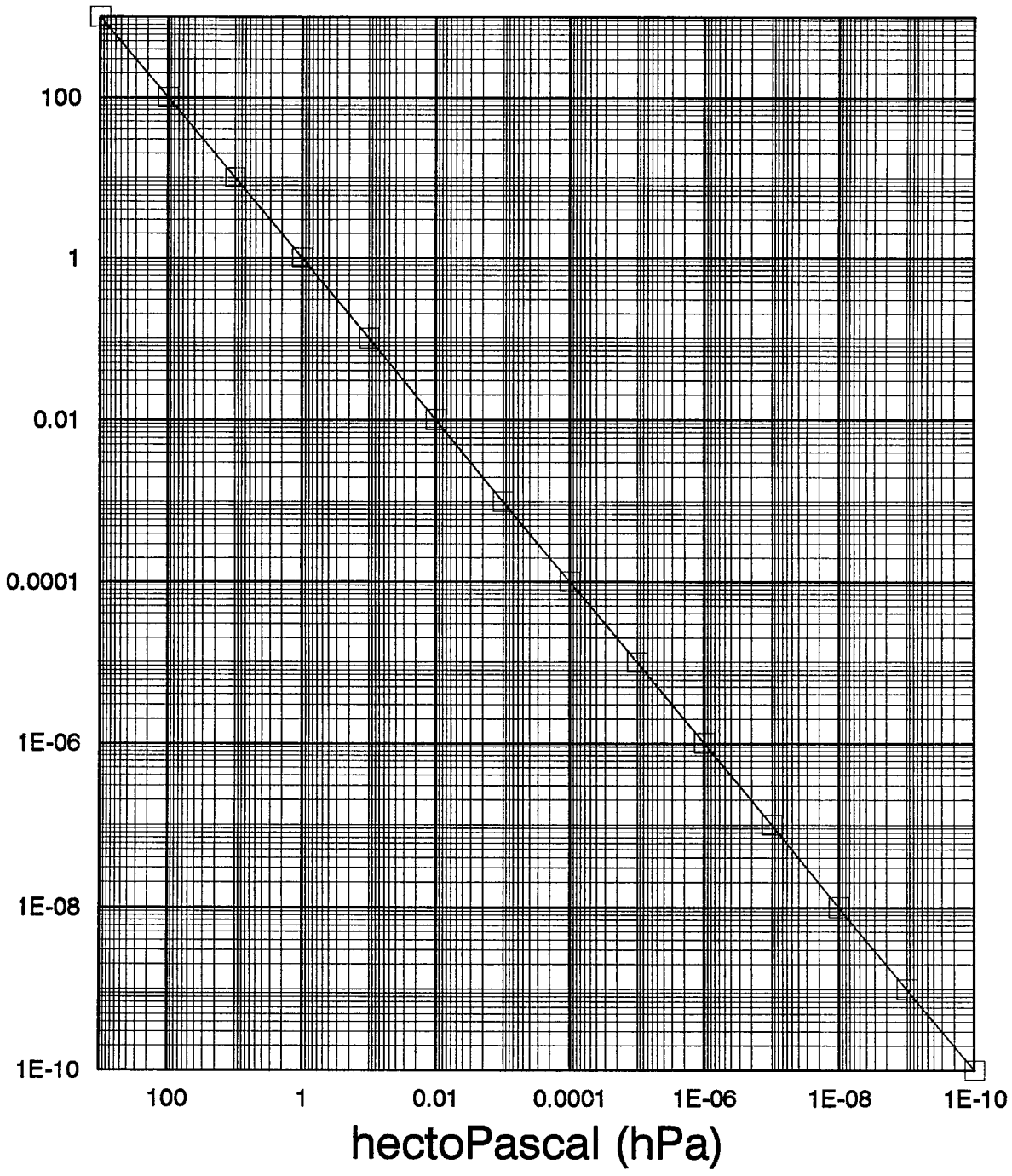
CONVERSION FACTOR: 1 mbar =100 Pa

Figure 14 - Conversion graph: (1000 to 1 x 10^{-4}) mbar to Pa



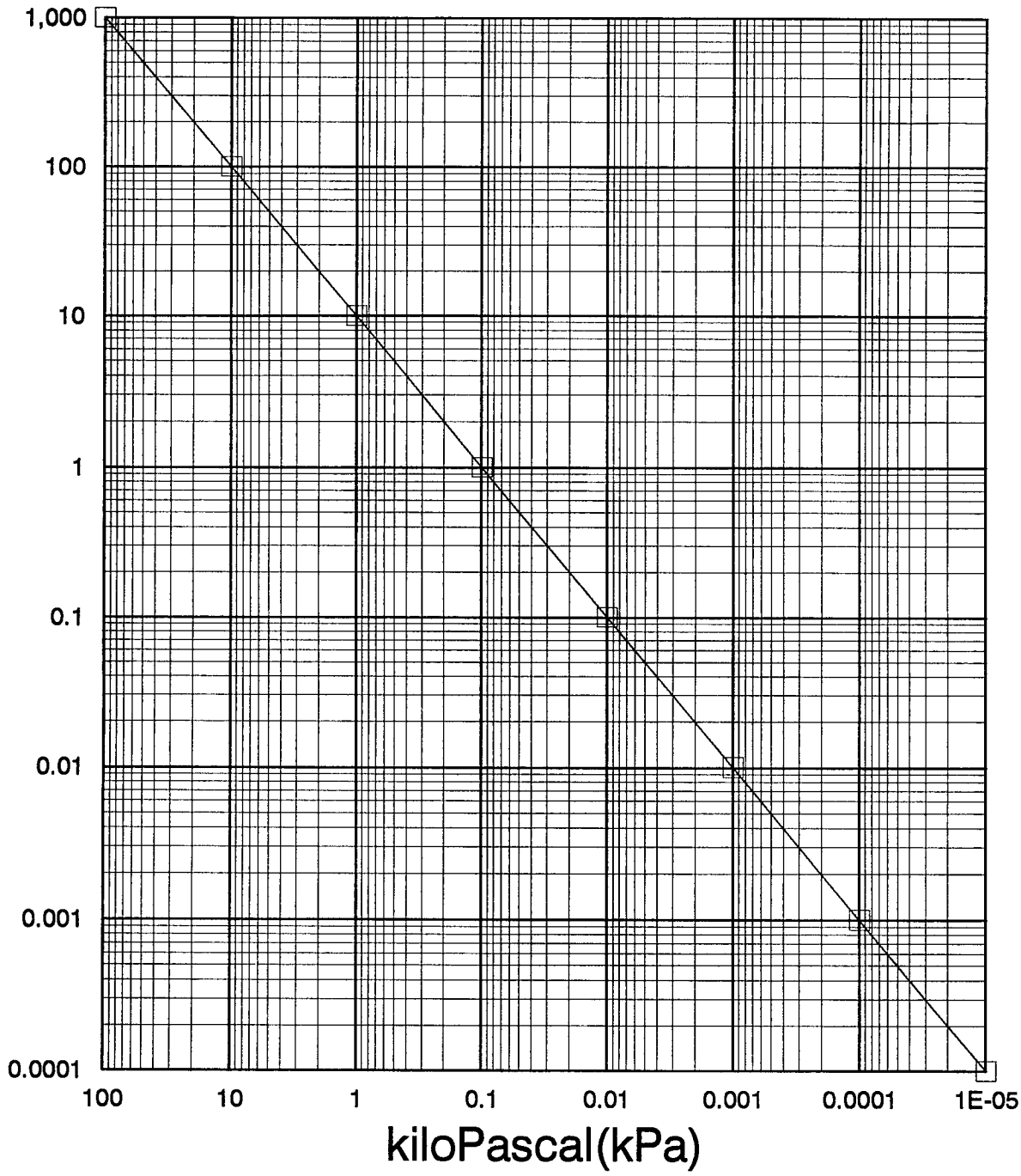
CONVERSION FACTOR: 1 mbar =100 Pa

Figure 15 - Conversion graph: (1×10^{-4} to 1×10^{-10}) mbar to Pa



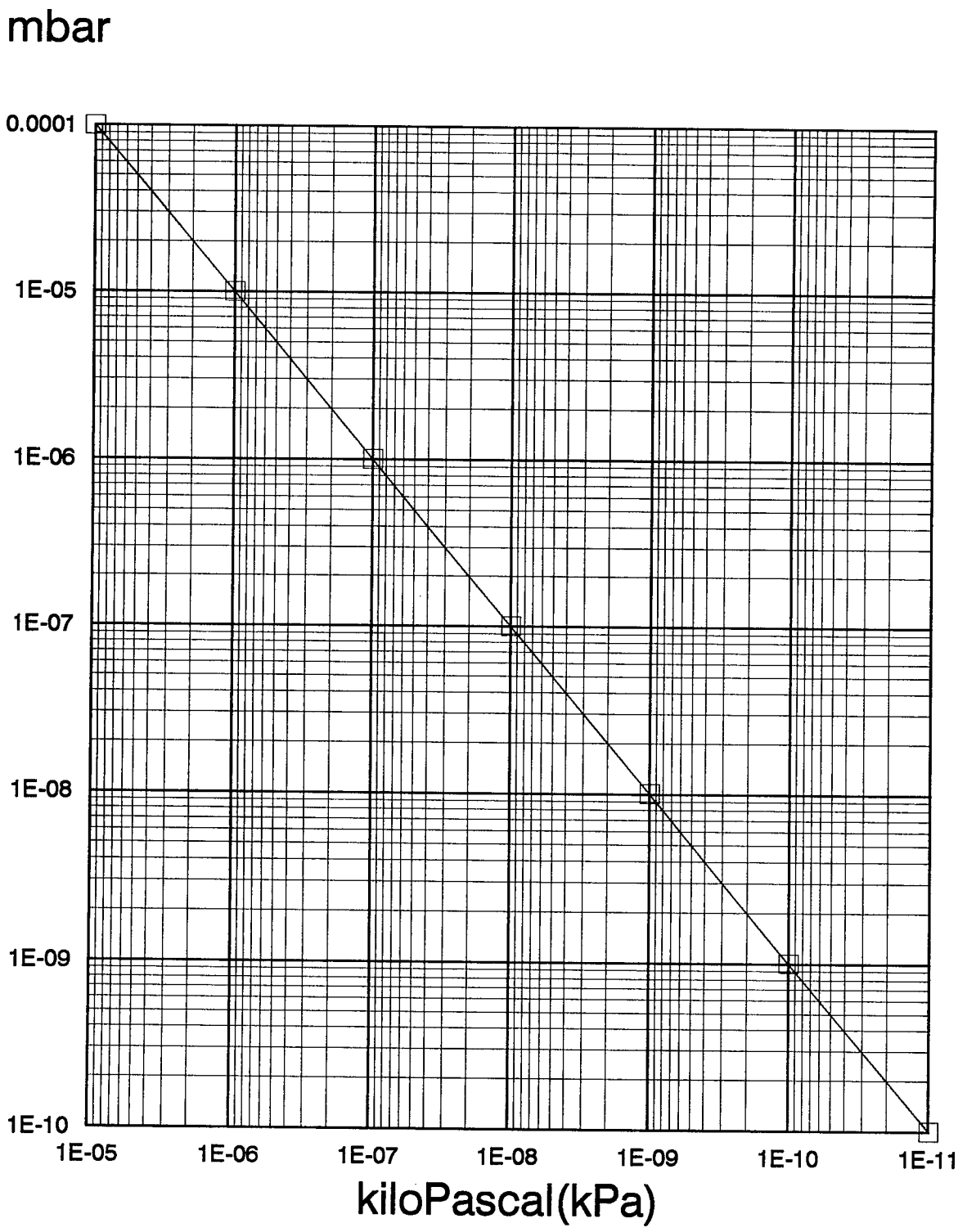
CONVERSION FACTOR: 1 mbar =1 hPa

Figure 16 - Conversion graph: mbar to hPa



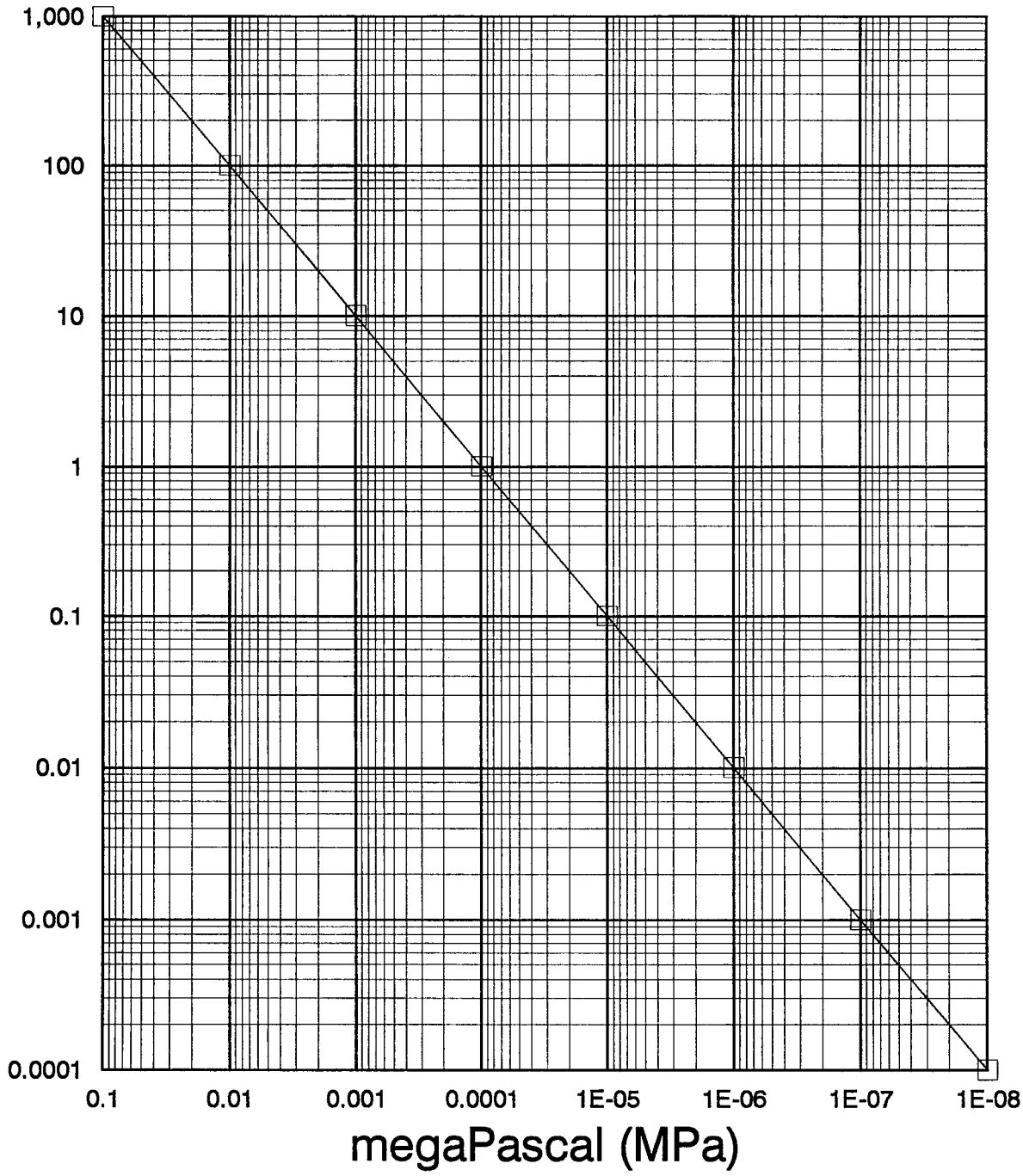
CONVERSION FACTOR: 1 mbar = 0.1 kPa

Figure 17 - Conversion graph: (1000 to 1 x 10^{-4}) mbar to kPa



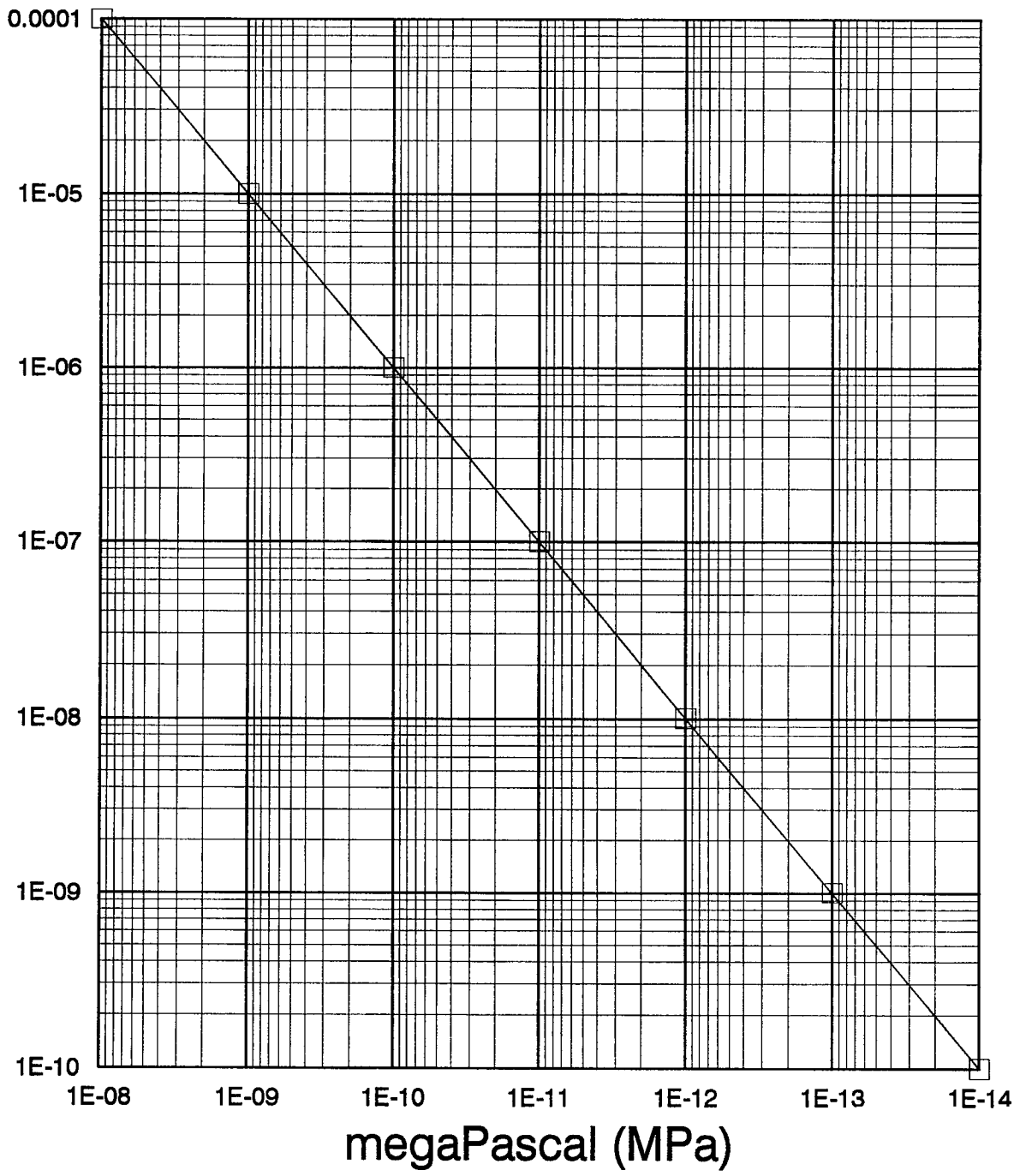
CONVERSION FACTOR: 1 mbar = 0.1 kPa

Figure 18 - Conversion graph: (1×10^{-4} to 1×10^{-10}) mbar to kPa



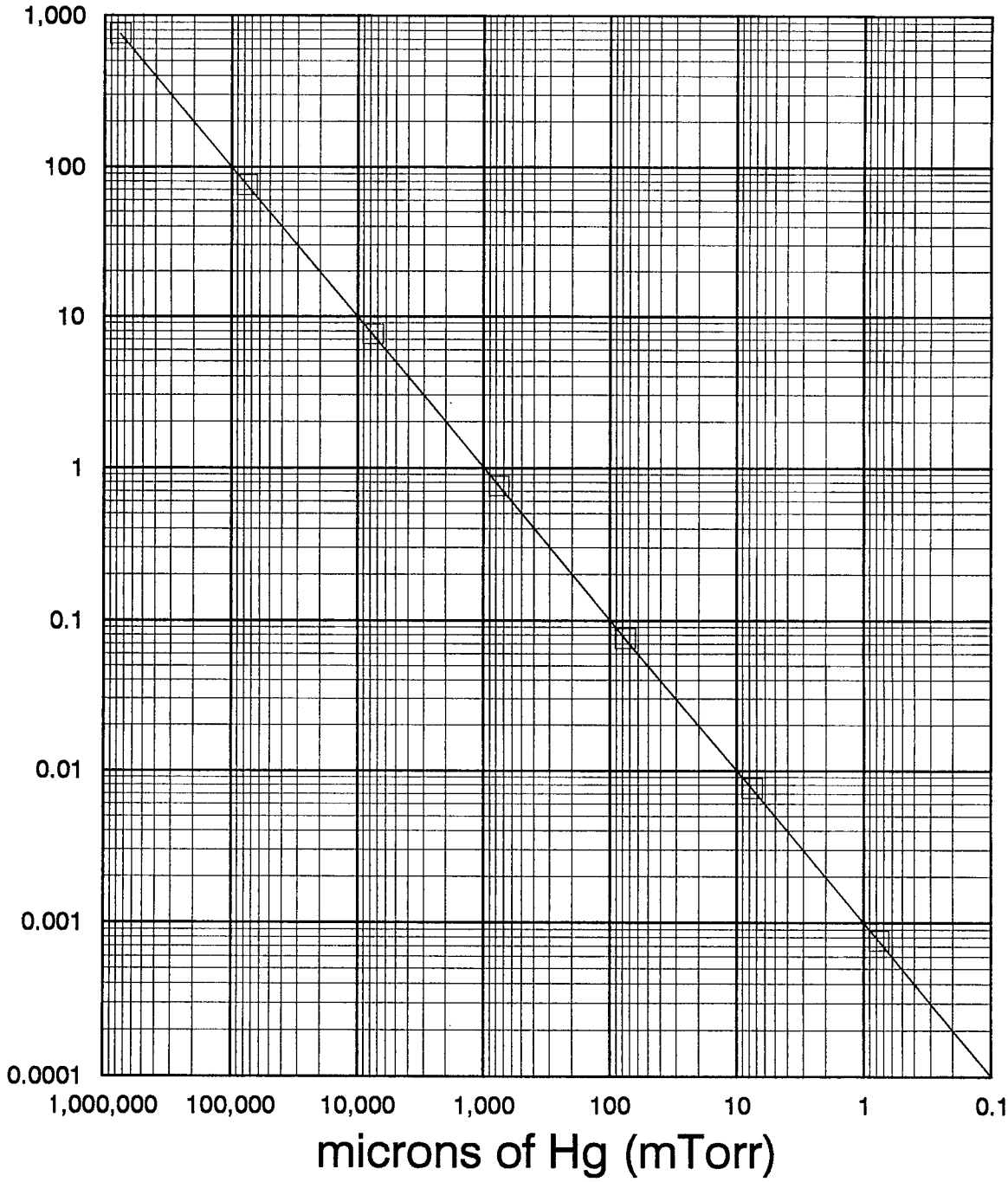
CONVERSION FACTOR: 1 mbar = 0.0001 MPa

Figure 19 - Conversion graph: (1000 to 1 x 10^{-4}) mbar to MPa



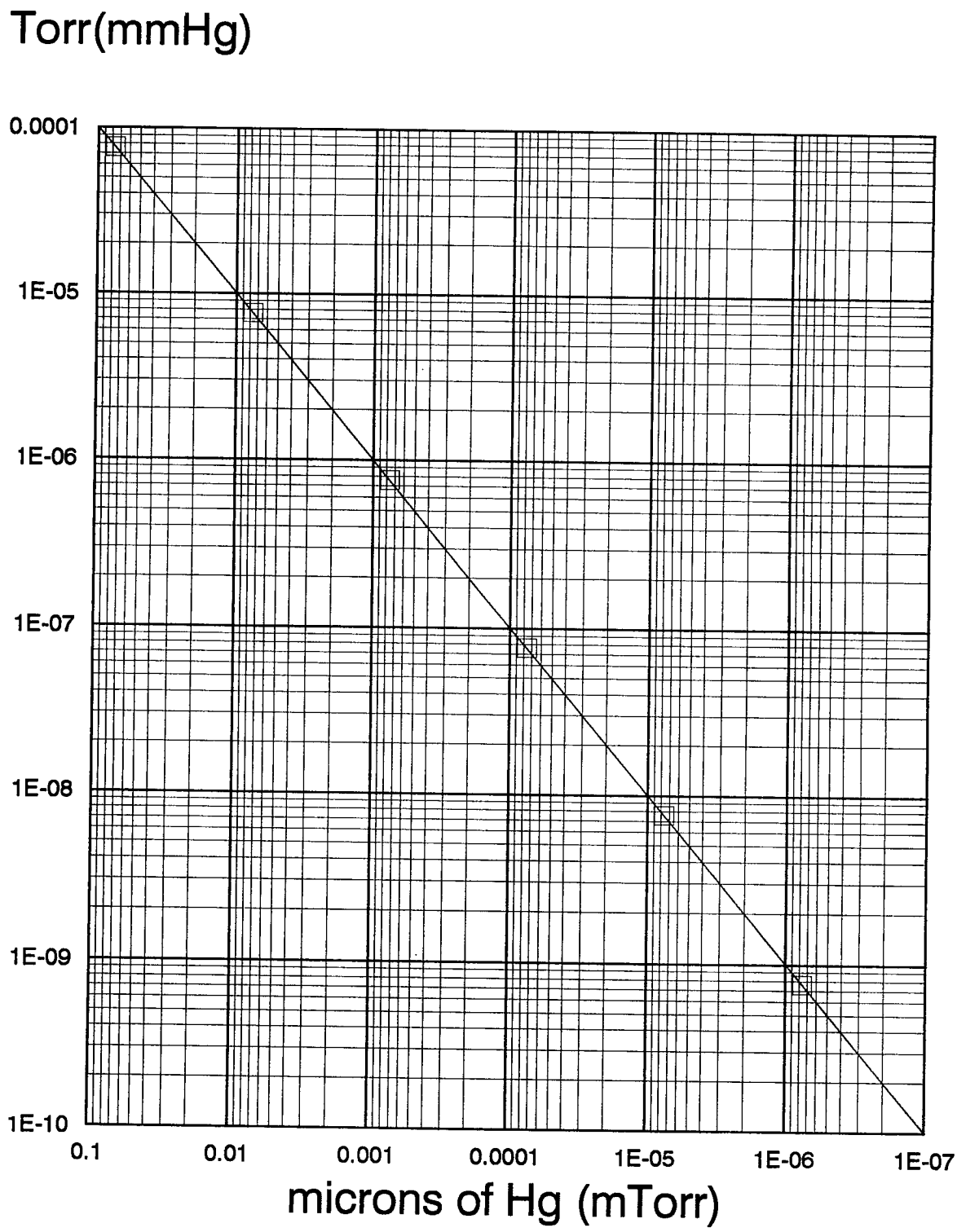
CONVERSION FACTOR: 1 mbar = 0.0001 MPa

Figure 20 - Conversion graph: (1×10^{-4} to 1×10^{-10}) mbar to MPa



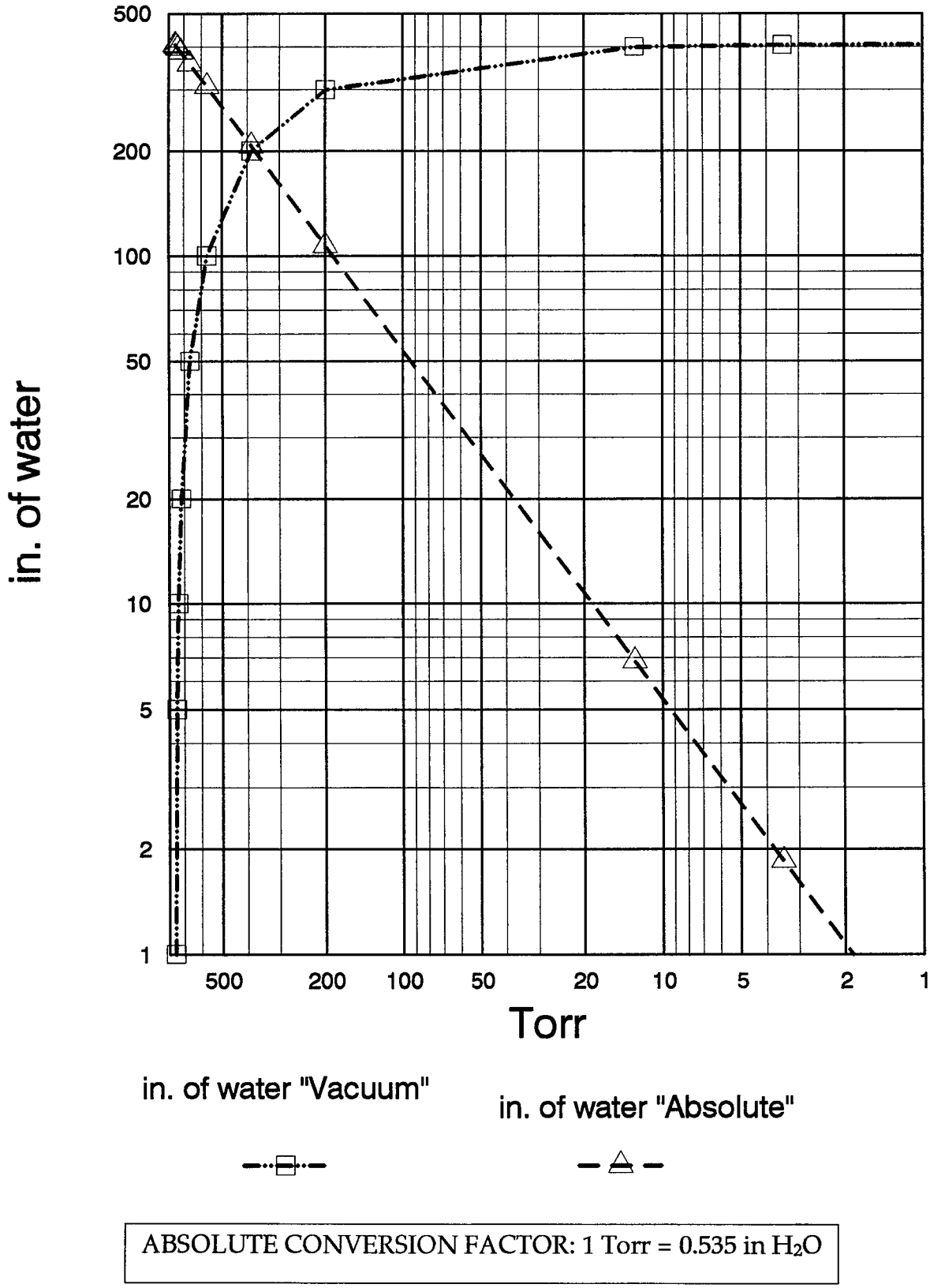
CONVERSION FACTOR: 1 Torr = 1000 mTorr = 1000 μm Hg

Figure 21 - Conversion graph: (1000 to 1 x 10^{-4}) Torr to mTorr (μm Hg)



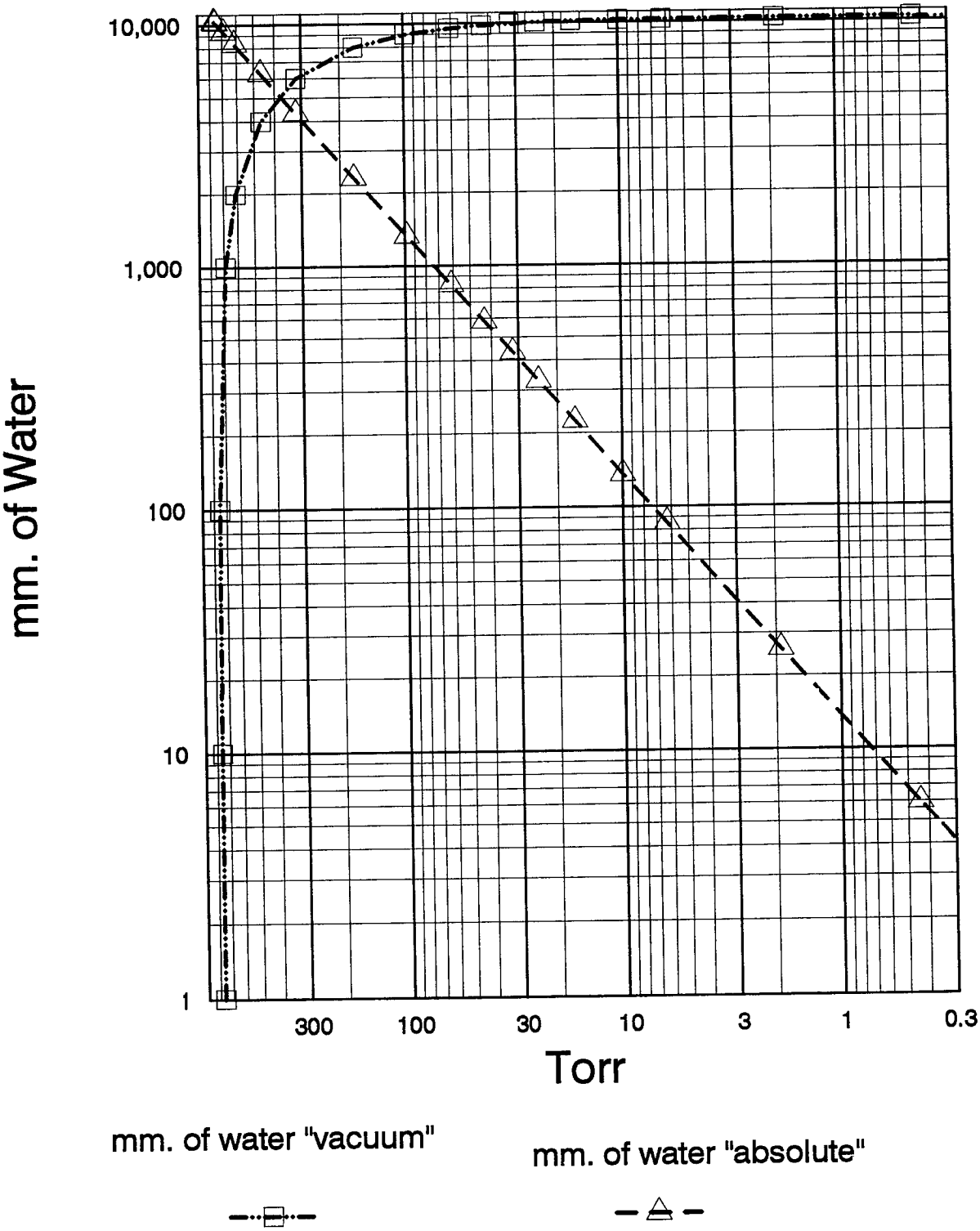
CONVERSION FACTOR: 1 Torr = 1000 mTorr = 1000 μm Hg

Figure 22 - Conversion graph: (1×10^{-4} to 1×10^{-10}) Torr to mTorr (μm Hg)



ABSOLUTE CONVERSION FACTOR: 1 Torr = 0.535 in H_2O

Figure 23 - Conversion graph: Torr to in H_2O



ABSOLUTE CONVERSION FACTOR: 1Torr = 13.6 mm H_2O

Figure 24 - Conversion graph: Torr to mm H_2O

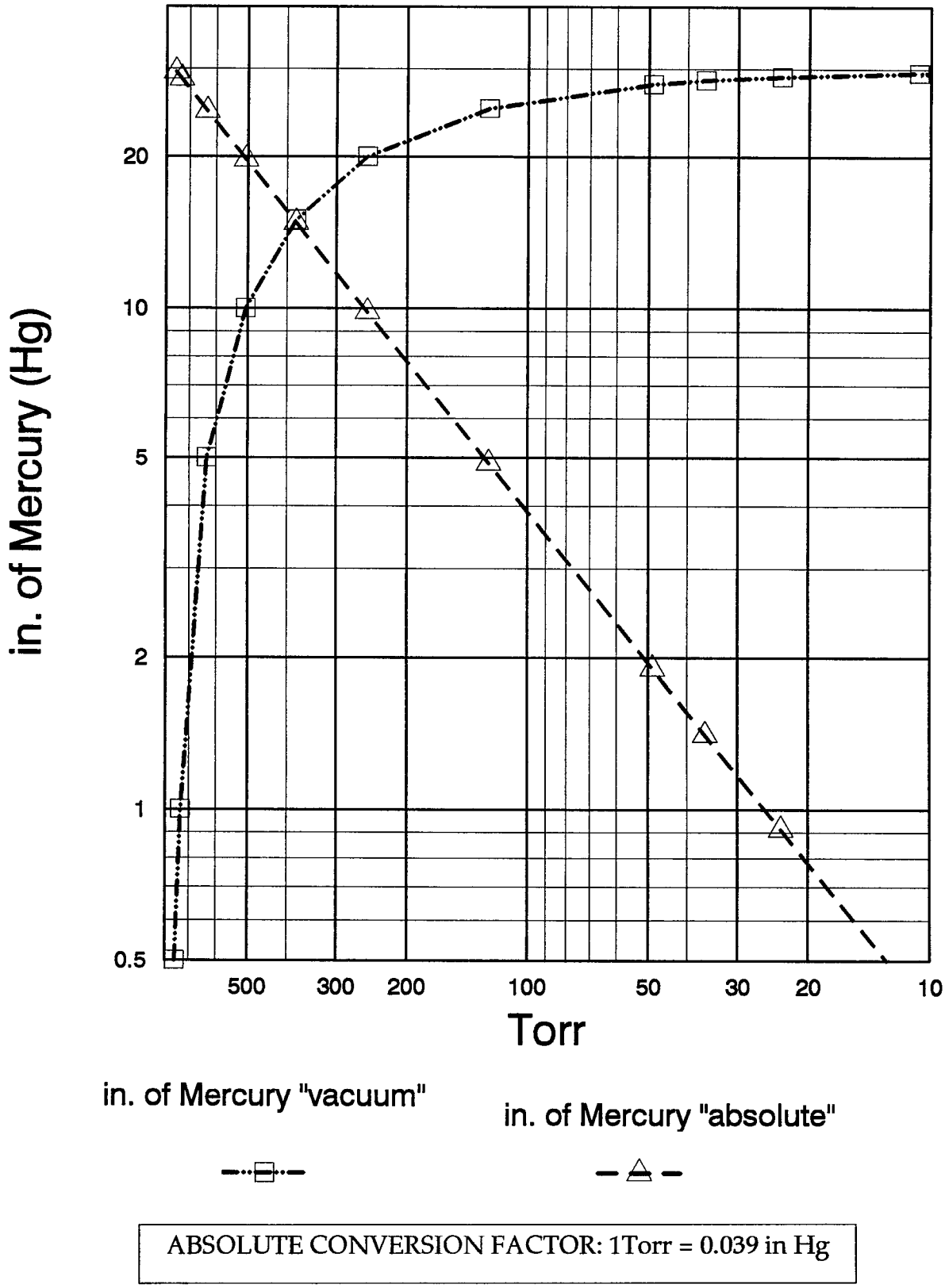
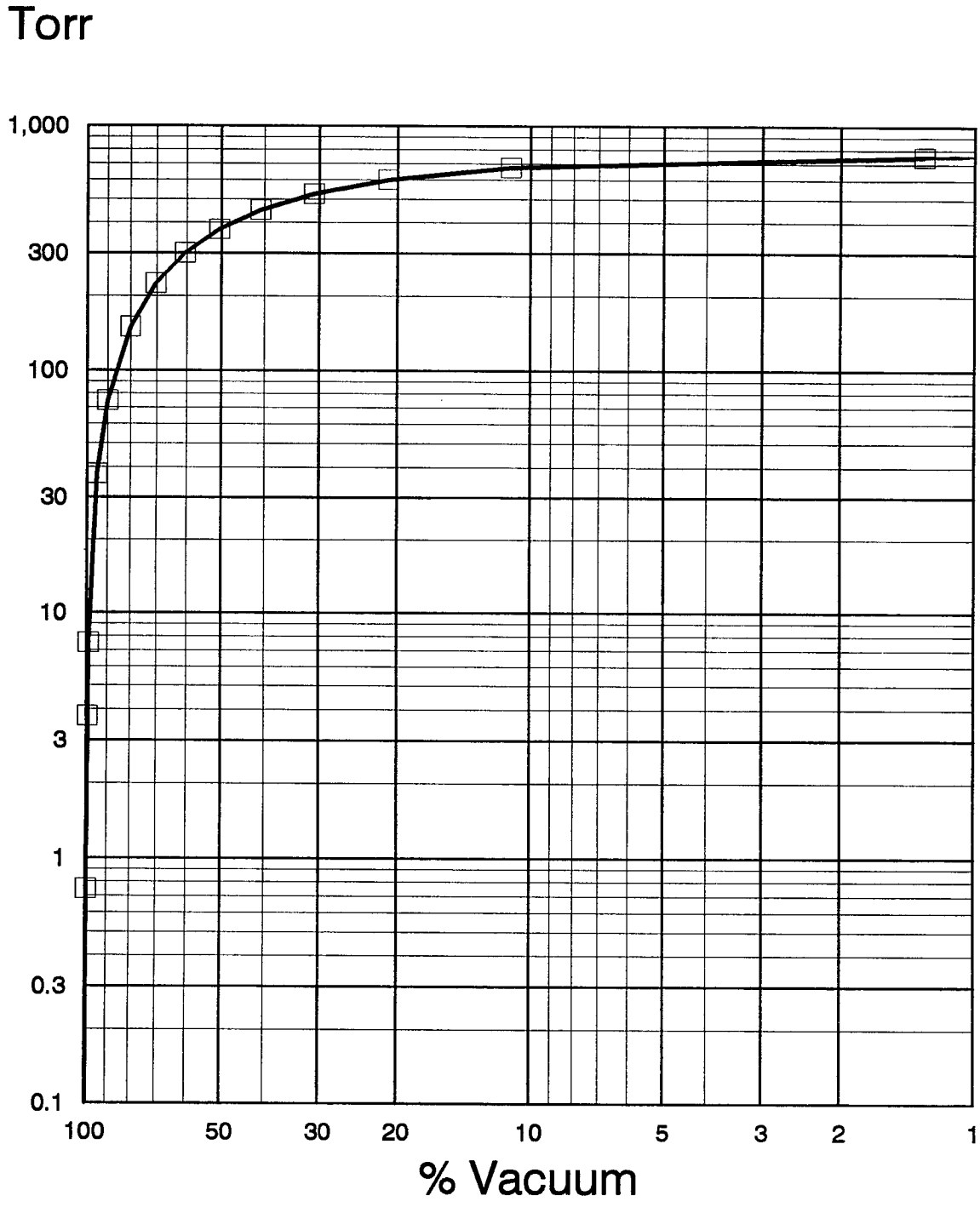


Figure 25 - Conversion graph: Torr to in Hg



A pressure change of 1 Torr corresponds to approximately 0.13% Vacuum change

Figure 26 - Conversion graph: Torr to % vac

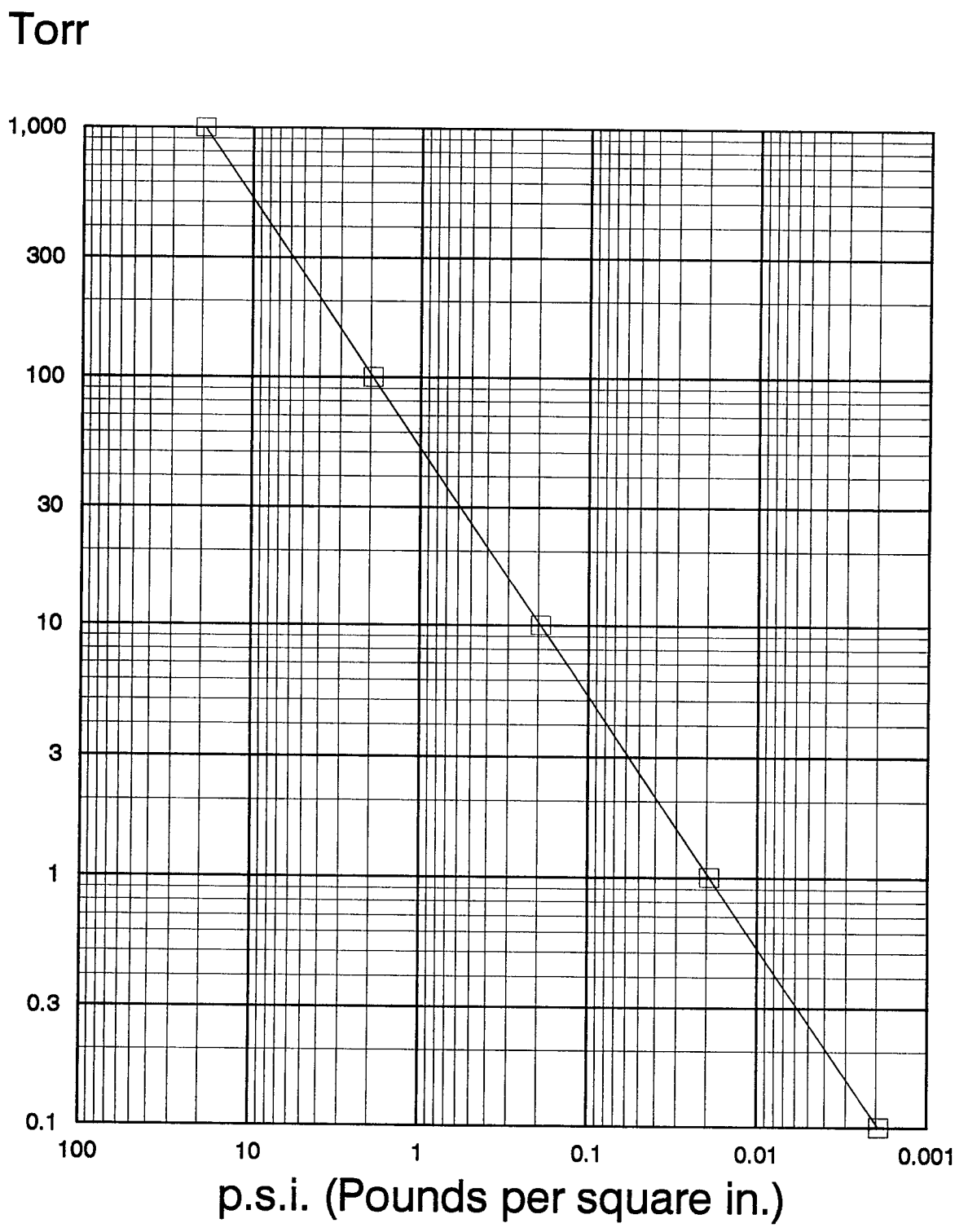
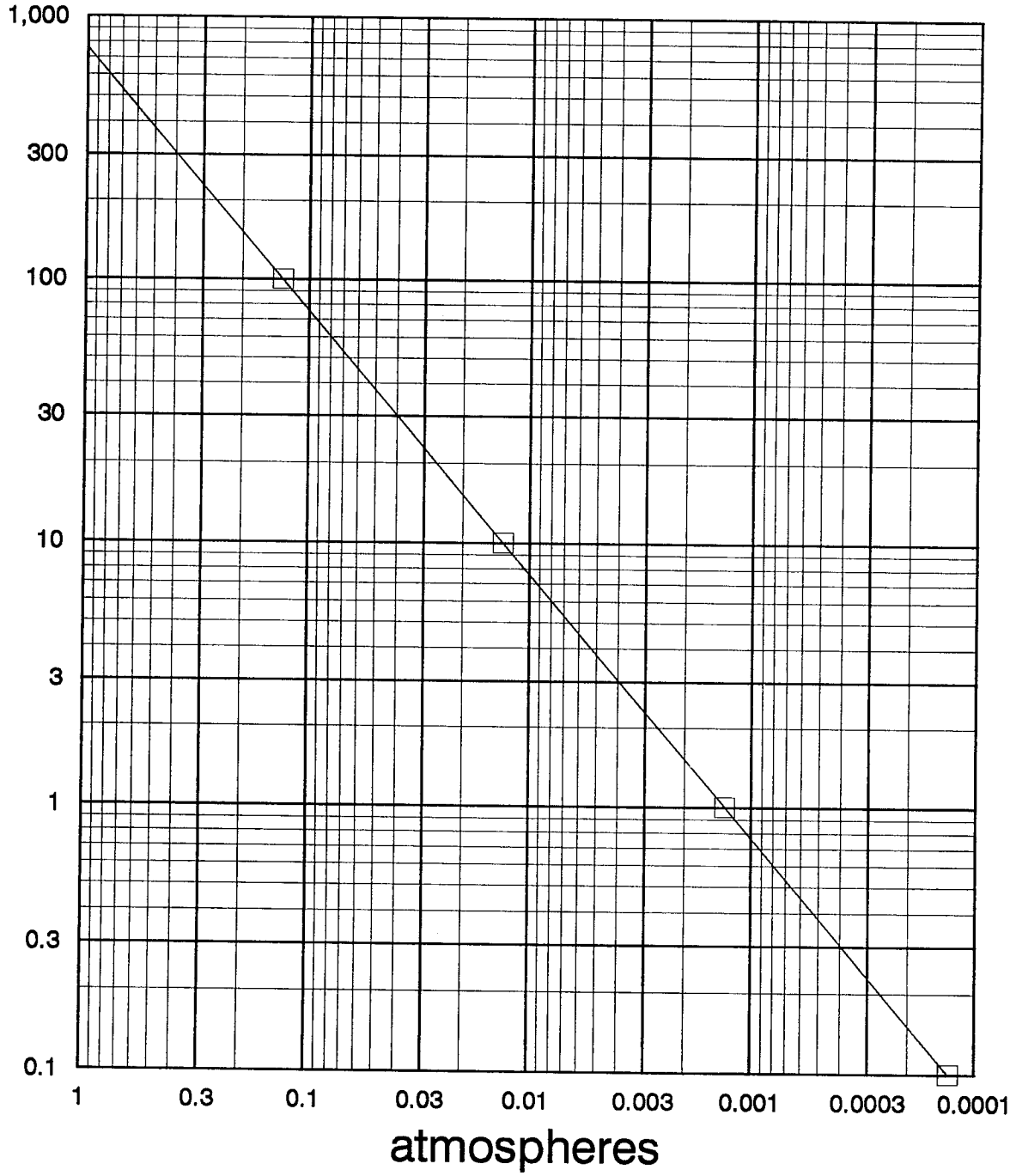
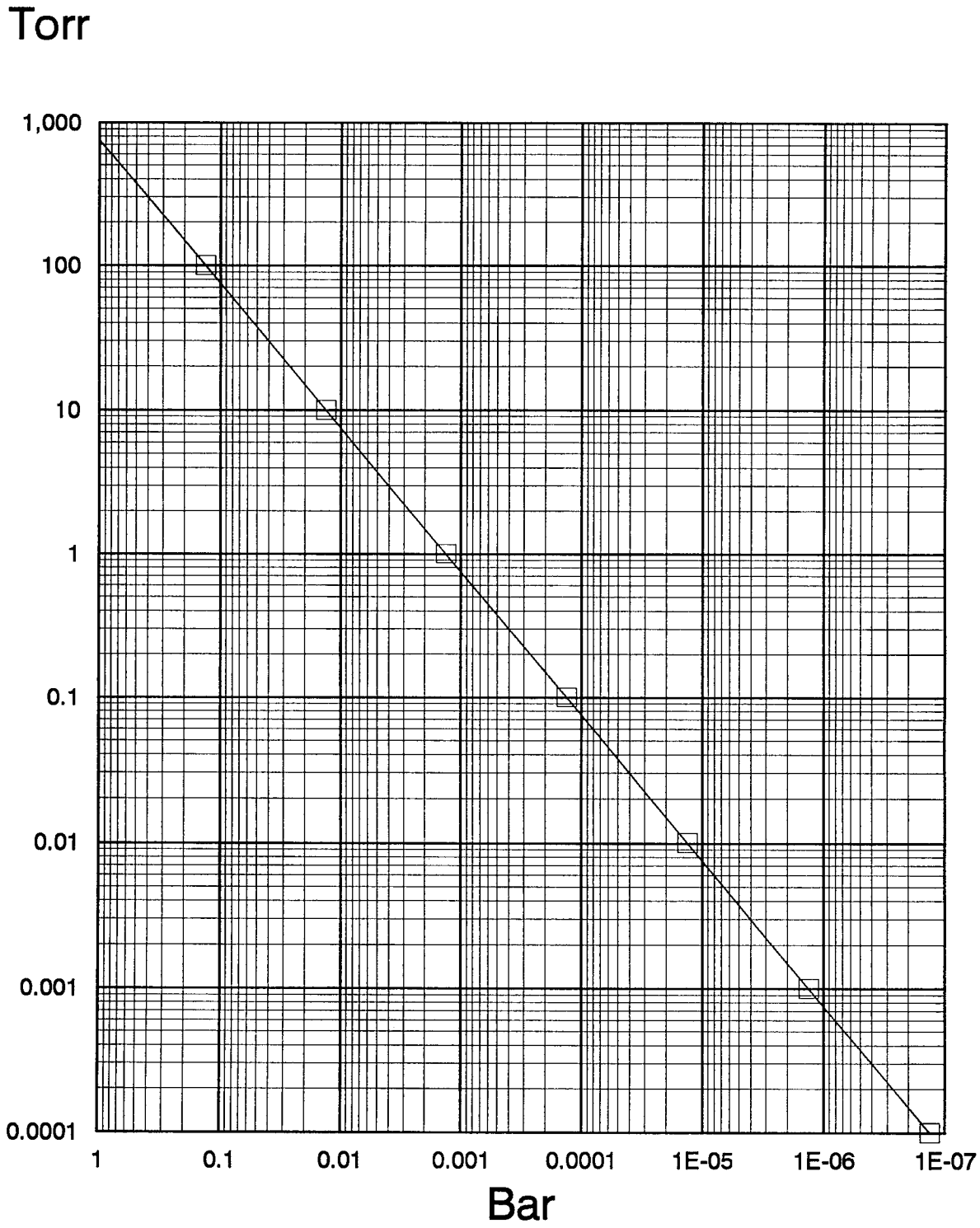


Figure 27 - Conversion graph: Torr to psi



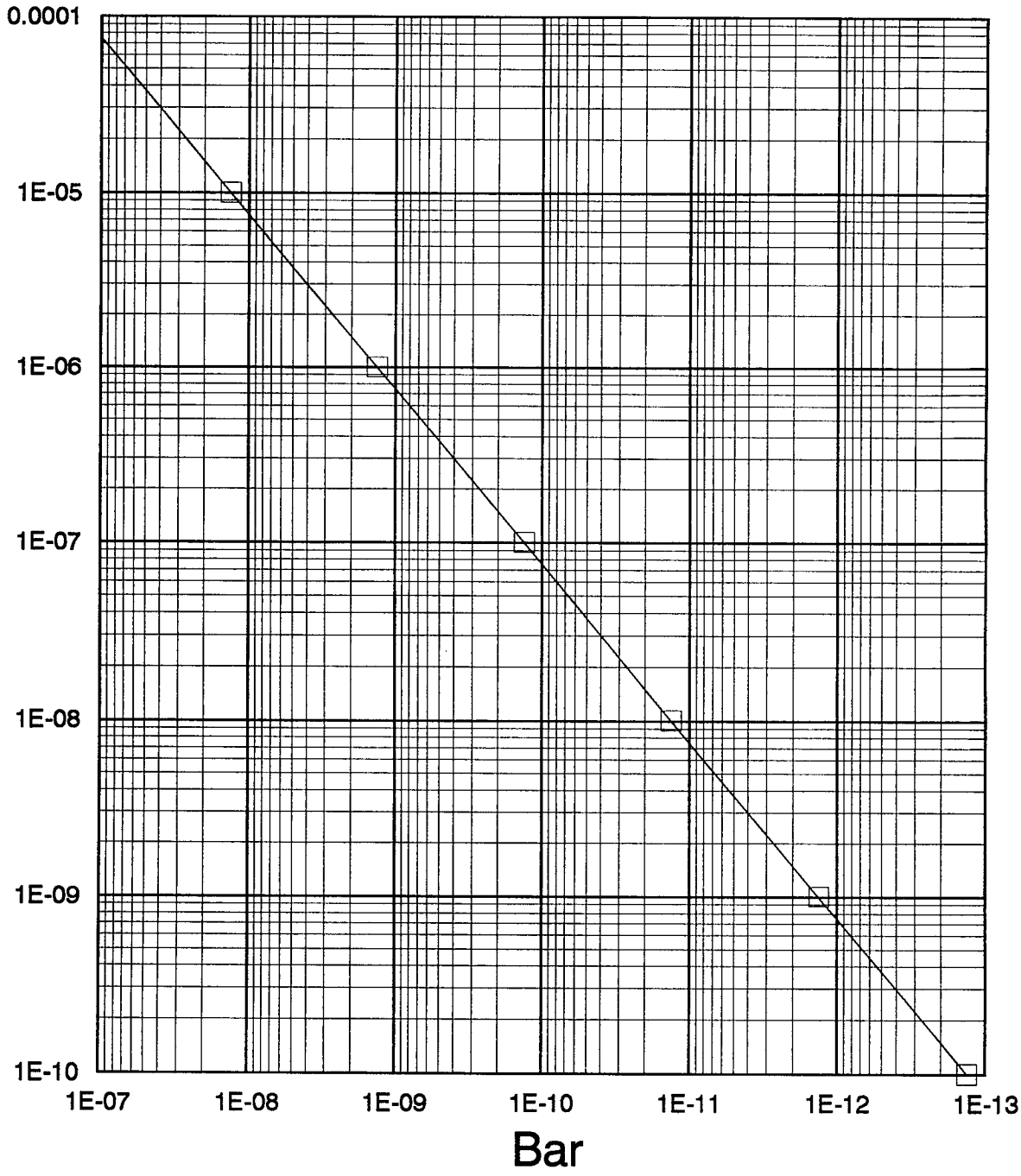
CONVERSION FACTOR: 1 Torr = 0.0013 at

Figure 28 - Conversion graph: Torr to atmospheres



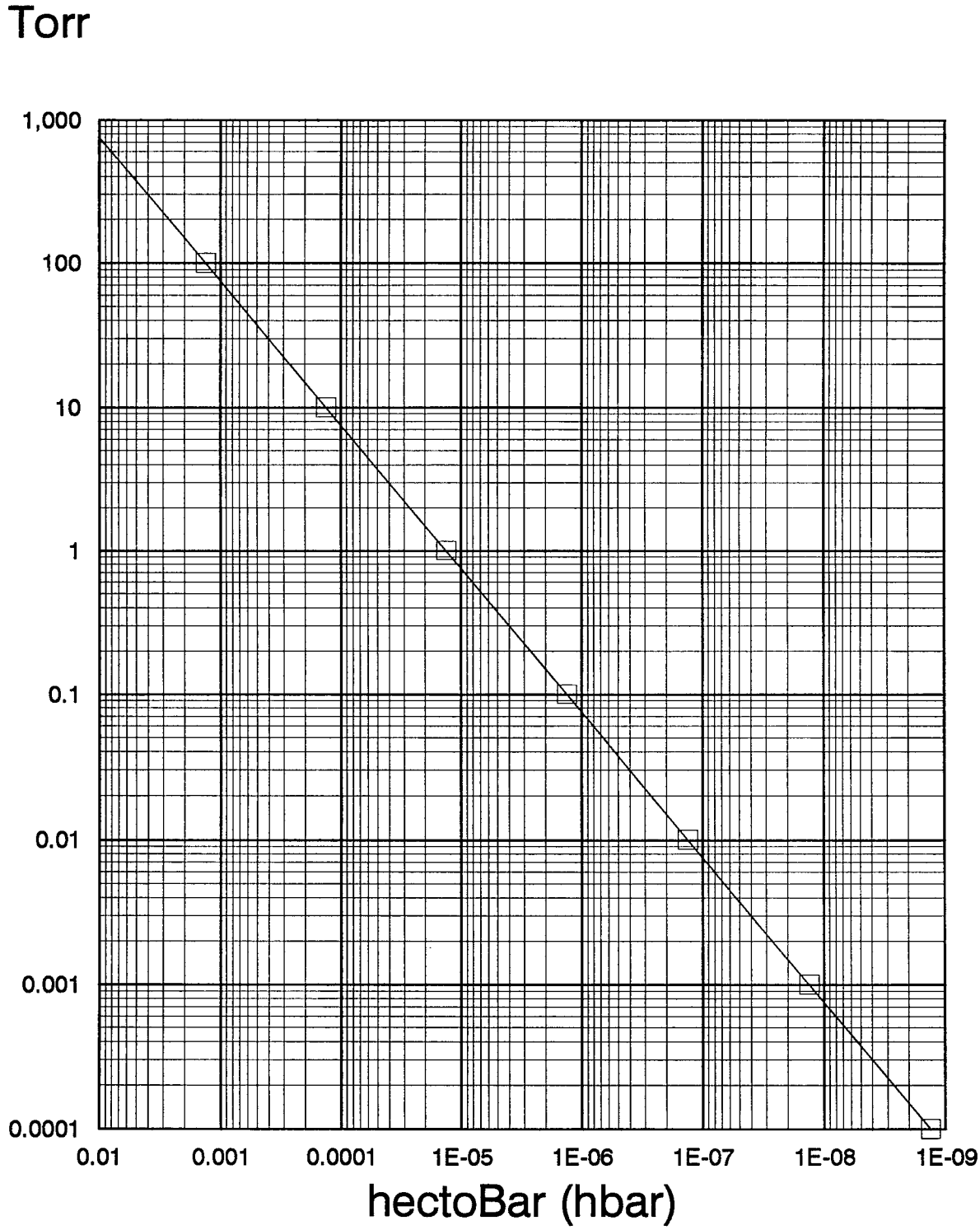
CONVERSION FACTOR: 1 Torr = 0.0013 bar

Figure 29 - Conversion graph: (1000 to 1 x 10^{-4}) Torr to bar



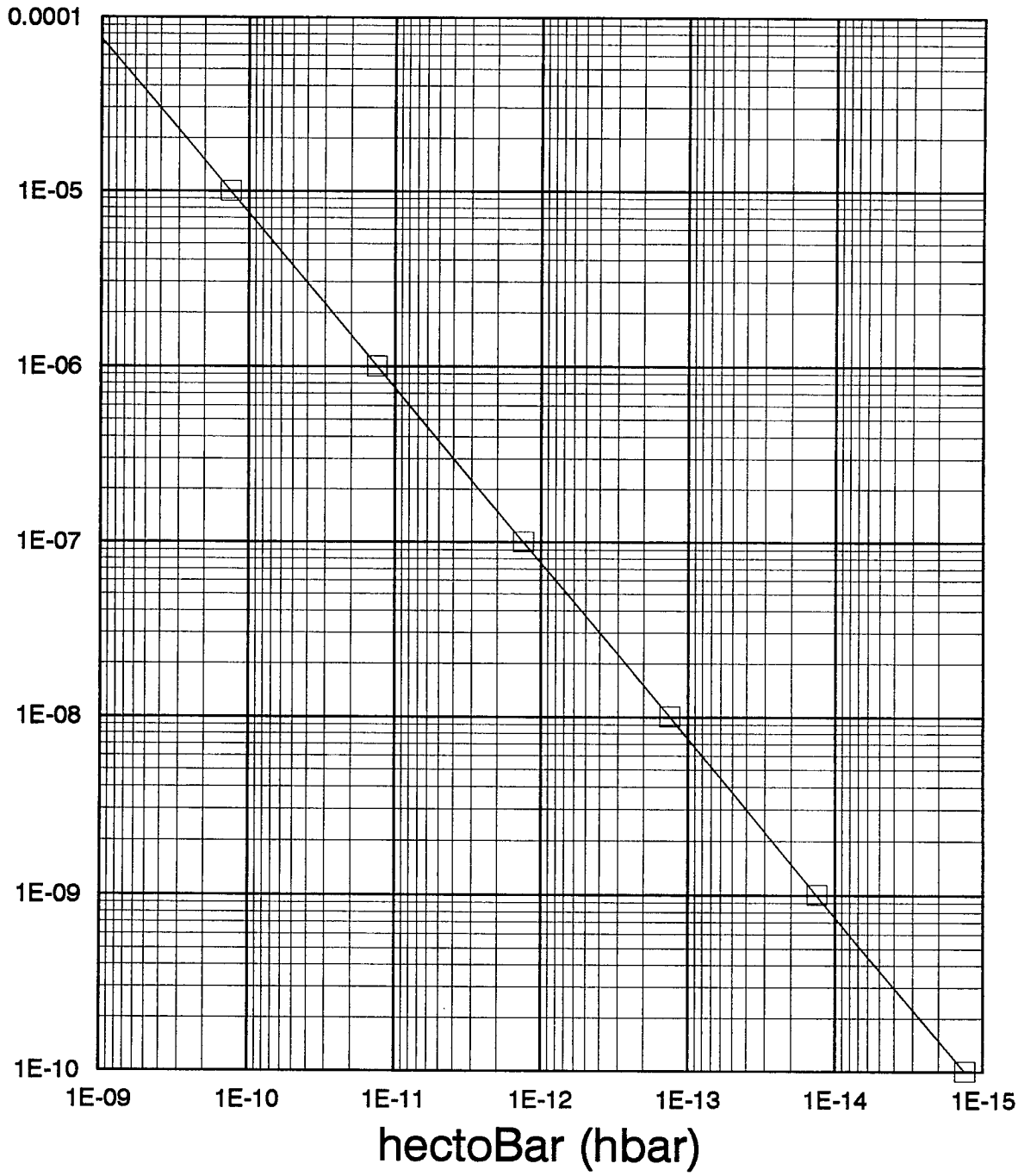
CONVERSION FACTOR: 1 Torr = 0.0013 bar

Figure 30 - Conversion graph: (1×10^{-4} to 1×10^{-10}) Torr to bar



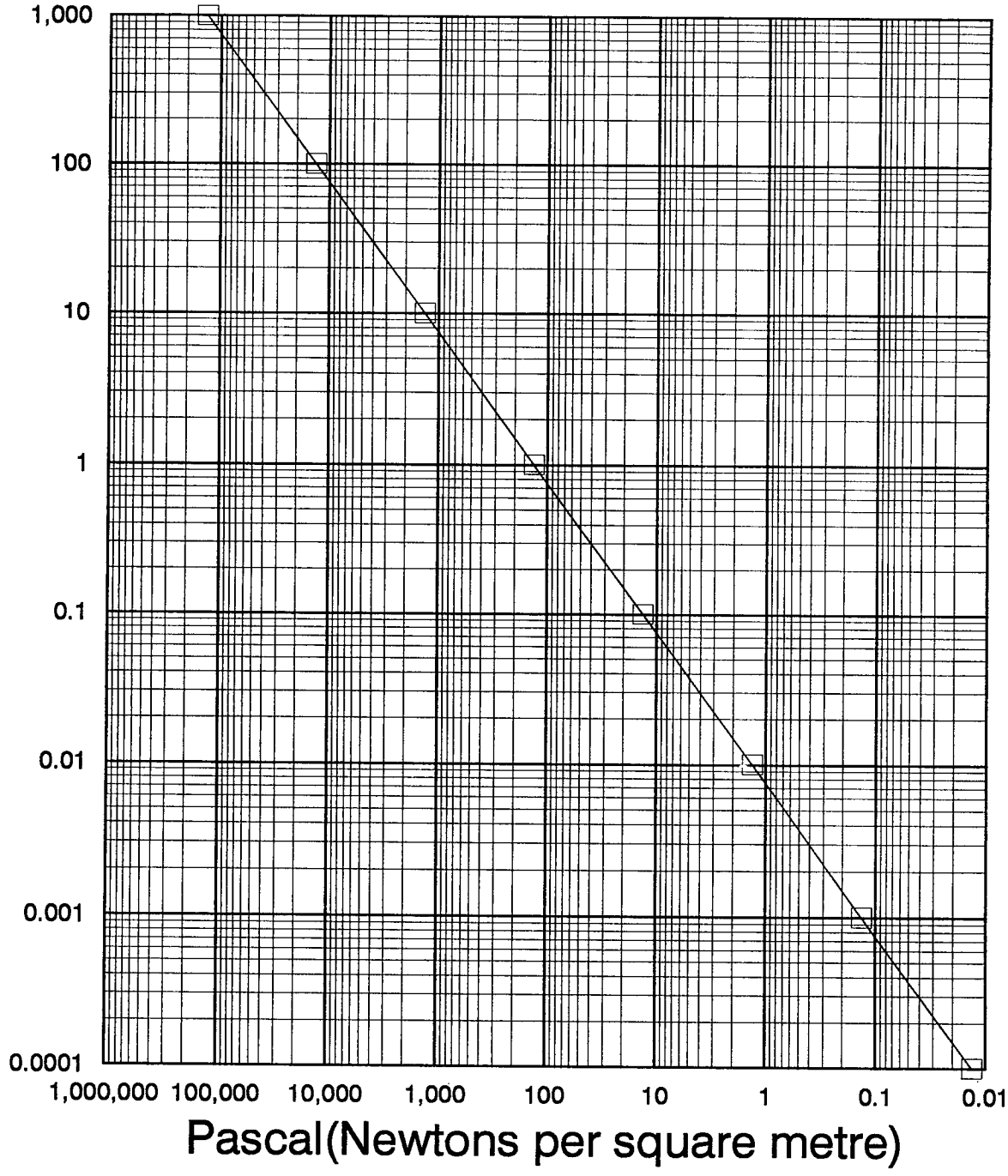
CONVERSION FACTOR: 1 Torr = 0.000013 hbar

Figure 31 - Conversion graph: (1000 to 1 x 10^{-4}) Torr to hbar



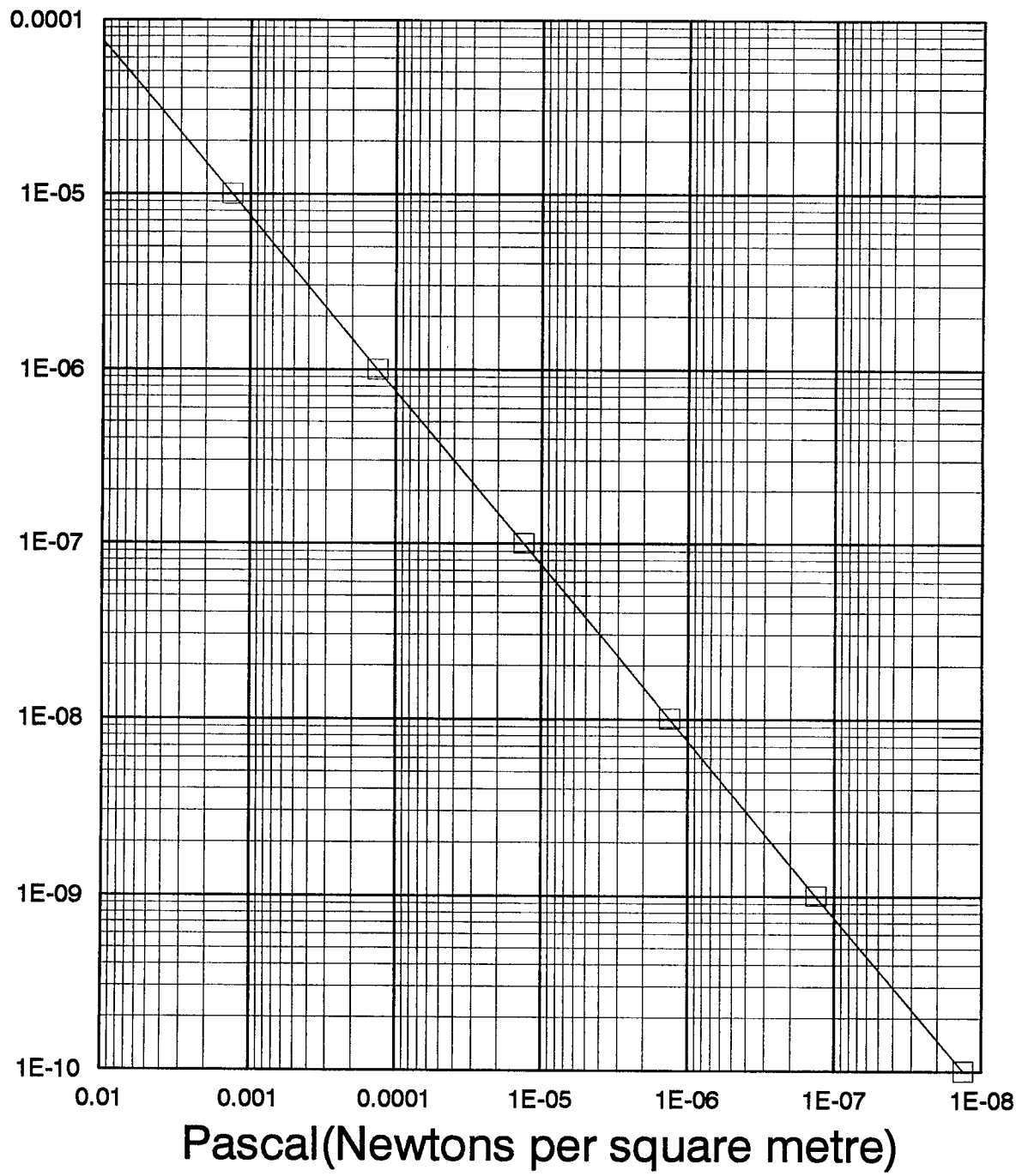
CONVERSION FACTOR: 1 Torr = 0.000013 hbar

Figure 32 - Conversion graph: (1×10^{-4} to 1×10^{-10}) Torr to hbar



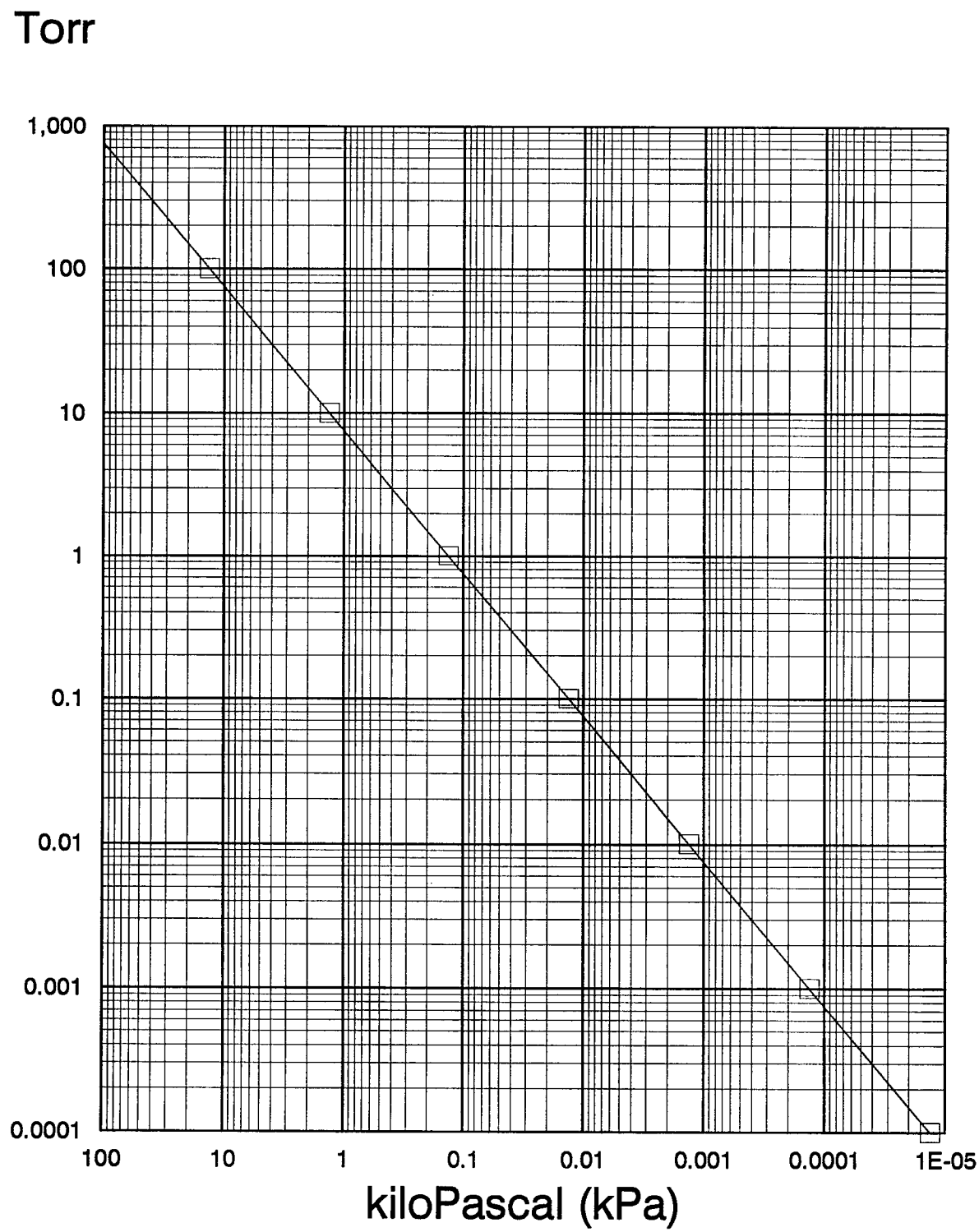
CONVERSION FACTOR: 1 Torr = 133.3 Pa

Figure 33 - Conversion graph: (1000 to 1 x 10^{-4}) Torr to Pa



CONVERSION FACTOR: 1 Torr = 133.3 Pa

Figure 34 - Conversion graph: (1×10^{-4} to 1×10^{-10}) Torr to Pa



CONVERSION FACTOR: 1 Torr = 0.133 kPa

Figure 35 - Conversion graph: (1000 to 1 x 10^{-4}) Torr to kPa

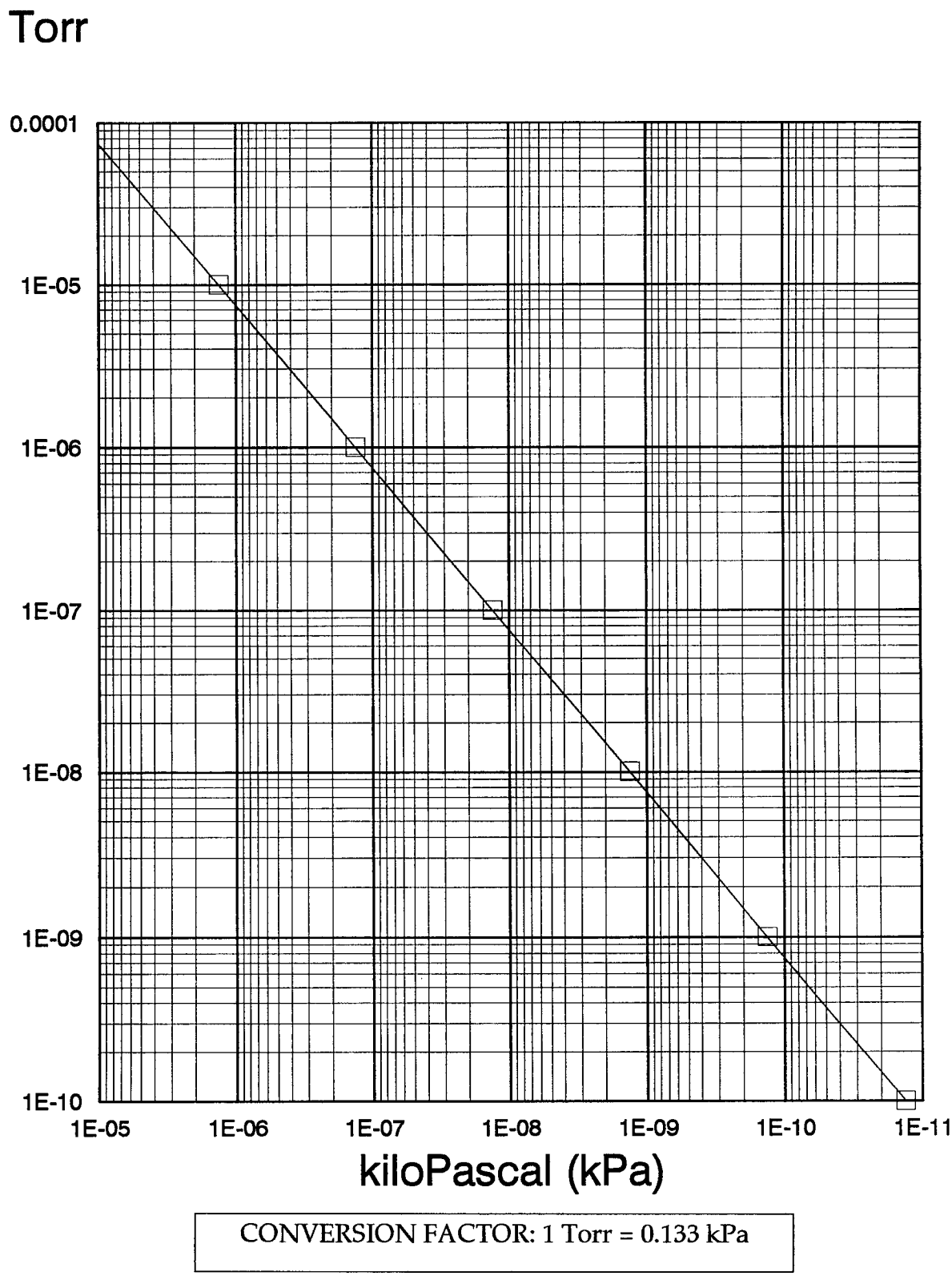


Figure 36 - Conversion graph: (1×10^{-4} to 1×10^{-10}) Torr to kPa

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