D. DEFINITIONS AND FILTER CHARACTERISTICS

D.1 Definitions and formulae

D.1.1 Basic symbols and notation

T - current period of the measurement.

$\mathbf{T_b}$ - period after which the results are saved in the logger set in the **LOGGER STEP** (*path: MENU / INPUT / MEASUREMENT SETUP / LOGGER STEP*).

$\mathbf{T_c}$ - period of the measurement is set in the **INTEGR. PERIOD** (*path: MENU / INPUT / MEASUREMENT SETUP / INTEGR. PERIOD*).

$\mathbf{T_e}$ - exposure time (period during which a person is exposed to the action of noise). This parameter can be set in the **EXPOSURE TIME** (*path: MENU / SETUP / EXPOSURE TIME*). The available values are from 1 minute to 8 hours with 1 minute step.

$\mathbf{T_{8h}}$ - period equal to 8 hours (28 800 seconds).

$\boldsymbol{\tau}$ - detector time constant is set in the **DETECTOR** (equal to **IMPULSE**, **FAST** or **SLOW** in the case of sound modes and equal to **100 ms**, **125 ms**, **200 ms**, **500 ms**, **1 s**, **2 s**, **5 s** or **10 s** in the case of vibration modes; *path: MENU / INPUT / PROFILE x / DETECTOR*). The available values are equal to **IMPULSE**, **FAST** or **SLOW**.

$\mathbf{a_W(t)}$ - the temporary value of the measured sound with the weighting filter **W** (equal to **A**, **C** or **Z** in the case of sound modes and equal to **HP1**, **HP3**, **HP10**, **KB**, **Wk**, **Wd**, **Wc**, **Wj**, **Wm**, **Wh**, **Wg**, **Wb** in the case of vibration modes; *path: MENU / INPUT / PROFILE x / FILTER*) on the input of the RMS detector.

$\mathbf{p_W(t)}$ - the temporary value of the measured sound with the weighting filter **W** (equal to **A**, **C** or **Z** in the case of sound modes and equal to **HP1**, **HP3**, **HP10**, **KB**, **Wk**, **Wd**, **Wc**, **Wj**, **Wm**, **Wh**, **Wg**, **Wb** in the case of vibration modes; *path: MENU / INPUT / PROFILE x / FILTER*) on the output of the RMS detector calculated from the equation:

$$\mathbf{p_W(t)} = \left(\frac{\mathbf{1}}{\boldsymbol{\tau}} \int_{-\infty}^{t} \mathbf{a_W^2(t_x)} \exp\left(\frac{\mathbf{t_x - t}}{\boldsymbol{\tau}} \right) \mathbf{dt_x} \right)^{1/2}$$

where:

$\mathbf{t_x}$ - time (variable of the integration).

$$\mathbf{r_W(t)} = \begin{cases} \mathbf{a_W(t)} & \textit{path : MENU / SETUP / RMS INTEGRATION / LINEAR} \\ \mathbf{p_W(t)} & \textit{path : MENU / SETUP / RMS INTEGRATION / EXPONENTIAL} \end{cases}$$

$\mathbf{p_0}$ - the reference value equal to 20 μPa.

Q - the exchange rate in decibels equal to **2**, **3**, **4** or **5** and is set in the **EXCHANGE RATE** (*path: MENU / INPUT / DOSEMETER SETUP / EXCHANGE RATE*). The value of **Q** influences the calculations of dose meter results, namely **DOSE**, **D_8h** and **LAV**. The exposure rate equal to 3 complies with ISO R 1999 “Assessment of Occupational Noise Exposure for Hearing Conservation Purposes”, while **Q** equal to 5 complies with the American “Occupational Safety and Health Act” – OSHA. The value of **q** used in the calculations of **DOSE**, **D_8h** and **LAV** is taken from the formula:

$$\mathbf{q} = \begin{cases} \dfrac{\mathbf{Q}}{\mathbf{\log 2}} & \text{for} \quad \mathbf{Q \neq 3} \\ \mathbf{10} & \text{for} \quad \mathbf{Q = 3} \end{cases}$$

L_T - the threshold sound level is set in the **THRESHOLD LEVEL** (*path: MENU / INPUT / DOSEMETER SETUP / THRESHOLD LEVEL*). The available values are as follows: **None**, **75 dB**, **80 dB**, **85 dB** or **90 dB**.

L_c - the criterion sound level is set in the **CRITERION LEVEL** (*path: MENU / INPUT / DOSEMETER SETUP / CRITERION LEVEL*). The available values are as follows: **80 dB**, **84 dB**, **85 dB** or **90 dB**.

$L(t)$ - sound level (a function of time) measured with the selected time constant (**IMPULSE**, **FAST** or **SLOW**; *path: MENU / INPUT / PROFILE x / FILTER*) and the weighting filter (equal to **A**, **C** or **Z**) calculated from the formula:

$$L(t) = 20 \log \frac{p_W(t)}{p_0}$$

$L_d(t)$ - sound level (a function of time), depends on the selected threshold level. In the case when the **None** option was selected:

$$L_d(t) = L(t)$$

In the other cases (when the **THRESHOLD LEVEL** (*path: MENU / INPUT / DOSEMETER SETUP / THRESHOLD LEVEL*) is equal to **75 dB**, **80 dB**, **85 dB** or **90 dB**) this sound level is taken from the formula:

$$L_d(t) = \begin{cases} L(t) & \text{for} \quad L(t) \geq L_T \\ -\infty & \text{for} \quad L(t) < L_T \end{cases}$$

D.1.2 Definitions of the quantities measured in sound modes

PEAK value

The **PEAK** value (Peak Sound Pressure or Peak Sound Level) depends on the weighting filter **W** (equal to **A**, **C** or **Z**) and is calculated for the given **T** from the formula:

$$PEAK = 20 \log \left(\max_T \left| \frac{a_W(t)}{p_0} \right| \right)$$

In the case of the **PEAK** value saved as the main result $T = T_c$. When the **PEAK** value is saved in the files of the logger (time history) - $T = T_b$.

SPL function

The **SPL** function (**S**ound **P**ressure **L**evel) - gives an equivalent of the **Sound Level Meter** according to the **IEC 651 Standard** (meeting the requirements for the **Type "1"** instrument). The value of the functions depends on the weighting filter **W** (equal to **A**, **C** or **Z**; *path: MENU / INPUT / PROFILE x / FILTER*) and is calculated from the formula:

$$SPL = 20 \log \left(\max_{T_1} \frac{p_W(t)}{p_0} \right)$$

where:

T_1 - the last second of the measurement.

MAX result

The **MAX** result means the maximal value on the detector output for the integration period. The **MAX** result for the period of 1 second is equal to the value of the **SPL** function. The **MAX** result is calculated according to the formula:

$$\mathbf{MAX} = \mathbf{20\ log}\left(\mathbf{max}_T \frac{p_W(t)}{p_0} \right)$$

In the case of the **MAX** value saved as the main result **T** = $\mathbf{T_c}$. When the **MAX** value is saved in the files of the logger (time history) - **T** = $\mathbf{T_b}$.

MIN result

The **MIN** result is calculated according to the formula:

$$\mathbf{MIN} = \mathbf{20\ log}\left(\mathbf{min}_T \frac{p_W(t)}{p_0} \right)$$

In the case of the **MIN** value saved as the main result **T** = $\mathbf{T_c}$. When the **MIN** value is saved in the files of the logger (time history) - **T** = $\mathbf{T_b}$.

LEQ function

The **LEQ** function enables the user to calculate the RMS value of sound pressure in the given time period. The instrument operates as the standard **Integrating Sound Level Meter** and conforms to the **IEC 804 Standard** (meeting the requirements for the **Type 1** instrument). The value of the **LEQ** function is calculated according to the formula:

$$\mathbf{LEQ} = \mathbf{20\ log}\left(\frac{1}{T} \int_0^T (r_W(t)/p_0)^2 dt \right)^{1/2}$$

In the case the **LEQ** value saved as the main result **T** = $\mathbf{T_c}$.

> ***Note:*** *For* ***T = T_b*** *the* ***LEQ*** *values are saved in the files of the logger (time history) as the RMS results (see below).*

RMS result

The **RMS** result, saved in the logger's file, is calculated according to the formula of the **LEQ** function. The value of the **RMS** result is calculated according to the formula:

$$\mathbf{RMS} = \mathbf{20\ log}\left(\frac{1}{T_b} \int_0^{T_b} (r_W(t)/p_0)^2 dt \right)^{1/2}$$

SEL result

The **SEL** result (Sound Exposure Level) is essentially the subset of the **LEQ** function. Its value is equal to the **LEQ result referred to the integration time equal to one second** (so, for the **INT. TIME=1 s**, **SEL** is always equal to **LEQ**). The value of the **SEL** function is calculated according to the formula:

$$\mathbf{SEL} = \mathbf{20}\,\mathbf{log}\left(\int_{\mathbf{0}}^{\mathbf{T}} (\mathbf{r_W(t)}/\mathbf{p_0})^2\,\mathbf{dt}\right)^{1/2} = \mathbf{LEQ} + \mathbf{10}\cdot\mathbf{log}\frac{\mathbf{T[s]}}{\mathbf{1[s]}}$$

In the case of the **SEL** value saved as the main result $\mathbf{T} = \mathbf{T_c}$. The **SEL** value is not saved in the files of the logger (time history).

Ltm3 and Ltm5 results

The **Ltm3** and **Ltm5** results (Takt-Maximal Levels) are calculated according to the German standard TA Larm.

LEPd result

The **LEPd** result (Exposure level related to 8-hours working day) is calculated on the base of the **LEQ** from the formula:

$$\mathbf{LEPd} = \mathbf{LEQ} + \mathbf{10}\cdot\mathbf{log}\frac{\mathbf{T_e}}{\mathbf{T_{8h}}}$$

OVL result

The **OVL** result (Overload) presents the percentage of the overloaded input signal, which occurred during the selected $\mathbf{T_c}$ - measurement time set in the **INTEGR. PERIOD** (*path: MENU / INPUT / MEASUREMENT SETUP / INTEGR. PERIOD*).

Statistical Levels Ln

The noise level **L(t)** is the continuous random variable. The probability that the temporary noise level **L(t)** belongs to the interval $\langle \mathbf{L_k}, \mathbf{L_k} + \mathbf{\Delta L} \rangle$ is called the class density and it can be expressed by the equation:

$$\mathbf{P_k}\left[\mathbf{L_k} \le \mathbf{L(t)} \le \mathbf{L_k} + \mathbf{\Delta L}\right] = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{\Delta t_i} \Big/ \mathbf{P}$$

where:

$\mathbf{\Delta t_i}$ - time intervals, in which the noise level $\mathbf{L(t)} \in \langle \mathbf{L_k}, \mathbf{L_k} + \mathbf{\Delta L} \rangle$ occurs,

$\mathbf{\Delta L}$ - so-called class interval or distribution class of the series,

$\mathbf{P}$ - total observation period.

In the case when the class interval approaches infinity, the probability of **L(t)** tends to the probability of $\mathbf{L_k}$. In practice, $\mathbf{\Delta L}$ value is strictly determined and it depends mainly on the dynamics of the measurements performed in the instrument. In SVAN 95 x instrument, there are 120 classes and the width of each class is equal to 1 dB.

The histogram is the set of the class density values calculated for all classes. In the SVAN 95x instrument the histogram is saved in the result files if the **SAVE STATISTICS** (*path: MENU / FILE / SAVE OPTIONS / SAVE STATISTICS*) is activated (cf. the detailed description of the relevant table in App. B).

The statistical distribution function, which determines the probability (expressed in %) of the noise occurrence on the level equal or less than $\mathbf{L_k} + \mathbf{\Delta L}$ is given by the formulae:

$$\mathbf{P}\left[\mathbf{L(t)} \le \mathbf{L_j}\right] = \sum_{\mathbf{k=1}}^{\mathbf{j}} \mathbf{P_k(L)}$$

The cumulative density function, expressed by the equation:

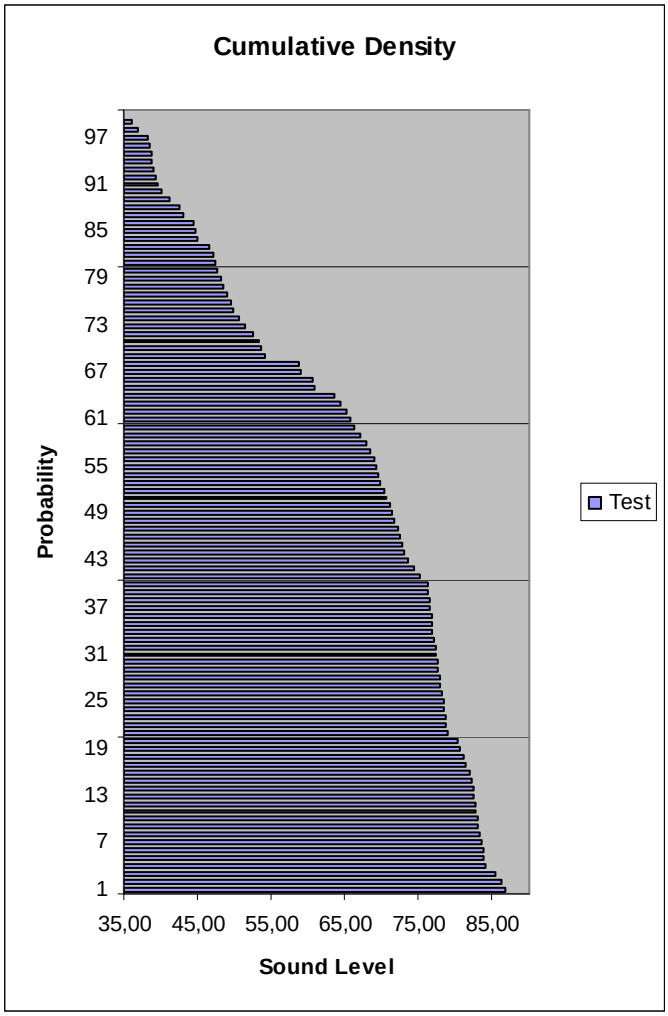
$$\mathbf{P}\left[\mathbf{L}(\mathbf{t}) > \mathbf{L_j}\right] = \mathbf{1} - \mathbf{P}\left[\mathbf{L}(\mathbf{t}) \le \mathbf{L_j}\right]$$

is directly used to determine so-called statistical levels **Ln** or position parameters of the distribution.

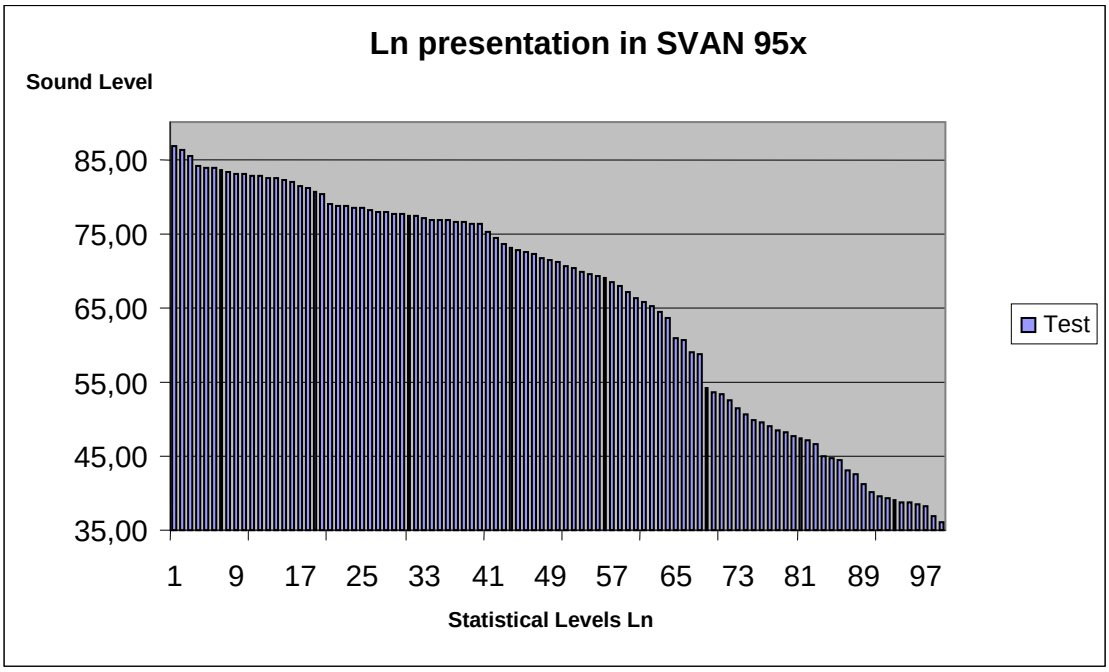
The **Ln** is the certain boundary level surpassed by the temporary noise level values in not more than **n%** of the observation period.

Example: Let us assume that **L35** is equal to 76.8 dB. It means that during the measurements the noise level 76.8 dB was exceeded in not more than 35% of the observation period.

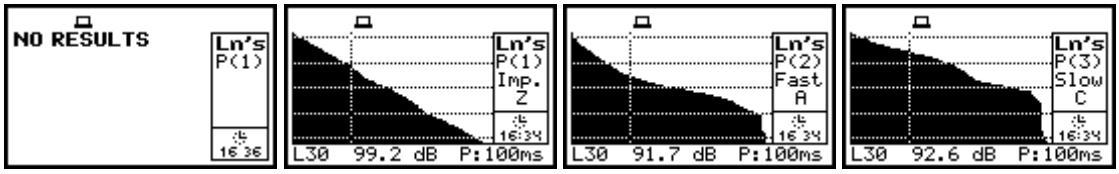
The cumulative density function for the exemplary data is presented in Figure on the right side. In order to determine the **Ln** level one has to draw the horizontal cursor and find out the crossing point between the cumulative density function and the cursor. In SVAN 95x instruments the user can determine 99 statistical levels - from **L01** to **L99** (1% step of observation period).



The display in SVAN 95x instrument has only 64 pixels on the vertical axis and 128 on the horizontal one. It is obvious that the change of the axes is more suitable for the presentation of 99 statistical levels. In this case, the user has to draw the vertical cursor and the value on it gives the required statistical level (the value of the noise level, which happened during the performed measurements in not more than selected percentage of the observation period).

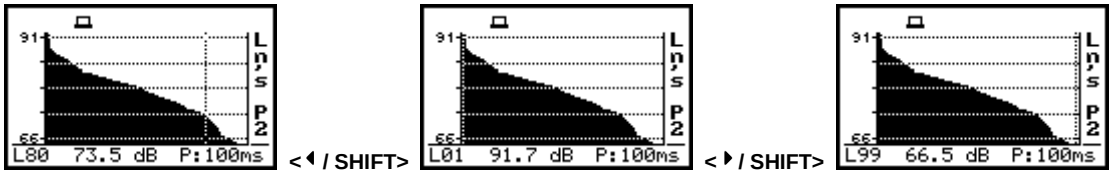


Two presentation modes of the statistical levels are available in the SVAN 959 instrument. In both modes, the **Ln** values, selected by the cursor, are displayed in the bottom line together with its value and units (dB). The P value indicating the observation period equal to 100 ms (it means that the statistical results are updated every 100 ms) is placed at the end of the bottom line. The profile's number the statistics are taken from, the RMS detector (**Lin.**, or **Exp.**: **Fast**, **Slow** or **Imp**.), the filter's name (**A**, **C** or **Z**) and real time are displayed on the right side of the view in the first presentation mode. The selection of the profile is made by pressing the **<SHIFT>** and **<▲>** or the **<SHIFT>** and **<▼>** push-buttons. The same result can be achieved after pressing the **<ALT>** and **<◀>** or **<ALT>** and **<▶>** push-buttons.



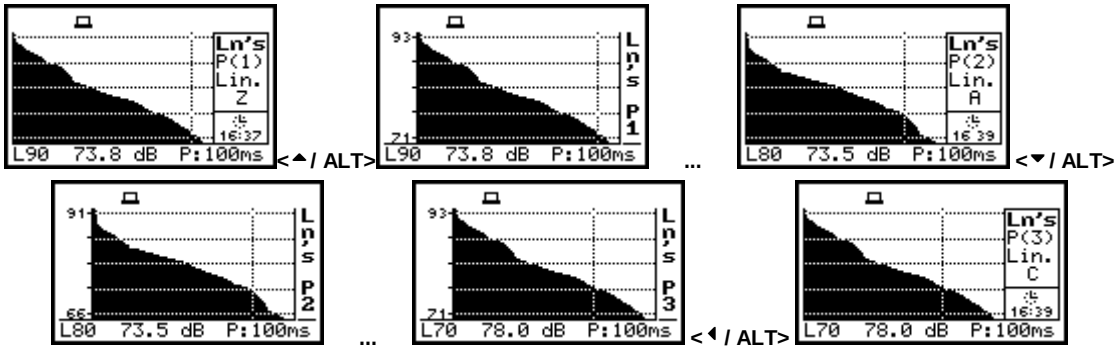
Results shown in the first presentation mode of statistical levels

The selection of the **Ln** to be displayed is done by pressing the **<◀>**, **<▶>** push-buttons. The statistics **L01** is immediately available after pressing the **<SHIFT>** and **<◀>** while the **L99** - after pressing the **<SHIFT>** and **<▶>** push-buttons.



Results shown in the second presentation mode; the selection of the statistical level

The change of the presentation mode is done by pressing the **<ALT>** and **<▲>** or the **<ALT>** and **<▼>** push-buttons. The second presentation mode of statistical levels differ slightly from the first one: the description on the left side is shorter but on the right side the value of the statistical levels are shown.



Results shown in both presentation modes of statistical levels; the change of the mode

D.1.3 Definitions of the results measured in dosimeter mode

DOSE result

The **DOSE** result is the quantity of noise received by the worker, expressed as the percentage of the whole day acceptable value. This result is calculated from the formula:

$$\mathbf{DOSE} = \frac{\mathbf{100\%}}{\mathbf{T_{8h}}} \int_{0}^{T} \mathbf{10}^{\frac{L_d(t)-L_c}{q}} \mathbf{dt}$$

D_8h result

The **D_8h** result is the quantity of noise received by the worker during 8 hours. This result is calculated from the formula:

$$\mathbf{D\_8h} = \frac{\mathbf{100\%}}{\mathbf{T}} \int_{\mathbf{0}}^{\mathbf{T}} \mathbf{10}^{\frac{L_d(t)-L_c}{q}}\,\mathbf{dt} = \frac{\mathbf{T_{8h}}}{\mathbf{T}} \cdot \mathbf{DOSE}$$

LAV result

The **LAV** result is the average level of the acoustic pressure for the given time period of the measurement. This result is calculated from the formula:

$$\mathbf{LAV} = \mathbf{q} \cdot \mathbf{log}\left(\frac{\mathbf{1}}{\mathbf{T}} \int_{\mathbf{0}}^{\mathbf{T}} \mathbf{10}^{\frac{L_d(t)}{q}}\,\mathbf{dt} \right)$$

In the case of **Q** (the exchange rate) equal to 3 the **LAV** result has the same value as **LEQ** (if the **EXPONENTIAL** option is selected in the **RMS INTEGRATION** (*path: MENU / SETUP / RMS INTEGRATION*).

TLAV result

The **TLAV** result is the average level of the acoustic pressure of the measurement. This result is calculated from the formula:

$$\mathbf{LAV} = \mathbf{q} \cdot \mathbf{log}\left(\int_{\mathbf{0}}^{\mathbf{T}} \mathbf{10}^{\frac{L_d(t)}{q}}\,\mathbf{dt} \right)$$

SEL8 result

The **SEL8** result is the **SEL result corresponding to the integration time equal to 8 hours**. The **SEL8** result is calculated on the base of the **LEQ** according to the formula:

$$\mathbf{SEL8} = \mathbf{LEQ} + \mathbf{10} \cdot \mathbf{log}\frac{\mathbf{T_{8h}[s]}}{\mathbf{1[s]}}$$

PSEL result

The **PSEL** result (individual Sound Exposure Level to the noise) is equal to the standing sound level in a measurement period. The **PSEL** result is calculated on the base of the **LEQ** according to the formula:

$$\mathbf{PSEL} = \mathbf{LEQ} + \mathbf{10} \cdot \mathbf{log}\frac{\mathbf{T}}{\mathbf{T_{8h}}}$$

E result

The **E** result (Exposition) represents the amount of the acoustical energy received by the worker. The **E** value is calculated according to the formula:

$$\mathbf{E} = \frac{\mathbf{T[s]}}{\mathbf{3600}} \mathbf{p_o^2} \cdot \mathbf{10}^{\frac{\mathbf{LEQ}}{\mathbf{10}}}$$

The **E** result is expressed in the linear units (Pa^2h).

E_8h result

The **E_8h** result (Exposition in 8 hours) represents the amount of the acoustical energy received by the worker during 8 hours. The **E_8h** value is calculated according to the formula:

$$\mathbf{E\_8h} = \mathbf{8[h]} \cdot \mathbf{p_o^2} \cdot \mathbf{10}^{\frac{\mathbf{LEQ}}{\mathbf{10}}}$$

The **E_8h** result is expressed in the linear units (Pa^2h).

D.1.4 Definitions of the quantities measured in vibration modes

PEAK value

The **PEAK** value is calculated for the given **T** from the formula:

$$\mathbf{PEAK} = \mathbf{max_T} \left| \mathbf{a_W(t)} \right|$$

In the case of the **PEAK** value saved as the main result $\mathbf{T} = \mathbf{T_c}$. When the **PEAK** value is saved in the files of the logger (time history) - $\mathbf{T} = \mathbf{T_b}$.

P–P value

The **P–P** result, saved in the logger's file, is calculated according to the formula:

$$\mathbf{P-P} = \mathbf{max_T(0, a_W(t))} - \mathbf{min_T(0, a_W(t))}$$

For the **P–P** result saved in the files of the logger (time history) $\mathbf{T} = \mathbf{T_b}$.

MAX result

The **MAX** result, saved in the logger's file, is calculated according to the formula:

$$\mathbf{MAX} = \mathbf{max_{T_b}(p_W(t))}$$

The **MAX** main result is calculated according to the formula:

$$\mathbf{MAX} = \mathbf{max_T(p_W(t))} \quad \text{for } \tau \neq \mathbf{1}\,\text{second}$$

MTVV result

The **M**aximum **T**ransient **V**ibration **V**alue - **MTVV**, saved as the main result, is defined (according to the **ISO 8041** standard) as:

$$\mathbf{MTVV} = \mathbf{max_T(p_W(t))} \quad \text{for } \tau = \mathbf{1}\,\text{second}$$

RMS result

The **RMS** result is calculated according to the formula:

$$\mathbf{RMS} = \left(\frac{\mathbf{1}}{\mathbf{T}} \int_{\mathbf{0}}^{\mathbf{T}} \mathbf{r_W^2(t)\,dt} \right)^{1/2}$$

For the **RMS** result saved in the files of the buffer (time history) $\mathbf{T} = \mathbf{T_b}$.

VDV result

The fourth power vibration dose value (**VDV**) expressed in meters per second taken to the power of 1.75 ($m/s^{1.75}$) is calculated from the formula:

$$\mathbf{VDV} = \left(\int_{\mathbf{0}}^{\mathbf{T}} \mathbf{r_W^4(t)\,dt} \right)^{1/4}$$