MONITORING
ELASTIC WAVES

CAUSED BY EXPLOSIONS OR MECHANICAL
SOURCES IN GROUND, IN AIR AND IN WATER

Roberto Folchi

HANDBOOK

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(COVER)

HANDBOOK for Monitoring ELASTIC WAVES induced by EXPLOSIONS by MECHANICAL SOURCES in GROUND, in AIR and in WATER

By Roberto Folchi[1]

Nitrex Srl
Via Mantova 61
25017 Lonato

[1] Born in Latina in 1960. Degree in mining engineering (Rome 1984), qualified in the profession of engineer (1985), qualified in the profession of geologist, qualified as a license holder for manufacturing explosives of any species according to arts. 101 and 102 D. of law 635/1940 (2000), technically qualified to manage factories for the production of armaments according to. art.8 L. of law110/75, member of the Consultative Commission for the control of Arms for functions in matters of explosive and inflammable substances at the Ministry of the Interior (since 2000), thirty technical publications for scientific reviews and conventions in Italy, Europe and the USA. Effective member of the International Society of Explosive Engineers and the Deutsche Sprengverband, founder partner of EU-Excert.
Exercises the profession since 1982 with experience in the sector of explosives and energy materials: technical studies, applied research, design and execution of work with explosives for excavating galleries, caves, mineral mining, demolitions (also in environments contaminated by radiation) industrial safety for handling energy materials, analysis of vulnerability of engineering works, analysis of risks, disputes.

Presentation of the handbook

The use of explosives in both our mining and civil yards has always been considered by the legislator a right for those who work with them but respecting the safety of people, protecting the property of third parties and reducing the environmental disturbance to the minimum.

Using explosive is a right, using them correctly is a duty.

Designing a mine rationally, or better still, the blast of a mine with the right quantity of explosive to obtain the work desired without provoking the anomalous projection of dangerous materials and vibrations in the surrounding structures is the synthesis of in-depth technical knowledge and consolidated experience over time. It can well be said to be an art.

The handbook written by Roberto Folchi is part of the didactic multimedia material developed by the Nitrex Company for theEU-Excert training program in the area of METROLOGY APPLIED to EXPLOSIVES ENGINEERING and is an extremely valid instrument for people interested in explosive materials to learn the art of making mines.

The use of this handbook is not meant only for those who are beginning to work in this discipline but also for those who already have experience and agree to broaden their knowledge or look at specific arguments in the sector. This is a valid instrument for both the staff authorized to set off mines and supervise the work and for the planners because is provides them with all the elements concerned with containing vibratory phenomenon within limits considered safe by the regulations of reference, in particular defining the maximum charge instantly and also cooperating in a precautionary manner through the formula of scaled distances.

Graphics, modules, sketches, bibliographical references, examples, information and basic data are reported in alphabetical order to record the vibration parameters and do not remain ends in themselves but become an essential instrument for the designer to modify successive blasts, optimizing the work and reducing vibrations to the minimum possible, even below the minimum safety regulations of reference, supported in this also by experience in the yards.

This handbook, in synthesis, is a needed working instrument with which Roberto, known and appreciated by me as the technical consultant for a work of excavation with great environmental difficulty, wished to transmit his many decades-long experience in the field of controlled demolition with explosives.

Programming controlled demolitions following the indications contained in the Handbook will help to create a climate of mutual trust between the operator of the controlled work and the owner of the structure, reducing quarrels, which is to say a lot!

Complements, therefore, to Roberto for the excellent work carried out.
I am sure that the Handbook will meet wide agreement among the operators in the sector.

Luciano Selve
Mining service of the Autonomous Province of Trento.

The EU-Excert Project

The propellant and pyrotechnical industry of energy materials in general occupies a strategic position in the economy of the European Union.

Understanding the science and technology of these materials and the ability to exploit them is fundamental for maintaining high standards of professionalism in national safety and creating and guaranteeing the competitiveness of the European industry.

The progressive deterioration of competence has led to an increase in accidents with explosives. These can assume notable relevance as in Nigeria, Russia, France (Toulon) and Holland (Enscheda), where deaths were respectively 1000, 118, 31 and 21 people. Other than the grave loss of human lives, there is also the relevant economic aspect of damage to the residential and industrial infrastructure and environment.

There is the perception that the level of preparation of the staff in this sector in Europe is noticeably reducing in the industry and, above all, in the Control Bodies. In several member States the greater part of the personnel with experience and competence is already pensioned-off or close to retirement. Urgent efforts are therefore needed to combat this grave gap in competence and experience.

The aim of the ***EU-Excert*** *project (*www.euexcert-org.nitrex.it/excert/index.asp *of which Nitrex is the Italian partner, is to define a program of instruction and training with European certification, targeted at re-establishing an adequate level of preparation in the explosives sector. Among the aims there is also the improvement of the quality and effectiveness of the didactic material and the teaching programs. Elevating preparation means improving the conditions of work, increasing the levels of public safety and creating incentives for European industrial competitiveness.*

Greater understand also leads to greater freedom to replace technicians and the capacity of Companies and Administrations to react swiftly to change.

The partners have a complete ongoing analysis of the industrial, administrative and government sector of explosives in the European Union in creating the ***EU-Excert*** *project. This analysis is aimed at identifying the levels of responsibility in productive activity and control, from the apprentice to the top manager, identifying the competences and experience needed to cover each level of responsibility. This is all created in strict collaboration with the qualified referents of the various areas in each Member State and coordinated by Committees of National referents.*

The training path at every level of responsibility of the staff is established in function of the competences required; the didactic methods are chosen and developed in cooperation with training Bodies, among which Universities, professional organizations, superior instructional Bodies and Trade Union organizations; pilot instruction and training programs are set up and experimented in the various member states.

The results of the project are also spread by articles, reports and seminars to favor the development of a community of people and organizations that can represent the European explosive industry in the world.

Marc Battocchio
NITREX Team

Areas of the EU-Excert training and certification program

- *Chemistry of explosives*
- *Use of explosives in civil environments*
- *Metrology applied to the engineering of explosives*
- *Analyses of the risks of relevant accident due to the explosion of energy materials*
- *Managing a deposit and the movement of explosives*
- *Clearance of explosive firebombs*
- *Italian and Community regulations*

Contents

CONTROLLED DEMOLITION WITH EXPLOSIVES – REC. NTX

General

Controlled demolition with explosives means demolition or excavation work in which the surrounding secondary effects induced (vibrations, noise, flying debris, toxic discharges, etc.) are contained within predefined limits of safety and tolerability for people nearby and artificial and natural structures (homes, buildings and industrial plants, slopes, etc.).

To guarantee the containment of the secondary effects within predefined limits and to minimize the risk of dispute, the following activities need to be carried out:

- acquiring in-depth file data relative to the work to be performed and the surrounding structures to protect, through surveys, tests and analyses;
- designing the controlled demolition;
- instrumental monitoring of the induced effects:
- activity of informing the people nearby.

Preliminary activity at the start of mining work

At the preliminary phase of the project, the placing of all the buildings, structures and plants around the area of work must be shown on 1:500 / 1:2,000 cartography.
A first approximation technical report must be drawn-up for each, containing photos, description of the structural and archeological type, plants and sections, conditions of maintenance and possible special characteristics (e.g. architectonic details particularly sensitive to vibrations, presence of thermal bridges, zones of concentration of static thermal stress, hydraulics, pre-existing state of lesions, fine art constraints, etc.).
In specific cases it might also become necessary to acquire the architectonic importance of the work performed, structural calculations and the results of the charge tests carried out for static testing, calculations and possible tests to check the foundations, the geo-mechanical and structural characteristics of the foundation ground, etc.
The level of approximation of the technical report must be established in function of the value of the building and the distance from the area of the work with explosives.

Controlled demolition design

The design can be developed using the following trace:

- characterization of the socio-urban context in which the work will be carried out
- indications of the suggestions for carrying out the work (presence of pipes for gas or fuels, plant sensitive to vibrations, such as instruments of analysis, turbines, etc., slopes in precarious conditions of equilibrium, historical buildings, etc.
- GEOLOGICAL, GEOTECHNICAL, GEOSTRUCTURAL OVERVIEW (in-depth analysis of the relevant aspects aimed at seismic safety).
- SEISMOLOGICAL CHARACTERIZATION.
- Description of the work to be carried out (with possible references to project documentation , expertise, state of the art, etc.
- Description of the buildings and plants to protect (with reference to the technical report drawn up during the BEFORE STARTING THE MINING PHASE activity).
- Indication of the approach that has been followed for quantifying the surrounding effects induced, the regulations and limit values to which reference has been made, the executive practices and the state of the art.
- Protection systems / minimizing flying demolition fragments.
- System for containing vibrations.
- System for containing airblast overpressure waves,
- System for containing dust.
- System for containing the gas of the explosion.
- Analysis of dynamic stability of the surrounding structures.
- Quantifying the surrounding effects induced carrying out the work with explosives.
- Checking respect for the regulations of reference with indications and definitions of the activities to follow so that they are rigorously guaranteed, conditions of tolerability and safety for the staff, buildings and plant within the area established, for external people and buildings.
- INSTRUMENTAL MONITORING PLAN with description of the technical characteristics of the measuring system installed.

- ACOUSTIC-SIESMIC MONITORING PLANT for measuring the vibrations: SIESMIC WAVES AND AIRBLAST OVERPRESSURE WAVES;

- video camera for recording the blast;
- gas detectors;
- etc.

- OUTLINE OF EXPLODING THE BLAST (firing plan) with drawings and charge tables and indication of the succession of priming the charges.

- Method of checking the firing circuit, whether electric, non-electric or electronic.

- EXPLOSIVE PRODUCTS FILES and the detonators to be used.

- File of safety data of the explosives and the detonators to be used.

<u>Continuous control of the seismic waves</u>

Instrumental control of the seismic waves induced by the blasts must be carried out to check respect for the predefined limits for the vibrations. Experience deriving from the practice of numerous disputes teaches that this monitoring should, in short, be performed 24 hours a day, 7 days a week in order to record every SIGNIFICANT SEISMIC EFFECT, even possible "environmental" seismic sources (passage of heavy trucks, microseisms, etc.) and not only those connected to the demolition blast.

This is the way in which the environmental seismic context in which the work is taking place could be characterized.

Tri-axial SPEED SEISMOGRAPHS are generally used to measure the vibrations (velocimeters with measurement of the vertical, horizontal, longitudinal and transversal components) or rather measurement of the components of speed along the z. x, y, axes. In particular cases MOVEMENT SEISMOGRAPHS or ACCELERATION SEISMOGRAPHS can also be used. The preference for employing speed seismographs derives from their ease and reliability of use and from the fact that it is precisely the vibration speeds that better than the other magnitudes can be used to establish levels of correlation with the damage. In addition, measurement with velocimeters needs less technical preparation and less commitment for installation by the operator since these instruments are less sensitive to vertical errors with respect to accelerators. Besides, the latter are capable of a recording dynamic much wider than MOVEMENT SEISMOGRAPHS but are unstable practically everywhere, unlike DEFORMATION SEISMOGRAPHS.

The drawing-up of a periodic MONITORING REPORT, e.g. weekly or monthly, and a CONCLUSIVE REPORT ON MONITORING is indispensable. All the significant seisms recorded must be included in the report, highlighting those referable to the monitored source.

The instruments used must be certified and periodically calibrated as envisaged in the UNI 9916 regulations and the installation also carried out in conformity with the REGULATION.

Measurement must be carried out at a sufficient number of points with seismographs able to guarantee the reconstruction of the physical phenomenon with the desired MARGIN OF APPROXIMATION, or rather characteristics able to constitute a measurement point that does not relevantly alter the measured phenomenon. In the case where this is not reasonably possible, the system of measurement must be characterized and the measurement should be compensated by dynamic analysis.

The results of the measurements must be shown in a BILOGARYTHMIC GRAPH in which the speed of vibration must be associated with the normalized scale on the explosive charge (SCALED DISTANCE).

The REDUCTION CURVE OF THE MAXIMUM SPEED OF VIBRATION AT THE VARIATION OF THE SCALED DISTANCE must be calculated by a regression analysis, adopting the necessary shrewdness to maximize the reliability of the results of the statistical analysis and indicating the limits of its representative character.

The estimate of the SPEED OF VIBRATION at points other than those of measurement is possible by EXTRAPOLATION from the reduction curve of the site for the specific direction, or by INTERPOLATION of the measurements carried out, straddling along an alignment.

Even though disturbances propagated through the air are not directly correlated to movement on the ground, airblast overpressure waves induced by the blast of an explosive charge contributes to the discomfort of the surrounding population and it is, therefore, advisable to document it. Measuring the airblast overpressure waves, if synchronized with the seismic waves, in addition, allows the INDIRECT VERIFYING OF THE DISTANCE OF THE POINT OF MEASUREMENT FROM THE BLAST. The measurement of the airblast overpressure waves synchronized with the measurement of the seismic waves must, therefore, always be carried out, making the comparison of the time interval between the first arrival of the seismic and airblast waves possible.

The measurements put on paper (GRAPH OF THE SEISMS) and conserved in the yard, must be made available, accurately dated, by the Bodies and Administrations concerned with controlling the work.

The synthesis data of each measurement must be reproduced in a SUMMARY TABLE in which the data of the relative blast will also be reported.

See the other arguments treated

MEASUREMENT OF THE VIBRATIONS INDUCED BY THE EXPLODING MINE - I.S.E.E. guidelines for good practice, and MONITORING REPORT - information that must be contained as in UNI 9916.

<u>Communications and public relations</u>

Good information about the activity carried out and the precautions adopted greatly help to reduce disputes.
The practice of explosives is not widespread in Italy, practiced at a non-advanced professional level and in any case little known.

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Experience teaches that vibrations and noise induced by the use of explosives, even of a lesser degree to those induced by traffic or industrial plant are considered more dangerous.

A preliminary activity of information and involvement of the local authorities is often appropriate to minimize the risk of dispute (mayor, technical office, Police, and sometimes even the Bishop, etc.) and also, if necessary, the resident population in an area where some resentment is predictable.

Distributing a LEAFLET OF A PRIOR WARNING OF A MINE EXPLOSION is very effective, in which the work to be carried out, the regulations to which the precautions refer, the precautions taken and the controls carried out are explained simply.

5

Numerical calculation of the values of the speeds recorded

The recordings of the speeds of vibration can be converted into acceleration by derivatives.
Calculating the derivative at a point means finding the value of the inclination of the line tangent to that point of the curve. When a digital signal is derived, calculate the value of the derivative for each of the sample points.

The derivation is the operation that allows calculating the inclination of the upright tangential to a point on the curve of the vibration speeds. At equal speed of vibration, while the movement increases in direct proportion to the reduction of the frequency, acceleration increases in direct proportion to the frequency.

Before speaking of derivatives we must define the limits. Consider the following equation:

$$\lim_{x \to a} f(x) = b \qquad \text{(eq. 1)}$$

where *f*(x) is a function for which for each value of x exists one and only one value of *f*(x) (function of x). It follows that, for example, $y = x^2$ is a function in which $f(x) = x^2$, while $x^2 + y^2 = 4$ is not a function because at every value of x corresponds two possible values of y. The recordings of the SEISMIC ACOUSTIC MONITORING PLANT can be considered as functions since at each point (time) corresponds one and only one value of *f*(t) (speed of vibration) for each recording channel.

The equation reported above says simply that as the value of x gradually tends to approach “a”, the value of the *f*(x) function tends to approach “b”.
Considering, for example, the function:

$$\lim_{x \to 3} f(x) = 2x \qquad \text{(eq. 2)}$$

as the value of x gradually tends to approach “3”, the value of *f*(x) tends to approach “6”.
The inclination of the upright line between any two points (x^1,y^1) and (x^2,y^2) is equal to $(y^2-y^1)/(x^2-x^1)$
If (x^2-x^1) is substituted with h, the equation can be written as follows:

$$\frac{f(x+h) - f(x)}{h}$$

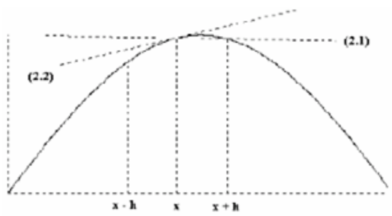
in which y^2 becomes the value for *f (x+ h)* and y^1 becomes the value for *f(x)*.

The derivative is a limit . To be able to find the derivative you must find the limit of the function. Given function *f(x)*, the derivative is written $f^1(x)$.

This derivative can therefore be written with the following limit:

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$ (eq. 3)

In the following figure note that two uprights exist identified as (2.1) and (2.2),
These uprights are the result of the use of two different numerical methods for finding the derivative at point "*x*".
The variable "h" is the space existing between the two adjacent sample points..



For simplification, consider only the first half of the sinusoidal curve.
It is proven that if $f(x) = \sin(x)$ then $f'(x) = \cos(x)$ (eq.4)

The derivative at any point on a sinusoidal curve corresponds to the value of the same point on a co-sinusoidal curve.
Therefore the value of the derivative can be calculated for any point *"y"* of the curve.
To illustrate the procedure of derivation, put *x* = 0.22. To find the value of the sine for *x* = 0.22 we must first multiply this value by 2 π to find the corresponding radiant value.
Before doing this it is necessary to introduce another form of eq. 4:

If $f(x) = \sin(kx)$, then $f'(x) = k\cos(kx)$ (eq. 5)

where "k" is a constant.
In our case "k" is the circular constant 2 π.
Therefore, if *"x"* = 0.22, the sine derivative sen(2π x 0,22) = 2π x cos(2π x 0,22) = 1,177

Once noted, the value of the derivative is shown in a table with the values calculated with various h. Note that as the value of h gradually tends to approach 0, the value of *f(x)* tends to approach the value of the derivative.

h	x	x + h	*f*(x)
0,06	0,22	0,28	0,00000
0,03	0,22	0,25	0,59042
0,01	0,22	0,23	0,98275
0,002	0,22	0,222	1,13854
0,001	0,22	0,221	1,15795
0,0001	0,22	0,2201	1,17541
0,00001	0,22	0,22001	1,17716

A better method of finding the derivative for *(x)* is to substitute *f(x)* with *f(x-h).*
In this case the space between the two points is 2h.

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x-h)}{2h}$$ (eq. 6).

Now repeat the previous procedure using eq. 6.

h	x	x + h	x - h	*f*(x)
0,06	0,22	0,28	0,16	1,1497
0,03	0,22	0,25	0,19	1,1704
0,01	0,22	0,23	0,21	1,1766
0,002	0,22	0,222	0,218	1,1773
0,001	0,22	0,221	0,219	1,1773
0,0001	0,22	0,2201	0,2199	1,1774
0,00001	0,22	0,22001	0,21999	1,1774

Note that we also approach the correct value of the derivative for a wider value than h. Consequently, at the moment of performing a derivative, equation 6 offers results more accurate than equation 2.
Both methods provide better results when the space between the two points is less. This is important to take into consideration when choosing the sample frequency.

Estimate from the approximation of the sinusoidal movement:

presupposing once again that the recording of a speed is equal to a sinusoidal curve, i.e. that the recording can be described by the equation

$$v(t) = A \sin \omega t$$ (eq. 7)

in which "v(f)" is the speed at time "t". A is the maximum value assumed by the sinusoidal curve, "w" is equal to 2TT.*f* in which *f* is the frequency.
From the calculation we know that:

$$a(t) = v'(t) = A\omega \cos \omega t$$ (eq. 8)

in which *a(t)* is the acceleration at the *ft* instant.
Once again let us consider the maximum values:

$$v = A$$ (eq. 9)

$$a = A\omega$$ (eq. 10)

therefore

$$a = A\omega = 2\pi f v$$ (eq. 11)

The unit of measurement of acceleration used for visualizing is 'g' (the acceleration of gravity) equal to 9.81 m/s² or 9,814.6 mm/s².
To obtain the result of the acceleration in "g", equation 11 must be modified as follows:

$$a = \frac{2\pi f v}{9814{,}6 mm/s^2} \quad \text{(eq. 12)}$$

where the speed is expressed in millimeters per second.
As for movement, if the maximum vibration speed and frequency associated with it are noted, maximum acceleration can easily be approximated.
If we suppose again that the recording of the speed is sinusoidal, the maximum speed will be 14.48 mm/s, the maximum frequency will be 39,3 Hertz and the movement will be:

$$a = \frac{2\pi \cdot (39{,}3 Hz) \cdot (14{,}48 mm/s)}{9814{,}6 mm/s^2} = 0{,}364 g \quad \text{(eq. 13)}$$

Technical data of the BEDROCK

	Weight of the unit of volume (t/m^2)	Speed of the acoustic waves (km/s)*	Resistance to single axial compression (Mpa)	Resistance to cutting (Mpa)	Module of elasticity (Kg/cm^2)
water					
Sand, more or less compact attrition material					
Moraine, alluvium, fresh clay					
Compact sandstone					
Marley limestone					
Pure or dolomite limestone					
Effusive/lava rocks					

1. Rubber hammer (for checking the continuity of the structural parts).
2. 0.5 kg. piton hammer or any other equipped hard object (for energizing impulses from the measuring point).
3. Spike with pre-perforated brackets, washers, and pallets for coupling the seismograph.
4. Rigid bi-component resin or expansive cement (for fixing the c.s. spikes to the measurement point.
5. Rock scalpels (for adjusting the rock or concrete support level of the seismograph).
6. Sacks of sand (to fill with dry sand for covering the geophone).
7. Folding spade (for adjusting the support level of the seismograph in loose soil.
8. Gloves.
9. Protective goggles (for the fragments produced by the scalpel.
10. Drill for making holes.
11. Compass (for recording the orientation of the geophone and the microphone.
12. GPS positioning device for the unambiguous definition of the measurement point.
13. Spacer, metric tape, etc., (for measuring the distances from the energizing source.
14. …
15. …

CALIBRATING THE SEISMOGRAPHS

An error can be made by altering the setting of the seismographs. This is why during a dispute it is systematically disputed without regular checking and calibration even by experts lacking specific technical competence, simply with reference to other metrological disciplines where checking/calibration of the instruments of measurement is also set at legislative level.

A seismograph transforms the physical phenomenon it is measuring into an electric **signal.** The electric signal produced is in proportion to the amplitude of the physical phenomenon being measured.
Because of prolonged use, deformation of the component material, alteration of the geometric and elastic characteristics consequent to cycles of thermal and mechanical stress, the seismograph can arrive at “translating” the physical phenomenon into an electric signal outside the range of proportional tolerance envisaged by the constructor. In this way the information provided by the seismograph is affected by error, varying, even significantly, between the physical phenomenon measured and the amplitude of the electric signal produced.

Periodical verification checks of the seismograph must, therefore, be carried out to guarantee the reliability of the measurement. The Italian regulations indicate an annual verification interval.
In the case of seismographs subjected to frequent and intense measurement cycles a shorter verification interval is needed, even quarterly.
Verification takes place in authorized SIT centers or by the constructor of the apparatus who, in his turn, possesses a verified reference sample with primary samples at a SIT center. Verification is performed comparing the electric response of the seismograph made to oscillate on a table vibrating at different sinusoidal frequencies of amplitude, confirmed by the primary sample.

The electronic conditioning of the seismograph signal is acted upon to re-calibrate the measurement system, or rather the electric circuit parameters of the seismograph in order to bring the proportionality between the physical phenomenon and the electric signal measured back to within the characteristic approximation interval.

The authorized calibration centers therefore possess electric diagrams of the signal conditioning circuit and the procedures that the constructor has fixed for verification and calibration.

Photo

Conditioning electronics of the signal of a tri-axial velocimeter.

Photo

Geophone fixed to a vibrating equipped with a sensor of reference, also regularly calibrated.

The correct positioning of the seismographs is fundamental for the reliability of seismic monitoring.
If the seismograph is not placed in the correct way the measurements lose significance and the physical phenomenon measured is affected by error, in defect or excess, and the project developed on inaccurate data.

A measurement is taken correctly when the seismograph system - point of measurement, or rather the point of the structure to which the seismograph is coupled, is the same as the physical phenomenon measured.

The measurement is not correct when

- the seismograph is coupled to a point of measurement whose frequency of resonance is comparable to the predominant frequency of the transient seism, or in any case to frequencies in the spectrum with significant amplitudes (amplification of the response).
- the seismograph is coupled to an element not connected to the structure to be monitored and that, above all, has an ACOUSTIC IMPEDANCE (z = p - C - density of the means x speed of propagation of the acoustic waves in the means) lower than the means of propagation of the seismic waves (reduction of the response).

For example, placing the seismograph on a threshold that is not in structural continuation with the building and that, flat and elongated because of its geometry, is less rigid vertically and, therefore, oscillates freely in this direction, an amplified measurement of the vertical component of the speed of vibration is obtained:

- very much in the harmonic component of the frequency of resonance of the threshold in the vertical direction;
- a little less in the horizontal direction transversal to the longitudinal axis of the threshold;
- much less, almost nil, in the horizontal longitudinal direction.

It is sometimes not possible to establish the condition of the measurement point before measuring. It becomes necessary, therefore, to characterize, or rather verify that the natural frequency of resonance of the point of measurement is not included among those characteristic of the induced transient seism, or in any case does not amplify, or however alter, the measurement for the priming of a resonance.
A quick method for verifying the natural frequency of resonance of the point of measurement consists in energizing with an impulsive charge that, therefore, induces a form of wave with an extremely high frequency, e.g. like the impulse produced by the impact of a steel cylinder.

The composition of the transient seism in the elementary harmonic components (CALCULATION OF THE FREQUENCY ASSOCIATED WITH THE PEAK – FFT) allows identifying the frequency with a good margin of approximation, or the frequencies precisely from the point of measurement (or rather the seismograph measuring system point of measurement) and therefore able to exclude, or confirm, interference of the point of measurement.

Calculating the maximum COOPERATING CHARGE WITH VARYING THE DISTANCE FROM THE POINT OF EXPLOSION FOR A PRE-FIXED SCALED SAFETY DISTANCE

Given the scaled safety distance $DSs = \frac{R}{Q^{0,286}} = 20\frac{m}{MJ^{0,286}}$ =>

$$\frac{R}{20} = Q^{0,286}$$

$$(\frac{R}{20})^{\frac{1}{0,286}} = Q^{\frac{0,286}{0,286}}$$

it follows that the maximum cooperating charge allowed to explode with varying the distance will be equal to:

$$Q = (\frac{R}{20})^{\frac{1}{0,286}}$$

or, in function of the specific energy of explosion, equal to:

specific energy of explosion (MJ/kg)						
		3.1	4.1	4.5		
Seismic path	**Max charge. cooperating to explode**	**AN.FO. (kg)**	**Emulsion (kg)**	**Gelatine (kg)**		
(m)	**(MJ)**	**(kg)**	**(kg)**	**(kg)**		
50	24,6	7,9	6,0	5,5		
55	34,4	11,1	8,4	7,6		
60	46,6	15,0	11,4	10,4		
65	61,6	19,9	15,0	13,7		
70	79,9	25,8	19,5	17,7		
75	101,6	32,8	24,8	22,6		
80	127,4	41,1	31,1	28,3		
85	157,4	50,8	38,4	35,0		
90	192,3	62,0	46,9	42,7		
95	232,3	74,9	56,7	51,6		
100	277,9	89,6	67,8	61,8		
105	329,6	106	80,4	73,2		
110	387,8	125	94,6	86,2		

Tables

Pressure	
1 psi (lb/in^2 - libra su pollice quadrato) = 0,0689 Bar	1 Bar = 14,514 psi
1 psi = 6,90 kPa	kPa = 0,145 psi
1 psi = 0,096 kg$_f$/cm^2	1 kg$_f$/cm^2 = 10,417 psi
1 psi = 0,006895 Newton/mm^2	Newton/mm^2 = 145,03774 psi

Length	
1 ft (piede) = 0,3048 m	1 m = 3,2808 ft
1 inch (pollice) = 2,51 cm	1 cm = 0,398 inch

Weight	
1 lb (libra)= 0,454 kg$_f$	1 kg$_f$ = 2,20 lb

Scaled distance on the charge	
1 ft/lb^2 = 0,453 m/kg$_f^2$	1 m/kg$_f^2$ = 2,21 ft/lb^2
1 ft/lb^3 = 0,397 m/kg$_f^3$	1 m/kg$_f^3$ = 2,52 ft/lb^3

Scaled impulse on cube of the charge	
1 psi · ms / lb^3 = 0,0897 Bar · ms / kg^3	1 Bar · ms / kg^3 = 11,1439 1 psi · ms / lb^3
Calculation of decibels L (dB) = 20 Log_{10} (P/P_0) with P pressure measured P_0 reference pressure (20 · 10^{-6} N/m^2 oppure 2,9 · 10^{-9} psi	

Conversion from dB, mBar, psi – model

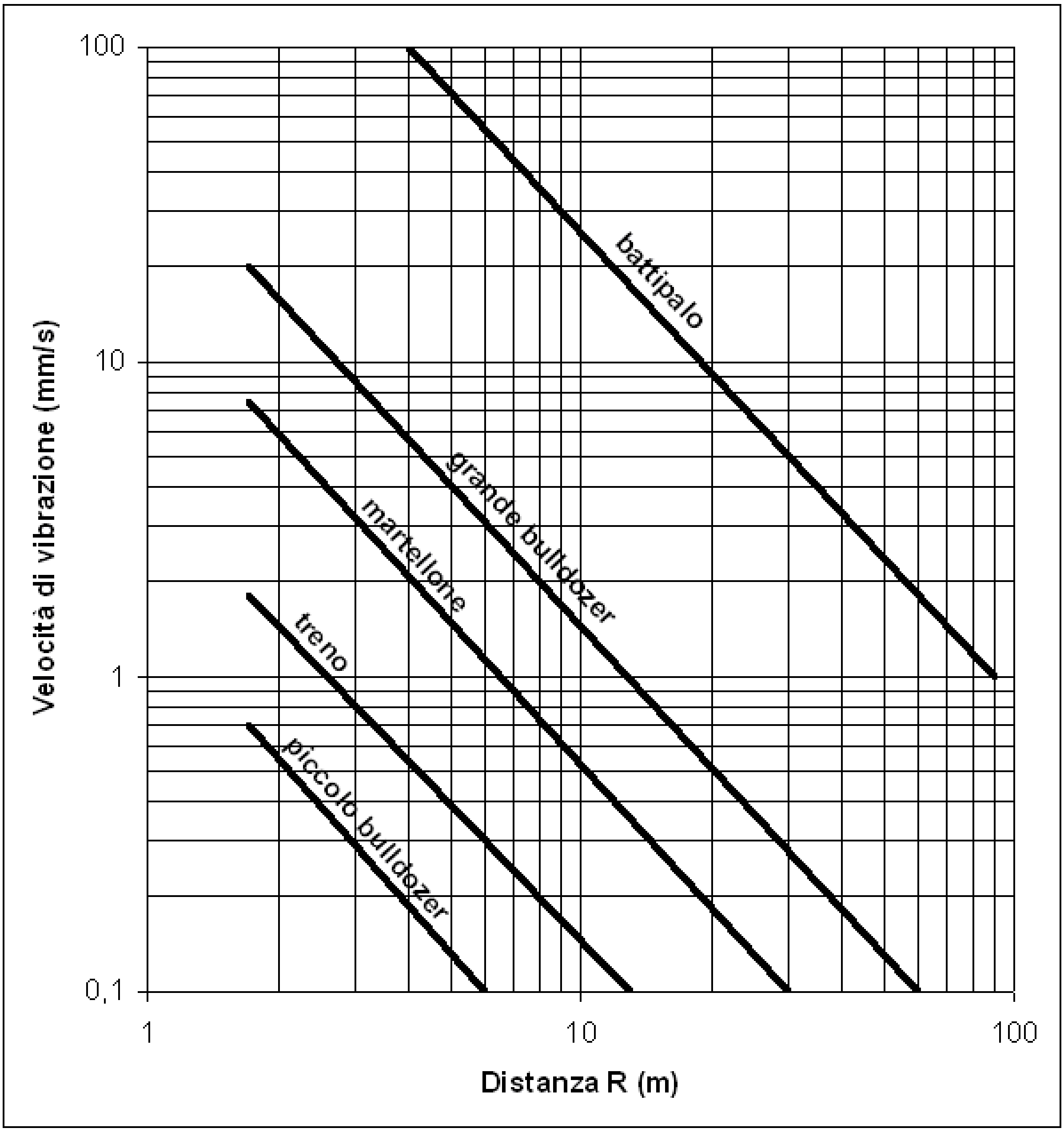
Graphic

Normogram for converting change in speed to acceleration in function of the frequency- model

Graphic

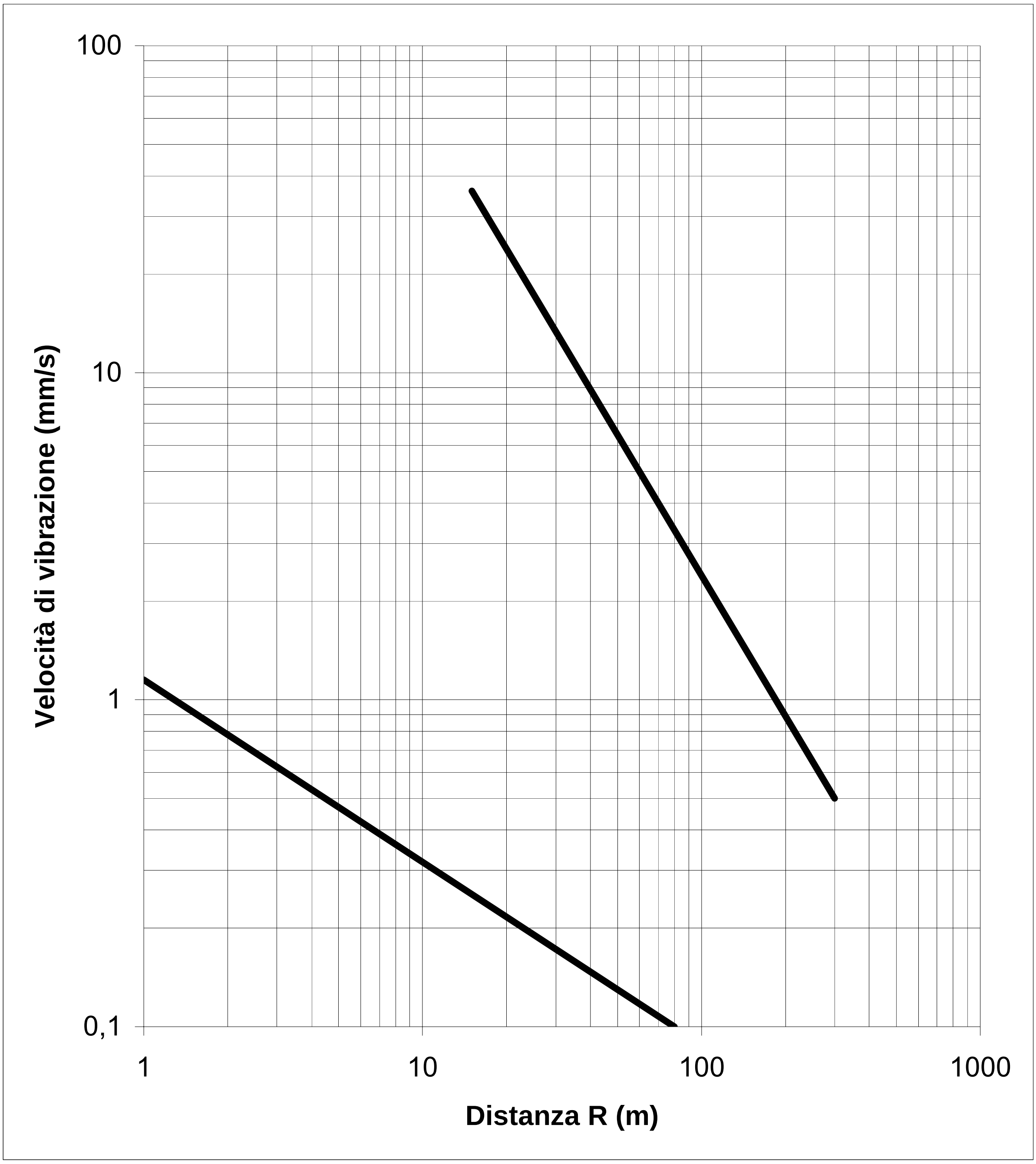
VIBRATION SPEED REDUCTION CURVES -
examples from various seismic sources

Mechanical sources



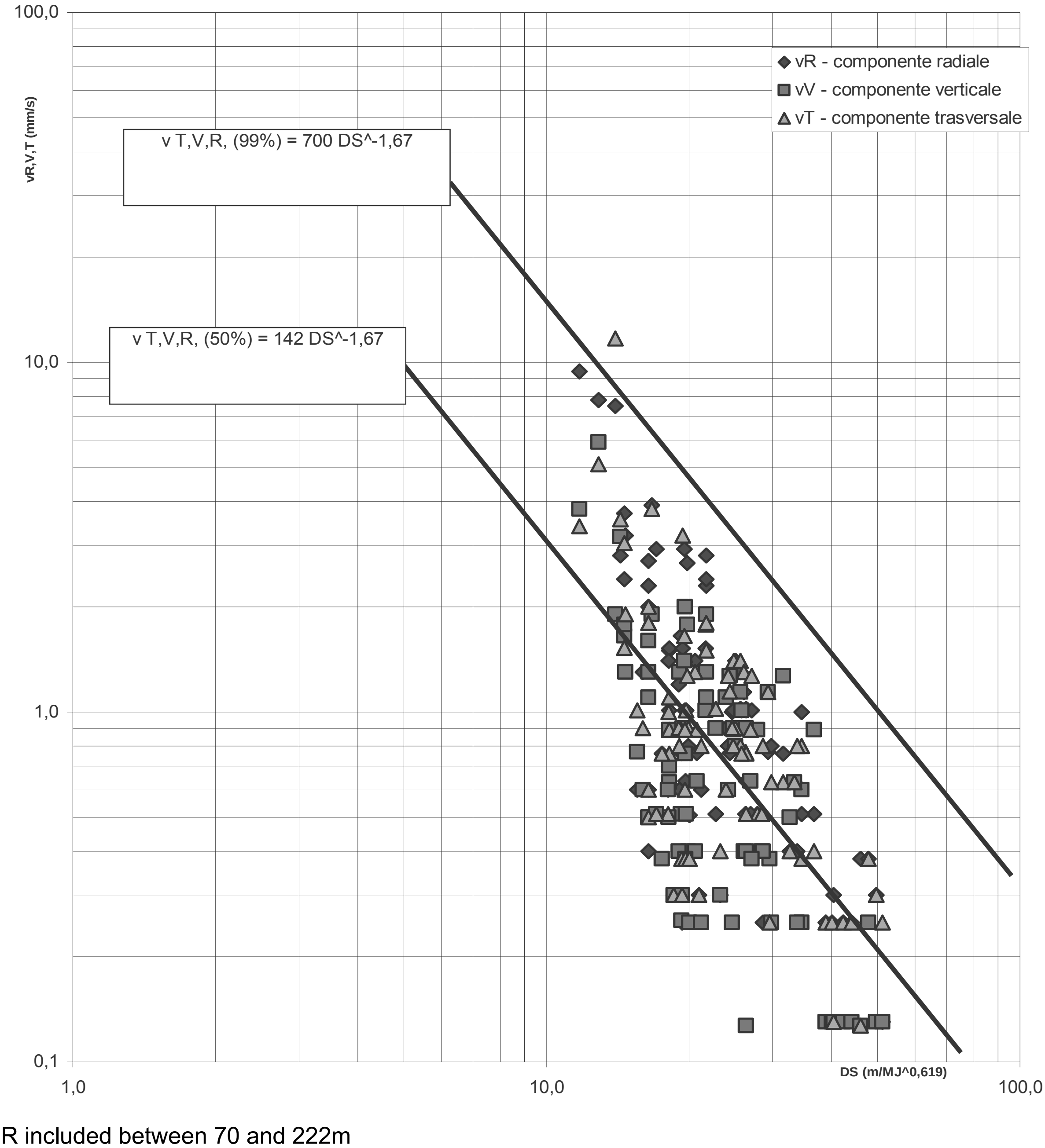
VIBRATION SPEED REDUCTION CURVES

Miscellaneous



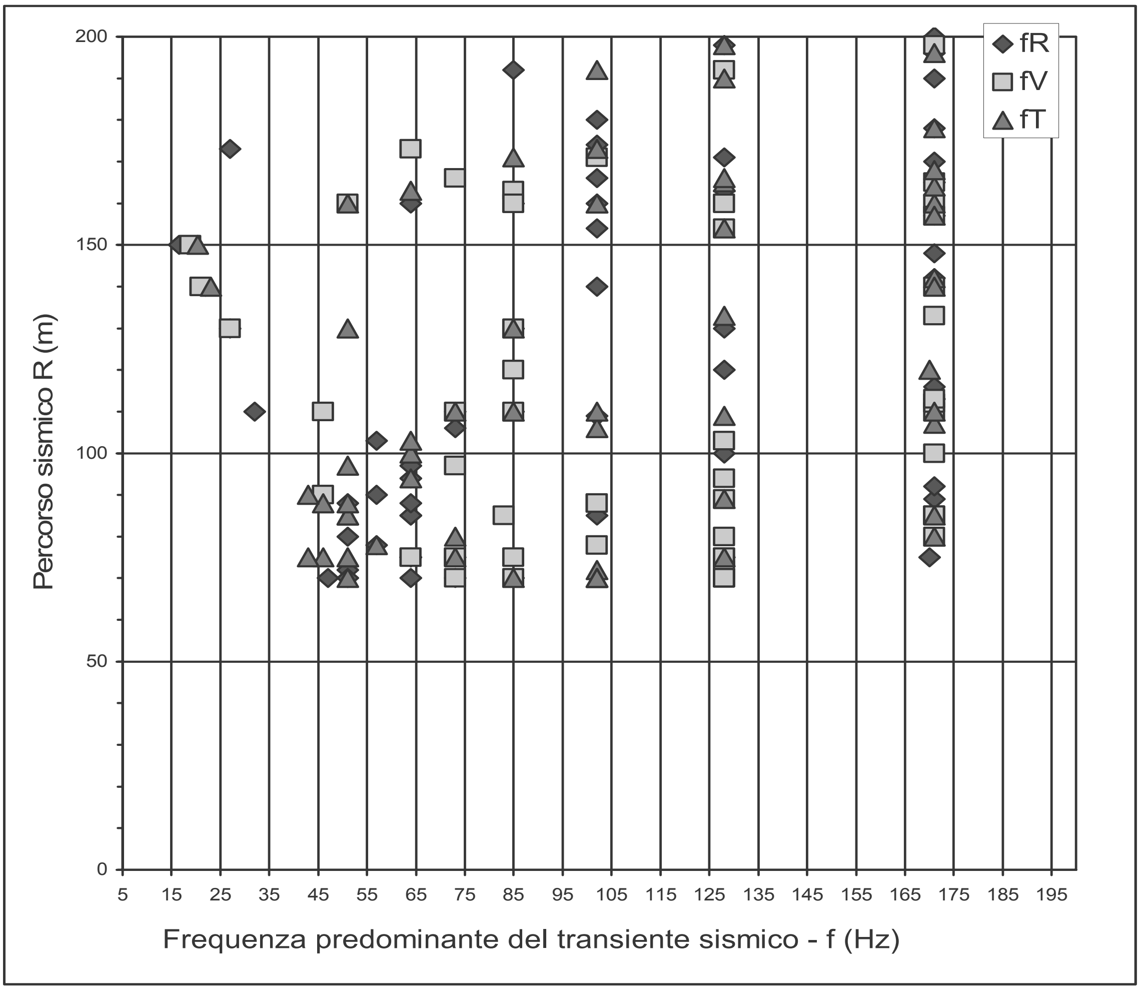
Excavating hydraulic tunnel (small section)

Excavating in carbonate rock – Palermo
(high dispersion of data on the average)



R included between 70 and 222m
Q included between 5 and 49.4 MJ
Vt, vR included between 0.1 and 11.7 mm/s

Standard error for the coefficient of Q	0.10
Standard error for the coefficient of R	0.20
Coefficient of determination	0.29
Standard error for the estimate of v	0.86
F statistic	53
degree of freedom	255

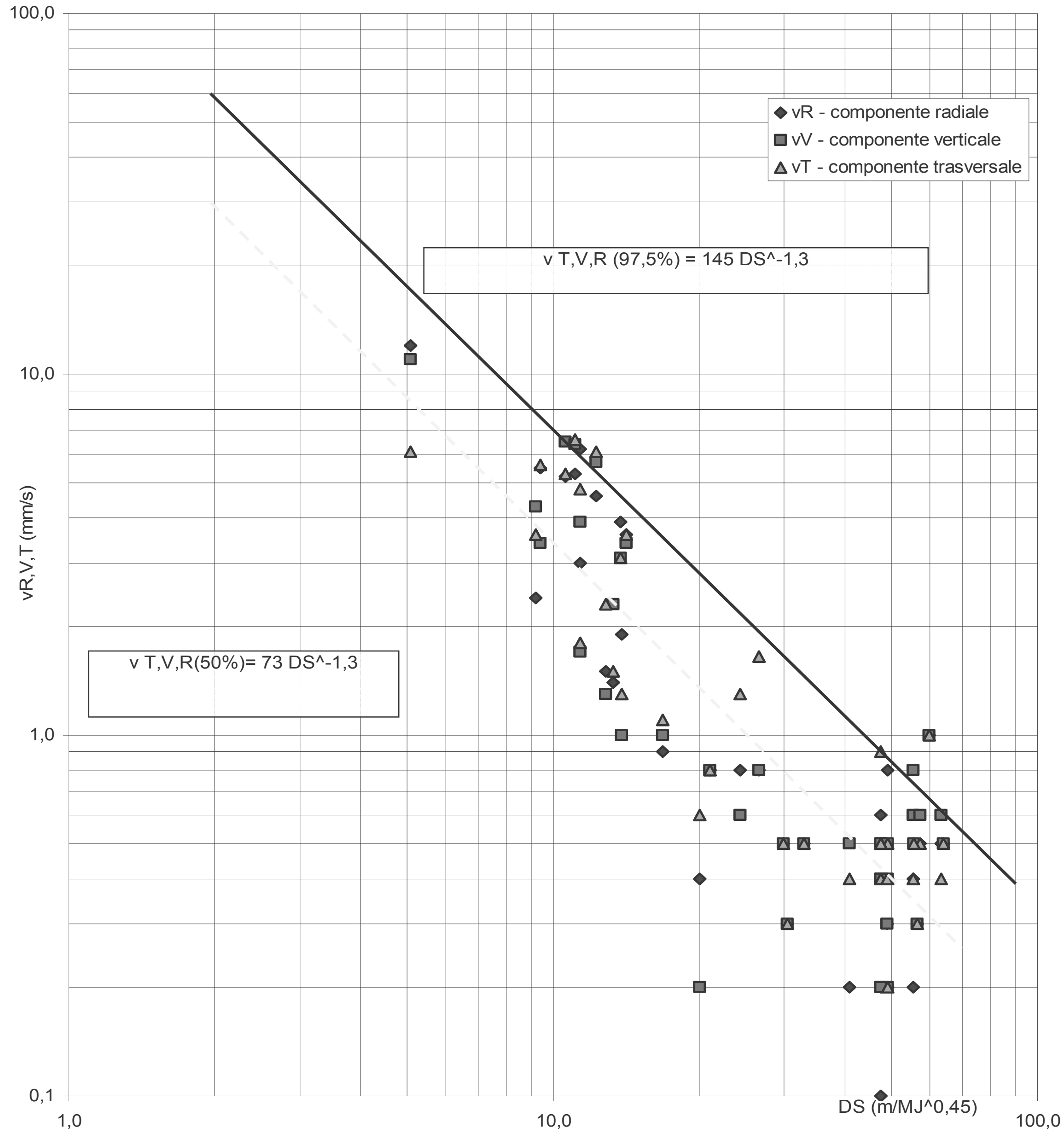


Graph of the Zero Crossing frequencies associated with the value of the peak of the speed

The predominant frequency of the transient seism (for all three components) remains high even at distances of hundreds of meters.
The high dispersion of the values of the predominant frequency at variations in the distance in the seismic path does not allow identifying a correlation with the distance.

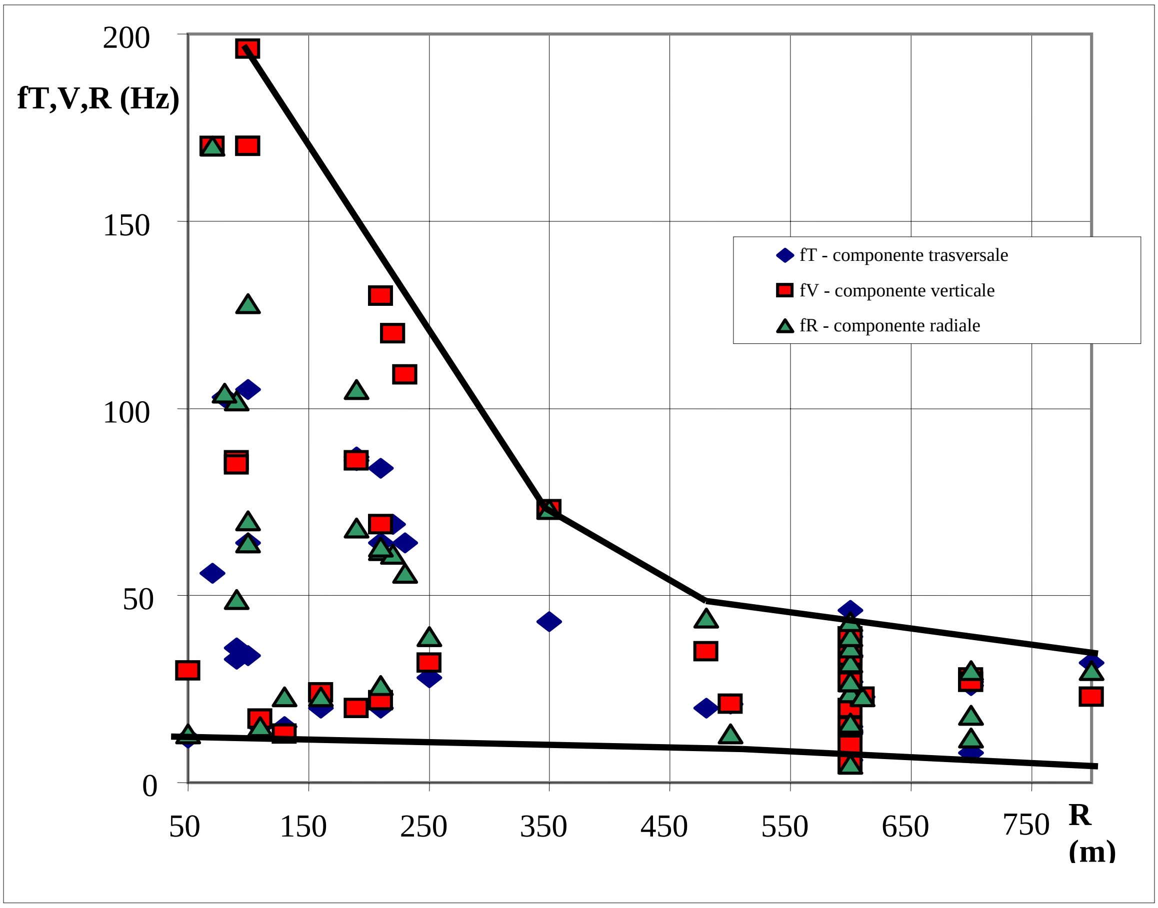
Mining an underground chamber (values calculated on surface)

Excavation in carbonate rock - Palermo



R included between 100 and 800m
Q included between 785 and 148MJ
VT, VR included between 0.1 and 11 mm/s

Standard error for the coefficient of Q	0.9281
Standard error for the coefficient of R	0.7745
Coefficient of determination	0.74
Standard error for the estimate of v	0.57
F statistic	172.55
degree of freedom	123



Grafic of the Zero Crossing frequencies graph associated to the value of the peak of the speed

The predominant frequency of the transient seism (for all three components) reduces progressively with the increase in the distance from the explosion point.
For distances of some tens of meters the predominant frequency assumes values around 100 Hz (with high dispersion).
For distances of some hundreds of meters the predominant frequency assumes values around 30 Hz (with a more contained dispersion).
Values of the predominant frequency around 80-100 Hz have been measured underground distant as far as 200 m.

Classification of levels of damage induced in the structures – rec. NTX

- RELEVANT - permanent deformation - takes place only for high values of the speed of the particles (in the order of hundreds of mm/s) and leads to serious weakening of the structure (e.g. large lesions, breaks in the foundations or the masonry leading to important subsidence determining distortion and misalignment of masonry.

- MINOR - fractures of movement - take place for high values in the speed of the particles in the order of tens of mm/s. They include superficial fractures that do not effect the static setting of the structure (e.g. broken windows, loosened or fallen plaster) slight fractures in the masonry.

- THRESHOLD - or cosmetic lesions - take place at lower speeds and only open old fractures or produce slight fractures in the plaster and can dislocate loose elements (e.g. loosen the brick lining of chimneys).

Zero Crossing frequencies graph associated with the value of the peak of the speed

The predominant frequency of the of the transient seism (for all three components) remains high even at distances of hundreds of meters.

Vibration speed limits to respect according to DIN 4150-3, Tab. 2 so that damage to the threshold in the buried pipes does not take place.

Oscillation speed of reference

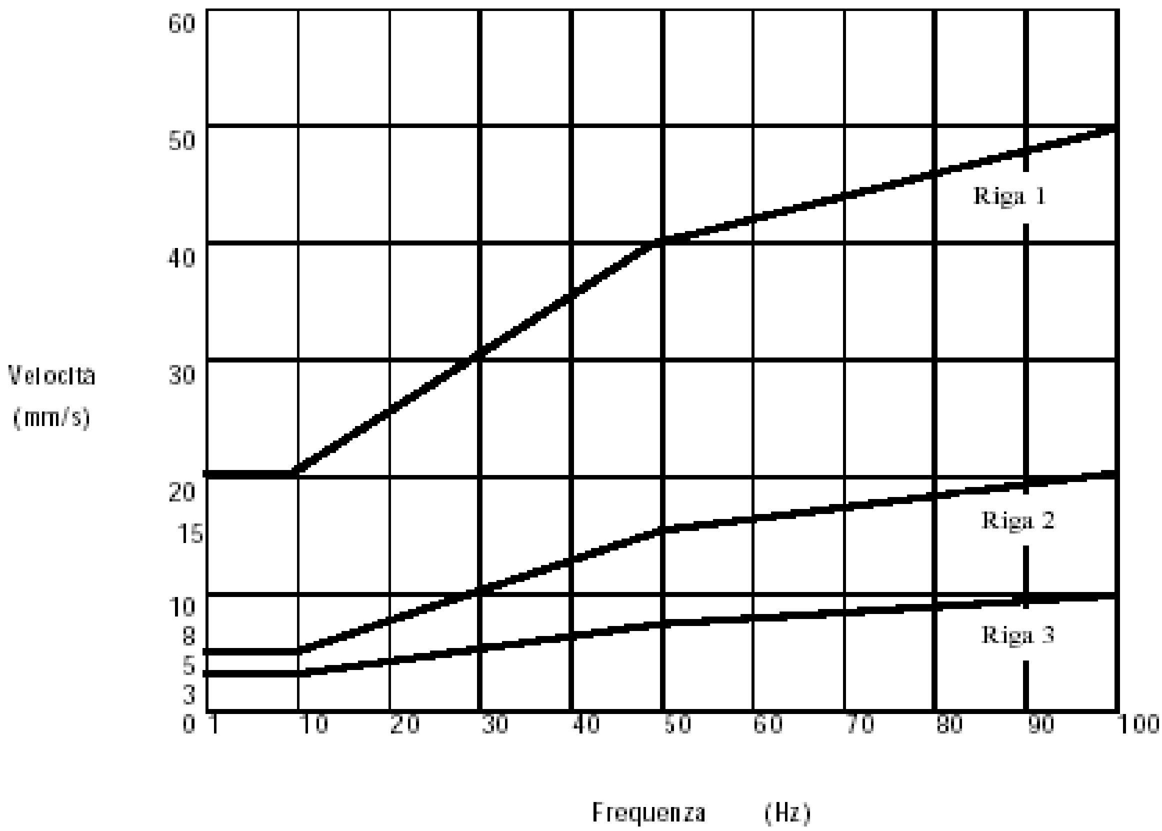
Line	Tubing material	Reference value for oscillation speed Vi in mms on the tubing
1	Welded steel	100
2	Stoneware, reinforced concrete, metal with or without flange	80
3	Plastic masonry	50

Limit values of speed of vibrations to respect for the constructions to avoid threshold damage, according to DIN 4150-3. Tab. 1

Oscillation speed of reference

		Reference values for max speed of oscillation in mm/s			
Line	*Type of building*	*Measurements on the last horizontal floor*			
1	Constructions for commercial activities, industrial constructions and constructions with similar structures	from 1 to 10 Hz	from 10 to 50 Hz	from 50 to from 50 to 100 Hz (*)	All frequencies
2	Dwellings or similar buildings for construction or use	20	from 20 to 40	from 40 to 50	40
3	Buildings that for their particular sensitivity to vibrations do not enter into the previous classifications or that are to be particularly protected (monuments under fine arts protection)	3	From 3 to 6	From 6 to 10	6

(*) For frequencies above 100 Hz, valuess for 100Hz can be adopted as minimum



Graph of the reference values in foundation

Verifying the speed limits for avoiding damage to the structure taking place, as in DIN 4150-3, Tab. 1.

Cava Spaccaroccia
Comune di Valcannuta (CN)
Punto di misura 1 - Casa Bianchi
- - -
Percorso sismico .... m
Carica massima cooperante .... MJ

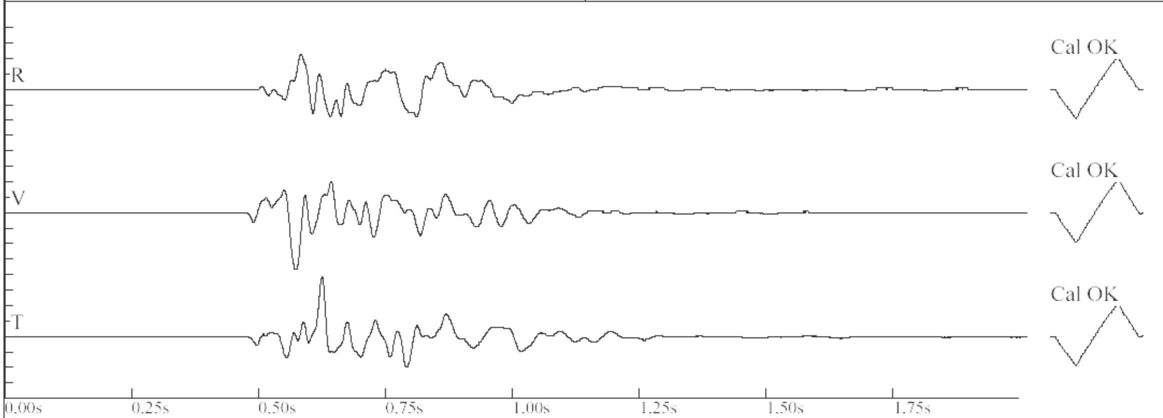
Nome archivio: GEMMA003.DTB
Numero: 003
Data: 15.10.2003
Orario: 15:55
Numero di serie: 2704
Trigger sismico: 0,0400 in/s 1,0160 mm/s
Trigger acustico: 142 dB
Frequenza di campionamento: 1024
Durata registrazione: 4,0 Seconds
Pre trigger: 0,50 Seconds
Guadagno del sensore: 2x
Batteria: 6,9

Amplitudes and Frequencies

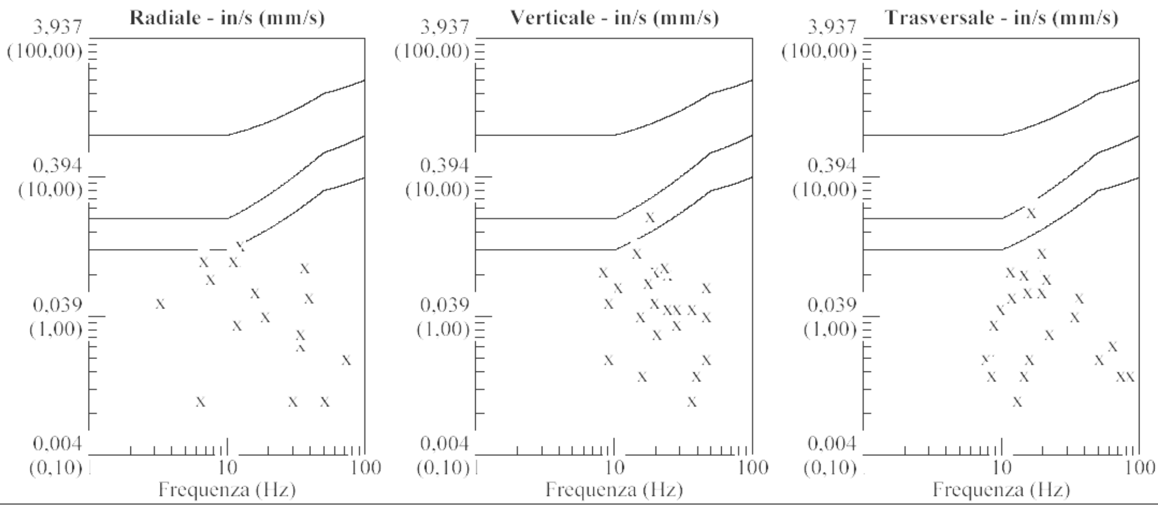
Radiale: 0,13in/s 3,302mm/s @ 12,4Hz
Verticale: 0,21in/s 5,334mm/s @ 18,2Hz
***Trasversale:* 0,225in/s 5,715mm/s @ 17,0Hz**
Spostamento: 0,002453in 0,062301mm
Accelerazione: 0,079503g's
Data di calibrazione: 26.09.2003

Graph Information

Durata: 0,000s To: 1,996s
Fondoscala sismico:
0,23in/s (0,058in/s/div) 5,84mm/s (1,461mm/s/div)
Linee marcatempo ad intervalli di: 0,25 s



UNI 9916 - DIN 4150-3 tabella 1



Values of the vibrations to respect for constructions, as in DIN 4150-3, Table 3

Reference speed of oscillation only for the horizontal component

Line	Tubing material component	Oscillation speed reference values in mm/s on the tubing
1	Constructions for commercial activities, industrial constructions and constructions with similar structures	Last floor., horizontal. all frequencies 10
2	Dwellings or similar buildings for construction or use	5
3	Buildings that for their particular sensitivity to vibrations do not enter into the previous classifications or that are to be particularly protected (monuments under fine arts protection)	**2.5**

Form for rapid acquisition of data for RESIDENTIAL BUILDINGS DATABASE – mod

Protocoò……………date………………..

BUILDING NAME…………………………………………..number……./………………………

destination of use……………………………………………………………….

locality………………………….road………………………………………….

plant……………………………………… number elevations from p.c………..

bearing structure…………………………………………………………………

static insol thermal insol acoustic insol thermal joints …………………..

cover……………………………………………………………………………..

foundations……………………………………………………………………….

sediments………………………………………………………………………….

materials…………………………………………………………………………..

………………………………………………………………………………….

state of maintenance…………………………………………………………….

…………………………………………………………………………………………

construction date………………in this case tab. 1 DIN 4150-3 line……………….

attachments:

static project, architectonic project, performance project, ,geological report,

geo-technical report, state of detection of cracks, …………………………………

NOTES…………………………………………………………………………………….

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

Drawn up by……………….

Calculation of the SCALED DISTANCE ON THE EXPLOSIVE CHARGE

To be able to show the amplitude of the vibrations in function of the distance from the explosion point and the explosive charge in a bi-dimensional graph, it is necessary to “condense” distance and charge into a single value, “the scaled distance on the charge” DS.

The charge can be considered in its characteristic amount of weight (in kg) or in the case in which it is necessary to have better representation of the measured data for comparing various types of different explosives in their characteristic total amount of explosive energy (in MJ).

Example of calculating the scaled distance DS (equation**) for a mine hole charged with two different types of explosive:**

Distance of the measurement point from explosion point R = 140 m

Type of explosive used and its specific explosive energy

Foot charge: Emulsion “XXYYZZ” - spec. energy 4.1 MJ/kg

Column charge AN;FO “AABBCC” – spec. energy 3.3 MJ/kg

(The data on the total explosive energy are shown on the PRODUCT FORM and the safety data forms).

Quantity of explosives used:

Foot charge: Emulsion “XXYYZZ” 25 kg

Column charge: AN;FO “AABBCC” 75 kg

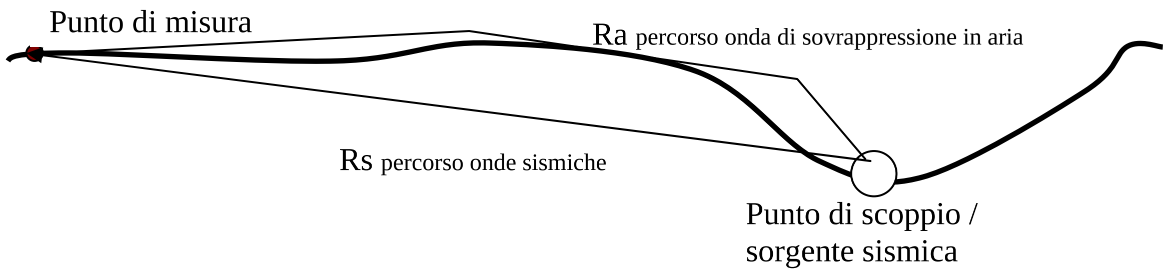
(Total charge in hole : 25 + 75 = 100 kg)

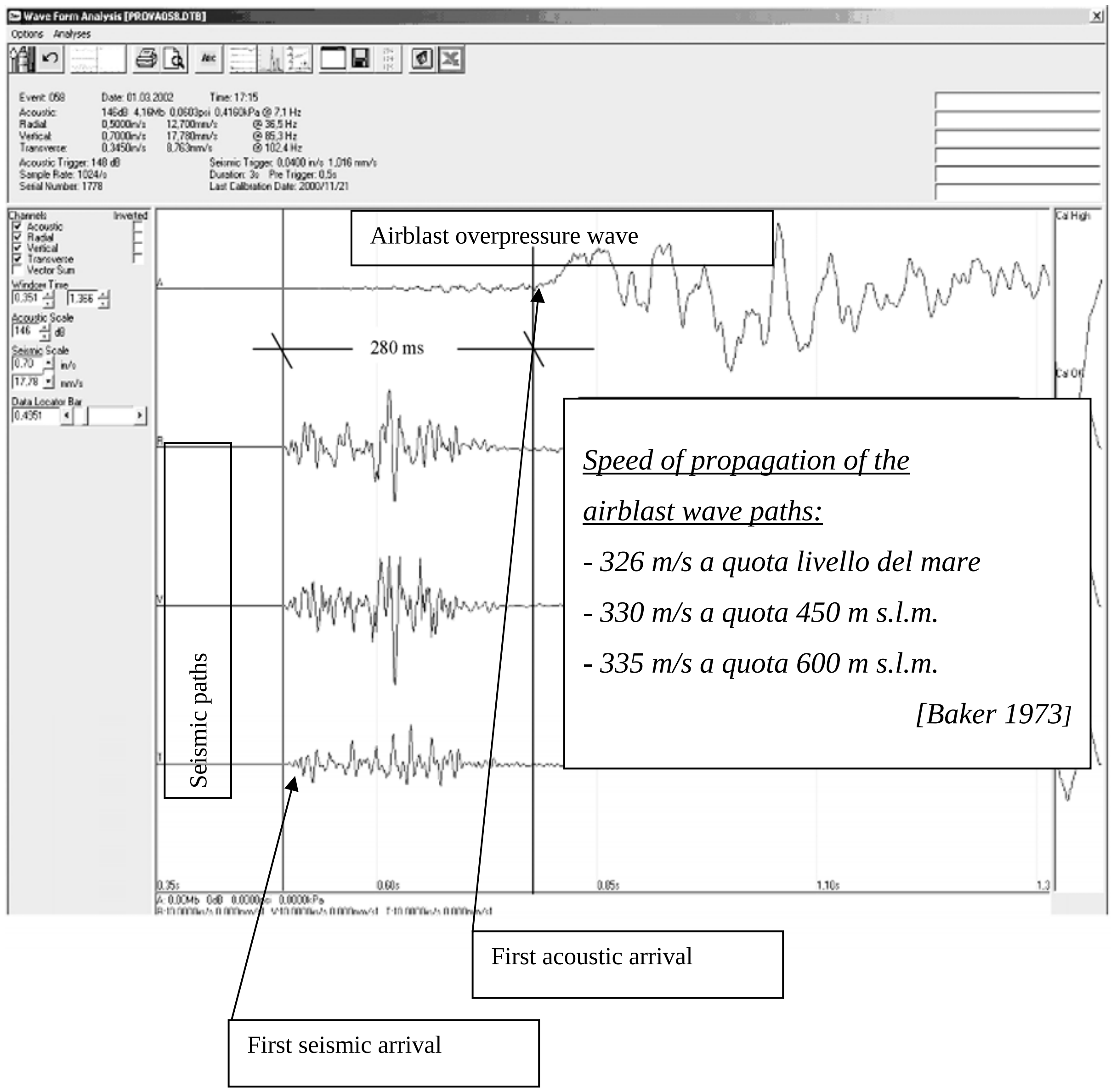
Explosion energy of charge Q = 25 kg x 4.1 MJ/kg + 75 kg x 3.3 MJ/kg = 350 MJ

Scaled distance on the square of the charge:

$DS = R/Q^{0,5} = 140\ m / (350\ MJ)^{0,5} = 7,4833 = 7,5\ m/MJ^{0,5}$

Estimate of the DISTANCE BETWEEN THE EXPLOSION POINT AND THE MEASUREMENT POINT between the first seismic and acoustic arrival





Example of calculating the estimate of the speed of propagation of the surface seismic waves once noted:

- VEL_a = speed of propagation of airblast overpressure waves: 330 mls
- R_s = seismic path: 115 m
- R_a = acoustic path: 105 m
- $\Delta t = t_a - t_s$ = interval time between the first seismic and first acoustic arrival : 280 ms (see figure)

<u>VEL_s = speed of the surface seismic waves</u>
From the instant of energizing the surface seismic waves will take the time to cover distance R_s at VEL_s speed
$VEL_s = R_s/t_s$
(In the absence of a trigger seismograph at the source the time is not noted, as in the case of the graph of the figure) and a t_s time to cover the distance R_s at the speed of VEL_a
$VEL_a = R_a/t_a$
$t_a = R_a/ VEL_a$ = 105 m / 330 m/s = 0.318 seconds
$\Delta t = t_a - t_s$ = 280 ms = 0.280s
0.3182 - t_s =.0.280s
t_s = 0.318 - 0.280s = 0.038s
$VEL_s = R_s/t_s$ = 115m / 0.038s = 3026 m/s approximated to 3,000 m/s (approximated to ±10%)

Estimate of calculating the distance of the seismic source from the measurement point (seismic path) once noted:

- VEL_a = speed of propagation of airblast overpressure waves: 330 m/s
- VEL_a= speed of propagation of surface overpressure waves: 3,000 m/s (e.g. calculated as above from a first measurement for which the seismic path has been measured with sufficient approximation)
- R_s / R_a = relation between seismic path and path:1 (or 0.95 or as likely from the surrounding morphology)
- $\Delta t = t_a - t_s$ interval time between the first seismic and first acoustic arrival: 564 ms

<u>R_s = Seismic path</u>

$R_a = VEL_a \cdot t_a = R_s$
$R_s = VEL_s \cdot t_s = 3{,}000.\ t_s$
$\Delta t = t_a - t_s$
$t_a = \Delta t + t_s = 0.564 + t_s$
$Vel_a \cdot t_a = R_s = 330 \cdot (0.564 + t_s) = 186.12 + 330 \cdot t_s$
$186.12 + 330 \cdot t_s = 3{,}000 \cdot 330\ t_s$
$186.12 = 3{,}000 \cdot t_s - 330 \cdot t_s = (3{,}000 - 330) \cdot t_s$
$186.12 / (3{,}000 - 330) = t_s = 0.0697$ s
$R_s = VEL_s \cdot t_s = 3{,}000 \cdot t_s = 3{,}000 \cdot 0.0697$ s = 209 m approximated to 210 m
(approximated to ±10%)

Example of DISTRIBUTING THE SEISMIC MEASUREMENT POINTS for the reconstruction of oscillatory phenomenon - rec. NTX

General

The movement of the ground can be divided into the sum of three vectors perpendicular to each other, however orientated. In practice, the vibratory movement is divided into its vertical, “V”, its longitudinal horizontal “L” and radial R” components with respect to the direction of propagation of the transient wave (or rather, coinciding with the upright that passes between the seismograph and the explosion point), and the horizontal transversal “T”. When the study is aimed at the structural response of a building, the axes can be distinguished by H1, H2 and V with H1 and H2 orientated parallel to the main axes of the structure.
The variation in the value of the characteristic peak of the movement for each of the three components has posed the problem of identifying the most important component. The horizontal movement seems to control the horizontal response of the masonry and high structures and the vertical movement seems to control the vertical response of the floor. In an absolute sense the value of the peak movement of the ground and consequently the deformation of the ground is the maximum vector sum of the three components, and this sometimes takes place in coincidence with the maximum value among the three components. This is the value of the vector speed of the particles of ground at the passage of the transient seism, not to be confused with the maximum pseudo-vector (used in the past when the lack of a digital recording system did not allow the precise reconstruction of the vector speed of vibration), which is calculated as the vector sum of maximum values for each component, independent of the instant in which these values take place. The maximum pseudo-vector can be up to 40% higher than the maximum vector that, in its turn, is usually 5%÷10% greater than the highest value among the three components. The experimental observations value beyond which the rise of cosmetic fractures is detected, which are at the basis of controls carried out in North America, have been correlated with the maximum value of each component, independent of their orientation. The use of the maximum pseudo-vector no longer, therefore, provides a justified high margin of safety.

Placing the measurement points and the number of measurements needed

If a critical point is noted in a structure the after-effect induced in the structure must be preferably measured at that specific point (e.g. particularly extensive and thin plugging, shelves, etc.). The speed of the particles can also be measured outside the structure (as suggested in the USA) or on the foundations (as suggested in Europe). Even if the minimum number of instruments, or rather the points of tri-axial measurement in recording the stress induced by setting off an explosion is equal to one it is also true that two measurement points provide a greater description of the spatial variation of the effects induced. Two or more synchronized measurement also allows the calculation of the speed of propagation of the seismic impulse in the surface formation.
If only one instrument is used it must be placed at the nearest or most delicate point.
This single instrument must record the particle speed of the three components at the passage of the transient seism and the airblast overpressure wave. The instrument must carry out a continuous check in the expectation of the event, therefore

it should be triggered on the minimum threshold of intensity of amplitude beyond which the phenomenon becomes of interest. Above all, it should also be able to record while printing or communicating the results of the previous measurement. When the explosion takes place in more than one place, or rather when it interests various structures sited at hundreds of meters distant from each other, then the minimum number of measurement points become equal respectively to two and four. An additional instrument available in case of damage to the others ensures continuous control in case of breakdown.

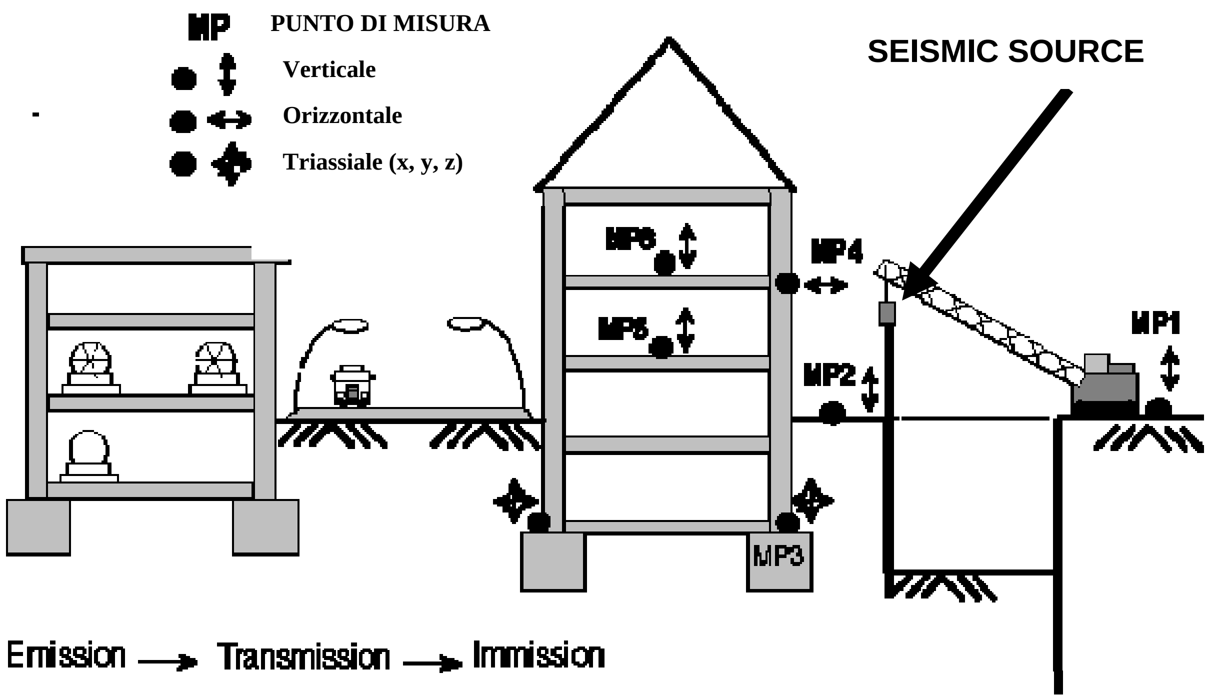
A greater number of instruments might, in any case, be requested for applying specific mining regulations or for respecting the work program. A greater number of instruments might be required for local responses in addition to the measurement of the induced stress.

Positioning the instruments in the test explosion phase

The choice of the point at which to position the instrument should be aimed at the rapid definition of the parameters characteristic of the declining curve of the seismic wave and the overpressure of the airblast wave. These parameters (intercept the exponent, coefficient of correlation and variance of the various perimeters, etc.) vary from site to site and are functions of the geology and the parameters characteristic of the blast.
It is also possible to identify from the test explosions the frequencies associated with to the transient seism induced for various scaled and absolute distances.

A minimum of four monitoring stations should be used during the testing phase, positioned along a direction at various real and scaled distances. In this way the parameters and the sequence of priming the charges will remain constant for each blast and the resultant laws of attenuation will show only the effects of the distance, the direction and/or the geology. The geophones should be aligned on a constant geology to determine the attenuation report better or should be placed near all the critical structures to determine the effects induced by the direction and with variable geology. The optimal alignment should be along a path with a constant thickness of formation and not through geological discontinuities such as faults. If the geology changes greatly it then becomes necessary, but not for all explosions, to measure the attenuations on two or more alignments along the direction of the tectonic-geological continuity.

E.g. ENERGIZING OF MECHANICAL ORIGIN: vibrodine for driving in sheet piling



Vibration values to respect – rec. UNI 9614

The human body is a good detector of vibrations but not a “measurer”, it is therefore rare, and engineering practice confirms, that vibrations able to guarantee the avoidance of damage in buildings are accepted without protests or complaints.

Generally, protests as a result of work that provokes vibrations are based upon motives exquisitely psychological. The sole vibration of the panes of a window considered normal and accepted if caused by wind or traffic, evokes apprehension and certainty of the existence of damage when linked to the blast of an explosive charge, excavations with demolition hammers or, more generally, activities that are outside the field of experience of the normal citizen.
Cases are not rare in which people residing around the areas where work that causes vibrations is being carried out start reckless quarrels or complaints without providing any technical evidence of the phenomenon that they accuse of causing unease.

The values to make reference to for guaranteeing levels of tolerability of vibrations such as those caused by excavation work can be taken for reference from the UNI 9614 regulations and shown in the following tables.

Limit values of acceptability of vibrations for people in the constructions
(overall acceleration weighted in frequency)
are valid for not more than three repetitions daily of the oscillatory event

	vertical component (z= passage for coccyx and head) mm/s^2	Horizontal component (x passage for back and chest) (y = passage for the two shoulders) mm/s^2
critical* areas	$5.0\cdot10^{-3}$	$3.6\cdot10^{-3}$
dwelling (day)**	0.30	0.22
offices and factories	0.64	0.46
(*) hospital operating theatres, local laboratories in which delicate manual work is carried out, etc. (**) from 7.00 a.m. to 10.00 p.m.		

(it is essential to study the reference regulations in depth to deal with the problem of disturbance.)

DISTURBANCE PRODUCED BY VIBRATIONS

Subjective response of the human body to a vibratory movement – model

(Goodman 1948)

Graphic

EXPLOSIVES: specific energy of explosion and other characteristic data

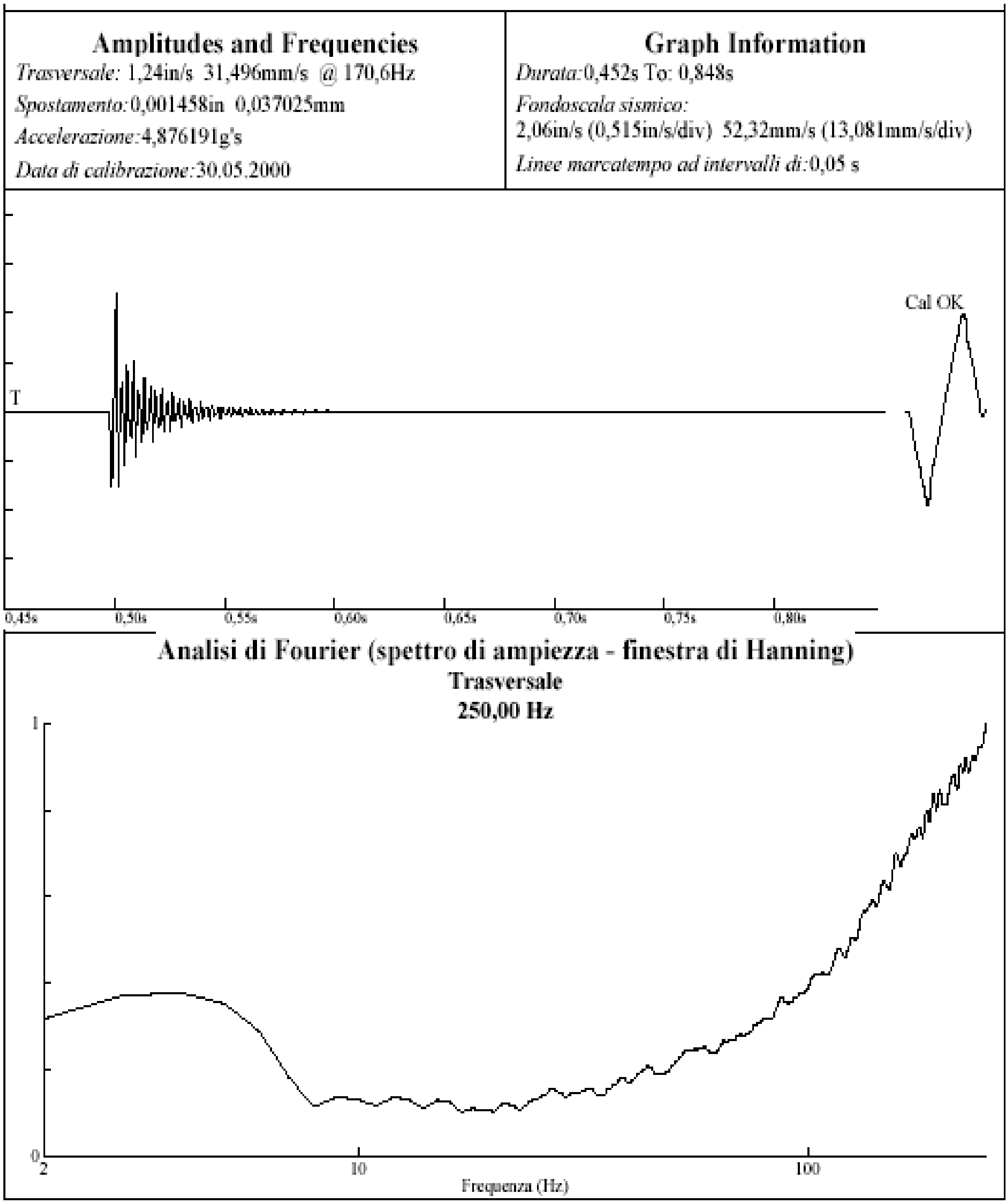
(Tabella)

Commercial name/ NAME OF SUBSTANCE	total energy* (MJ/kg)	density* (kg/cm²)	detonation speed* km/s
AN-FO 4	3,2	0,80	3,0
AN-FO 5	3,7	0,80	3,1
Cava 1a	3,5	1,00	4,1
Cava 2a	4,0	1,10	4,9
Emulgit 42 G	3,6	1,12	4,3
Emulgit 82 GP	4,4	1,20	4,1
Emulgit LWC AL	4,4	1,15	3,6
Emulgit RPT	3,0	1,10	4,5
Gelatina 1	5,5	1,45	6,6
Gelatina 2	4,4	1,42	6,1
Hanal 1 U	4,0	0,75	3,3
Nitram TX1	3,3	1,20	5,5
Nitram TX5S	3,5	1,20	5,5
Nitram TX9	4,0	1,20	5,5
Paxit	4,4	1,00	3,9
PENTRITE	5,8	1,77	8,4
Premex 2300	3,3	1,15	5,5
Premex 831	4,1	1,20	5,2
Premex 851	4,3	1,25	4,8
Prillex 1	3,1	0,98	3,8
RDX / T4	5,7	1,90	8,0
Semtex 1A	5,0	1,42	7,2
Sigma 605	4,1	1,15	5,0
TNT - trinitrotoluene	4,5	1,60	6,7
TRITONAL	7,8	1,72	---
Tutagex 121	3,1	1,20	4,8
Tutagex 331	3,1	1,21	4,2
Tutagex 821	4,3	1,14	4,4
Tutagex 831	3,9	1,12	4,8
Tutagex 851	4,0	1,30	5,4
Walonit W	4,4	0,90	3,5

- value declared by the producer

Characterizing measurement point 1 - at plate clamped to the bedrock

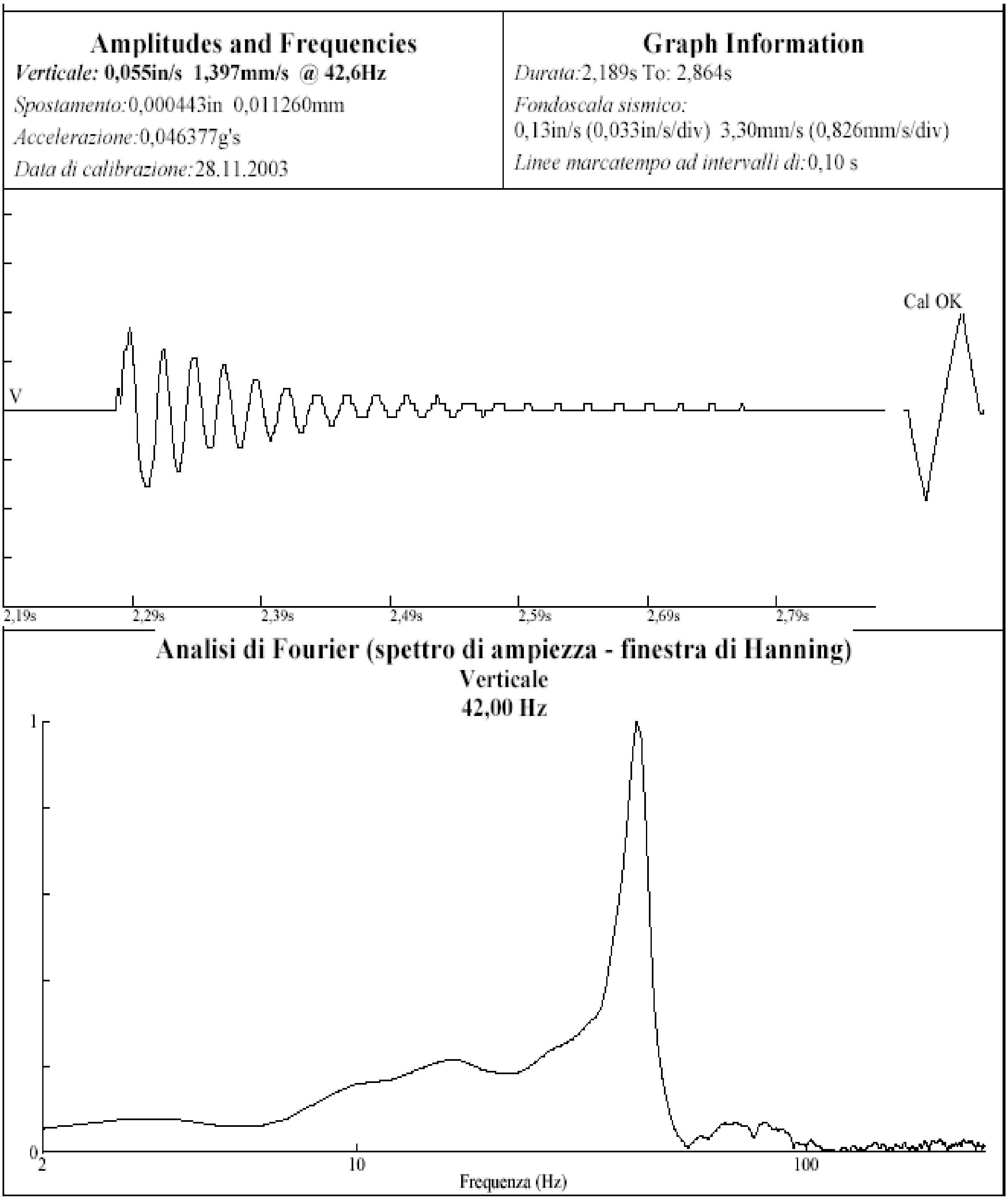
The measurement system is suitable for the transversal direction because its characteristic frequencies are much greater than those of the seism to measure (around 50 Hz).



GRAPH OF SEISMIC EVENTS

Characterizing measurement point 2 – on level structural element

Not suitable in transversal direction, frequencies are comparable to that of the seism to measure (around 50 Hz).



GRAPH OF SEISMIC EVENT

Demolition 1 – demolition of silos with alveolar structure in reinforced concrete with thin walls - charges in water.

Geophone clamped to the structure, measurement in a residential building at 30 m distant

Photos

Amplitudes and Frequencies

Acustico: 142 dB @ 170,6 Hz
(2,56Mb 0,0371psi 0,2559kPa)

Radiale: 0,48in/s 12,192mm/s @ 7,0Hz

***Verticale:* 1,16in/s 29,464mm/s @ 9,6Hz**

Trasversale: 0,22in/s 5,588mm/s @ 13,1Hz

Spostamento: 0,020904in 0,530951mm

Accelerazione: 0,516770g's

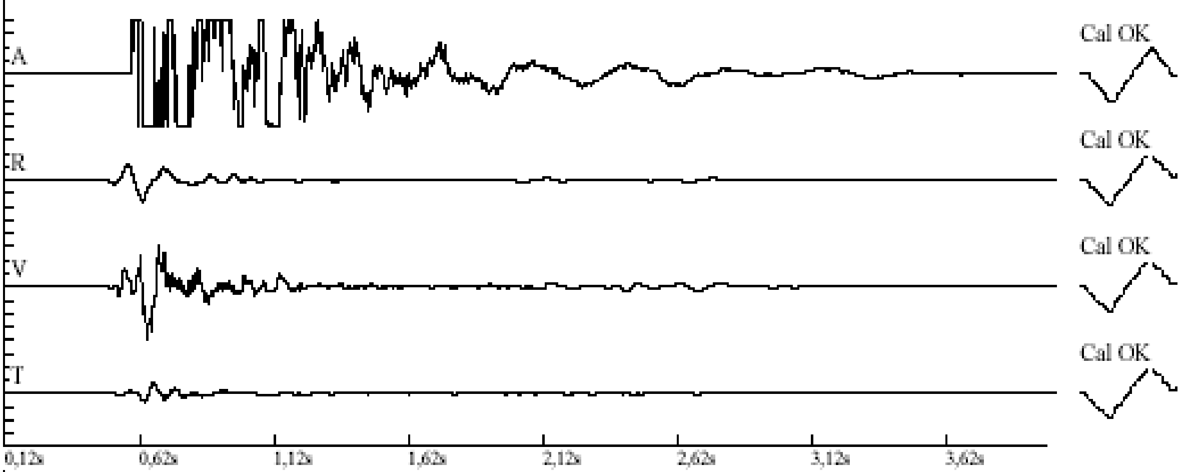
Graph Information

Durata: 0,121s To: 3,998s

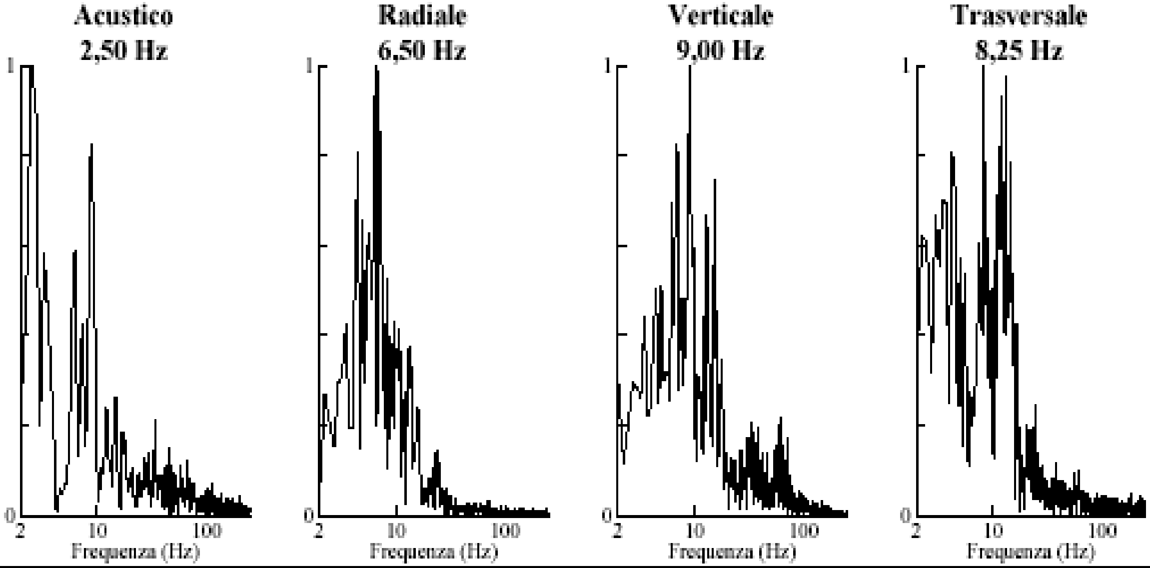
Fondoscala acustico:
142dB 2,52Mb (0,629Mb/div)

Fondoscala sismico:
1,16in/s (0,290in/s/div) 29,46mm/s (7,366mm/s/div)

Linee marcatempo ad intervalli di: 0,50 s



Analisi di Fourier (spettro di ampiezza - finestra di Hanning)



GRAPH OF SEISMIC EVENTS

Demolition 2 - impact on ground of 3 industrial buildings with the same blast.

Measured at 60 meters distance from the first (25 meters high), 36 meters from the second (60 meters high) and 45 meters from the third (16 meters high).

Photos

Amplitudes and Frequencies

Acustico: 148 dB @ 46,5 Hz
(5,12Mb 0,0742psi 0,5119kPa)

Radiale: 0,135in/s 3,429mm/s @ 9,1Hz

***Verticale:* 0,55in/s 13,97mm/s @ 9,8Hz**

Trasversale: 0,09in/s 2,286mm/s @ 8,1Hz

Spostamento: 0,008221in 0,208810mm

Accelerazione: 0,125880g's

Data di calibrazione: 16.04.1998

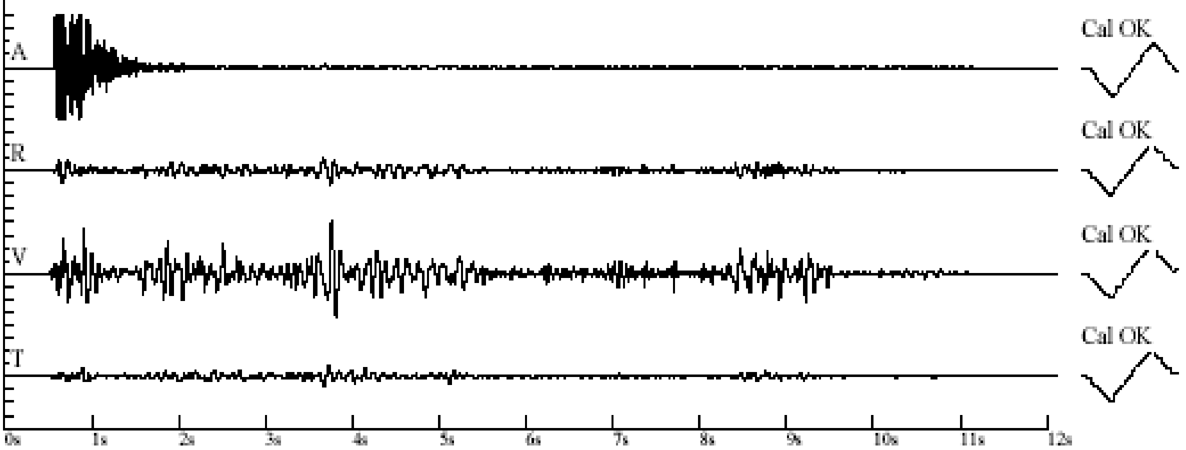
Graph Information

Durata: 0,000s To: 12,017s

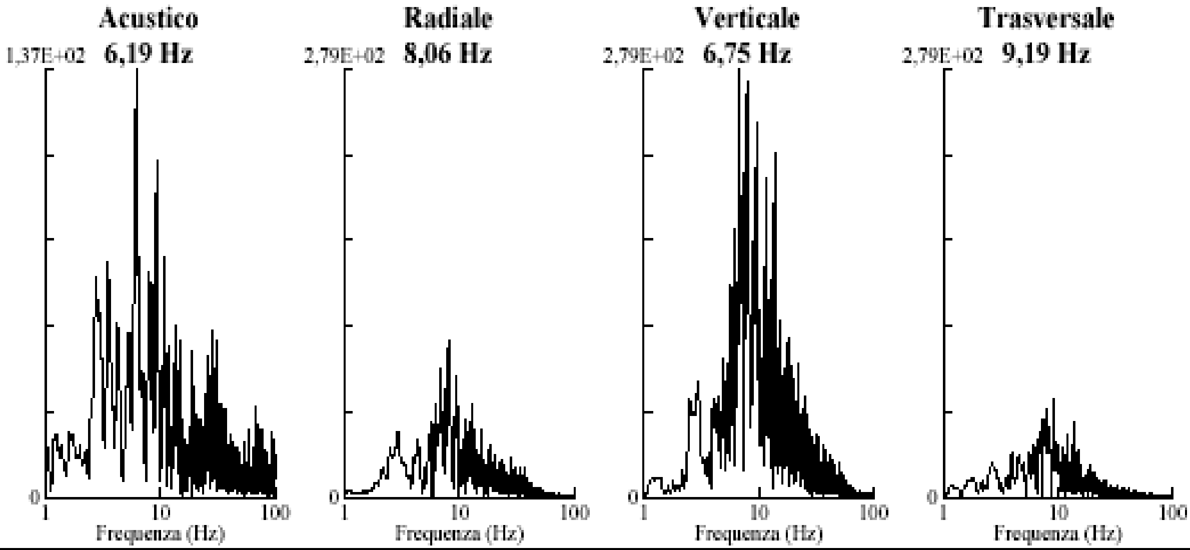
Fondoscala acustico:
148dB 5,02Mb (1,256Mb/div)

Fondoscala sismico:
0,46in/s (0,115in/s/div) 11,68mm/s (2,921mm/s/div)

Linee marcatempo ad intervalli di: 1,00 s



Analisi di Fourier (spettro di potenza - finestra di Hanning)



GRAPH OF SEISMIC EVENTS

Demolition 3 – underwater demolition of a wall in cls.

Measurement at 20 meters on a dock. Seism induced for the seismic wave (at higher frequency) and for the overpressure wave in water (at lower frequency, quasi-sinusoidal wave).

Photo

Amplitudes and Frequencies

Acustico: 100 dB @ 0,0 Hz
(0,02Mb 0,0003psi 0,0020kPa)

Radiale: 0,50in/s 12,70mm/s @ 3,3Hz

***Verticale:* 0,60in/s 15,24mm/s @ 3,7Hz**

Trasversale: 0,20in/s 5,08mm/s @ 341,3Hz

Spostamento: 0,025515in 0,648086mm

Accelerazione: 1,537060g's

Data di calibrazione: 08.12.2004

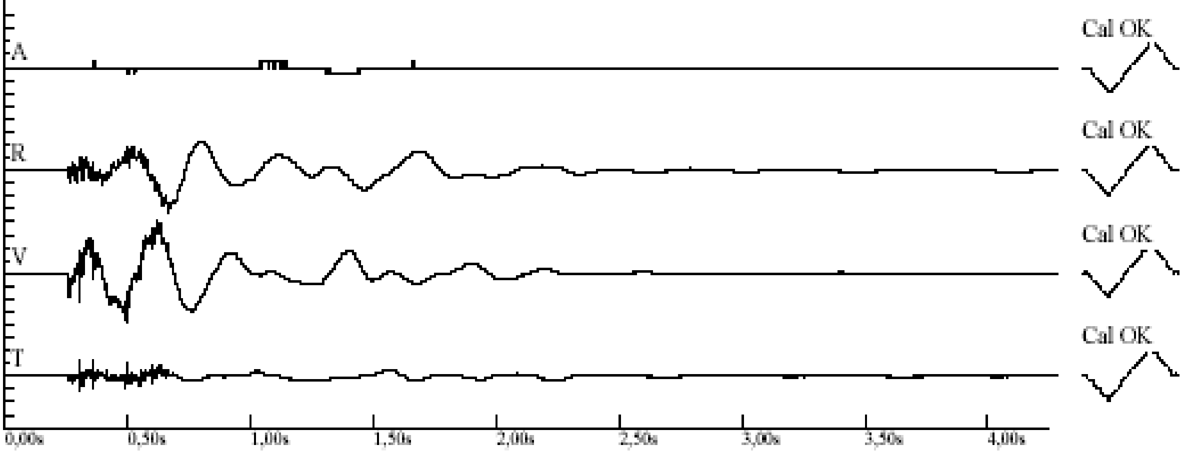
Graph Information

Durata: 0,000s To: 4,250s

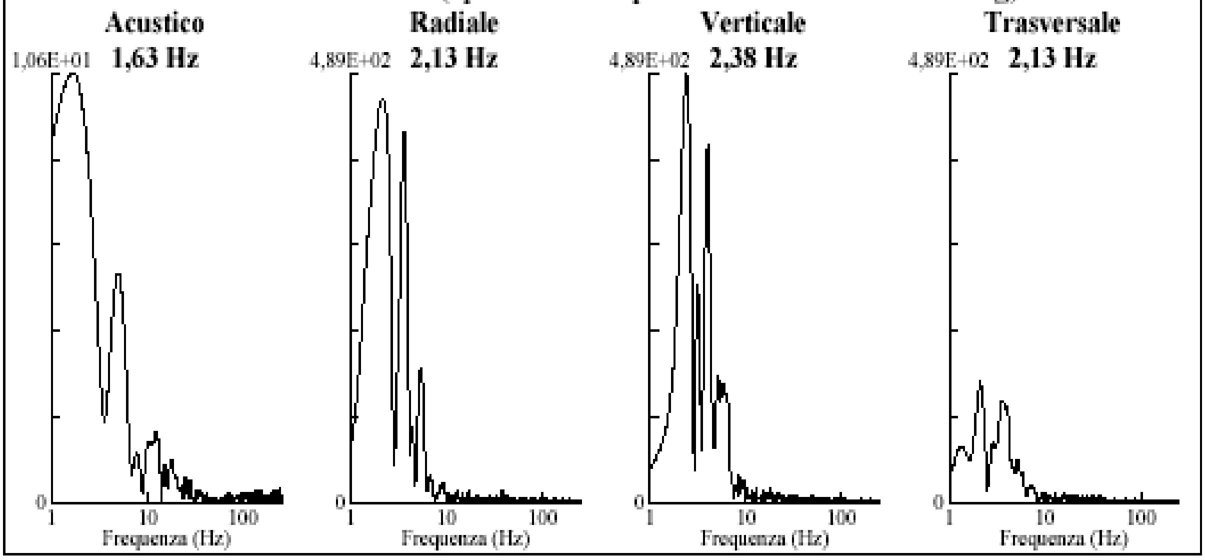
Fondoscala acustico:
120dB 0,20Mb (0,050Mb/div)

Fondoscala sismico:
0,60in/s (0,150in/s/div) 15,24mm/s (3,810mm/s/div)

Linee marcatempo ad intervalli di: 0,50 s



Analisi di Fourier (spettro di ampiezza - finestra di Hanning)

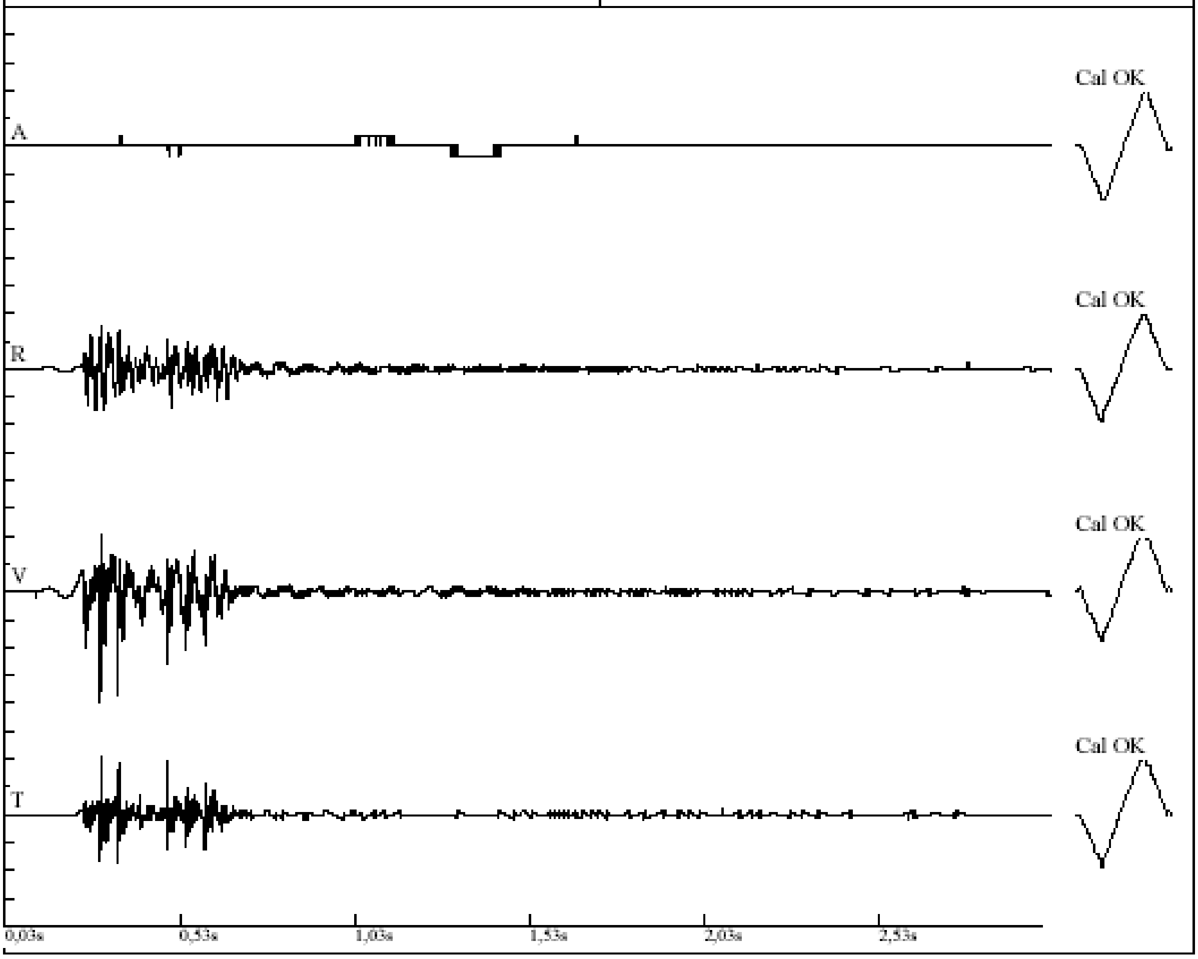


GRAPH OF SEISMIC EVENT

Demolition 3 - underwater demolition of a wall in cls - seismic component propagated on ground

Filtered: below the seismic frequencies - 10 Hertz

Amplitudes and Frequencies	Graph Information
Acustico: 100 dB @ 512,0 Hz (0,02Mb 0,0003psi 0,0020kPa)	*Durata:* 0,029s To: 2,998s
Radiale: 0,145in/s 3,683mm/s @ 102,4Hz	*Fondoscala acustico:* 120dB 0,20Mb (0,050Mb/div)
***Verticale:* 0,38in/s 9,652mm/s @ 204,8Hz**	*Fondoscala sismico:* 0,38in/s (0,095in/s/div) 9,65mm/s (2,413mm/s/div)
Trasversale: 0,20in/s 5,08mm/s @ 341,3Hz	*Linee marcatempo ad intervalli di:* 0,50 s
Spostamento: 0,025515in 0,648086mm	
Accelerazione: 1,537060g's	
Data di calibrazione: 08.12.2004	

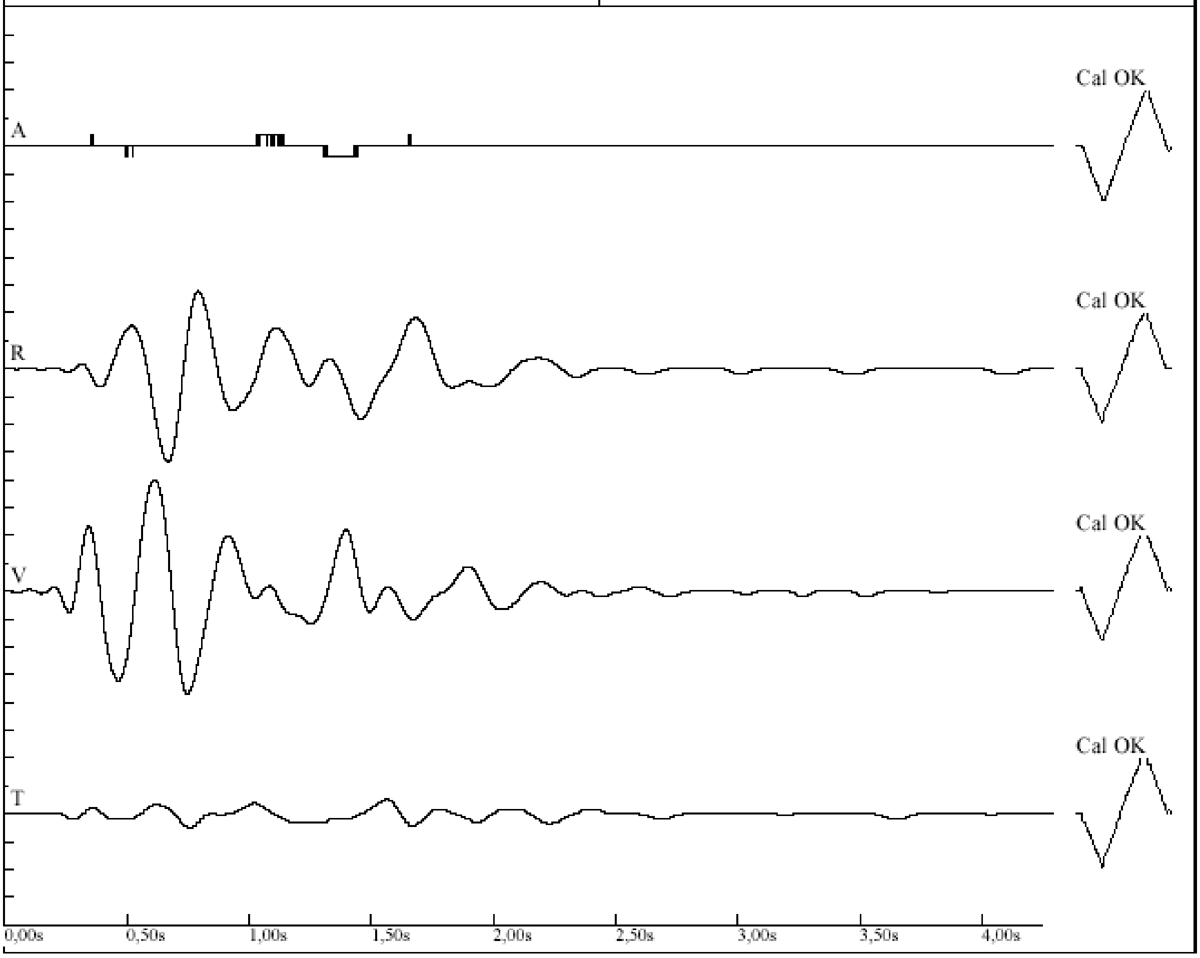


GRAPH OF SEISMIC EVENT

Demolition 3 - underwater demolition of a wall in cls - seismic component propagated in water

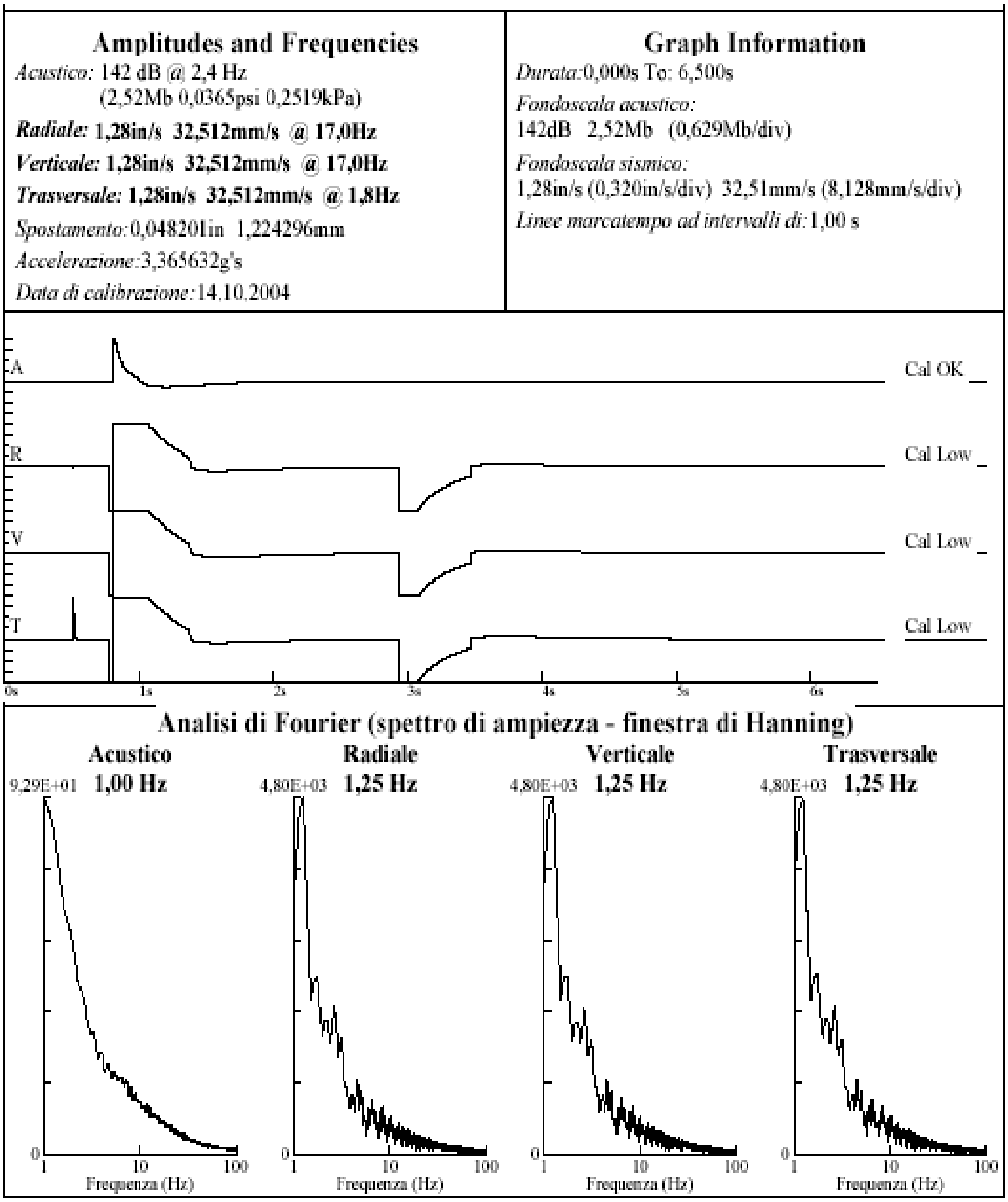
Filtered: above the seismic frequencies - 10 Hertz

Amplitudes and Frequencies	Graph Information
Acustico: 100 dB @ 512,0 Hz (0,02Mb 0,0003psi 0,0020kPa)	*Durata:* 0,000s To: 4,250s
Radiale: 0,405in/s 10,287mm/s @ 3,4Hz	*Fondoscala acustico:* 120dB 0,20Mb (0,050Mb/div)
***Verticale:* 0,48in/s 12,192mm/s @ 3,4Hz**	*Fondoscala sismico:* 0,48in/s (0,120in/s/div) 12,19mm/s (3,048mm/s/div)
Trasversale: 0,065in/s 1,651mm/s @ 3,3Hz	*Linee marcatempo ad intervalli di:* 0,50 s
Spostamento: 0,025515in 0,648086mm	
Accelerazione: 1,537060g's	
Data di calibrazione: 08.12.2004	



GRAPH OF SEISMIC EVENT

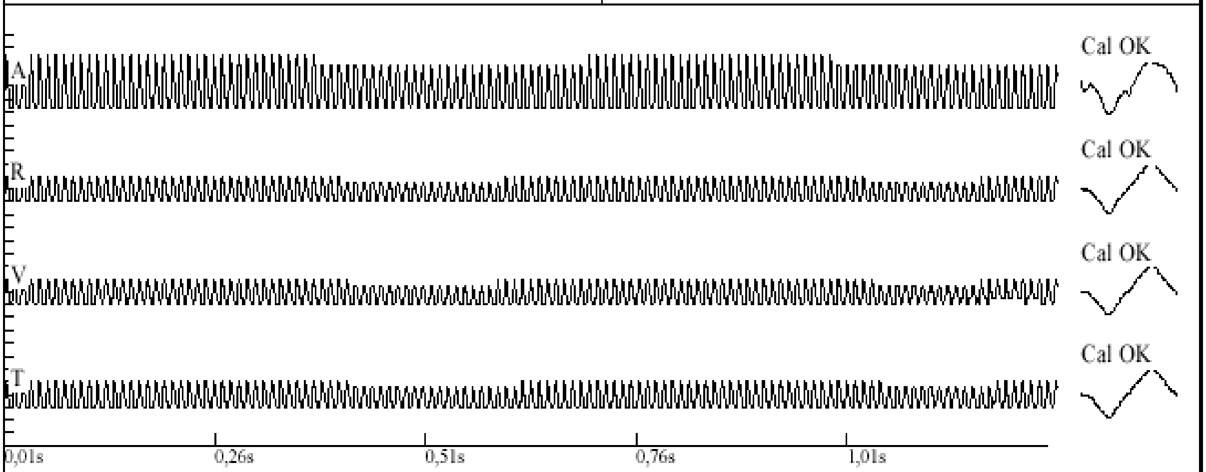
Electric disturbance 1



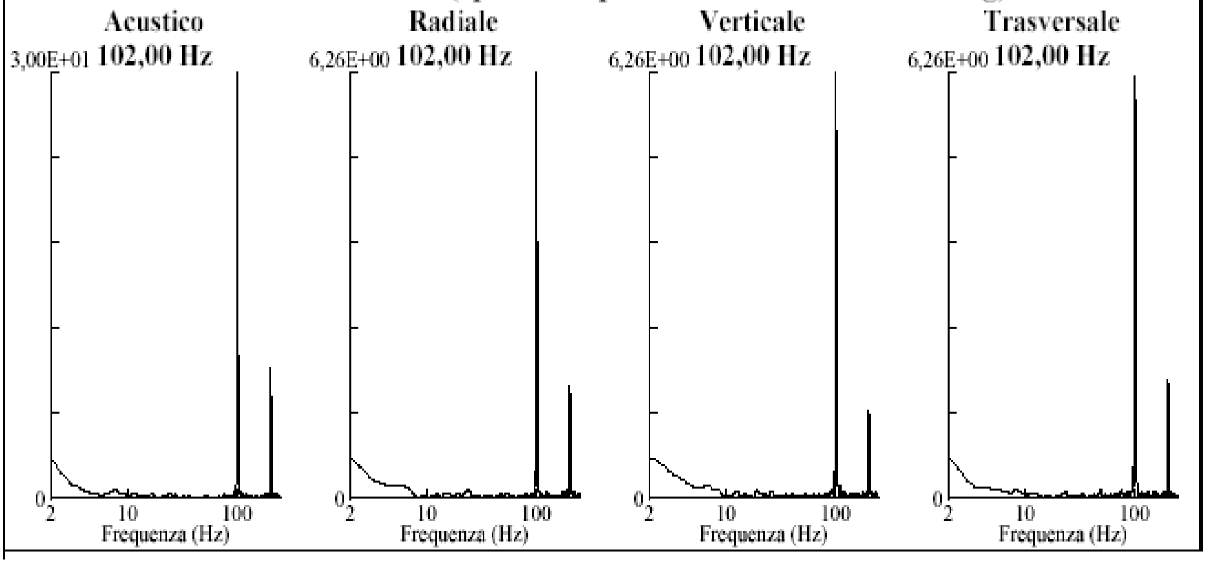
GRAPH OF SEISMIC EVENT

Electric disturbance 2

Amplitudes and Frequencies	Graph Information
Acustico: 116 dB @ 128,0 Hz (0,12Mb 0,0017psi 0,0120kPa)	*Durata:* 0,014s To: 1,252s
***Radiale:* 0,01in/s 0,254mm/s @ 0,0Hz**	*Fondoscala acustico:* 120dB 0,20Mb (0,050Mb/div)
***Verticale:* 0,01in/s 0,254mm/s @ 0,0Hz**	*Fondoscala sismico:* 0,04in/s (0,010in/s/div) 1,02mm/s (0,254mm/s/div)
***Trasversale:* 0,01in/s 0,254mm/s @ 0,0Hz**	*Linee marcatempo ad intervalli di:* 0,25 s
Spostamento: 0,000083in 0,002098mm	
Accelerazione: 0,013251g's	
Data di calibrazione: 24.05.2002	



Analisi di Fourier (spettro di potenza - finestra di Hanning)

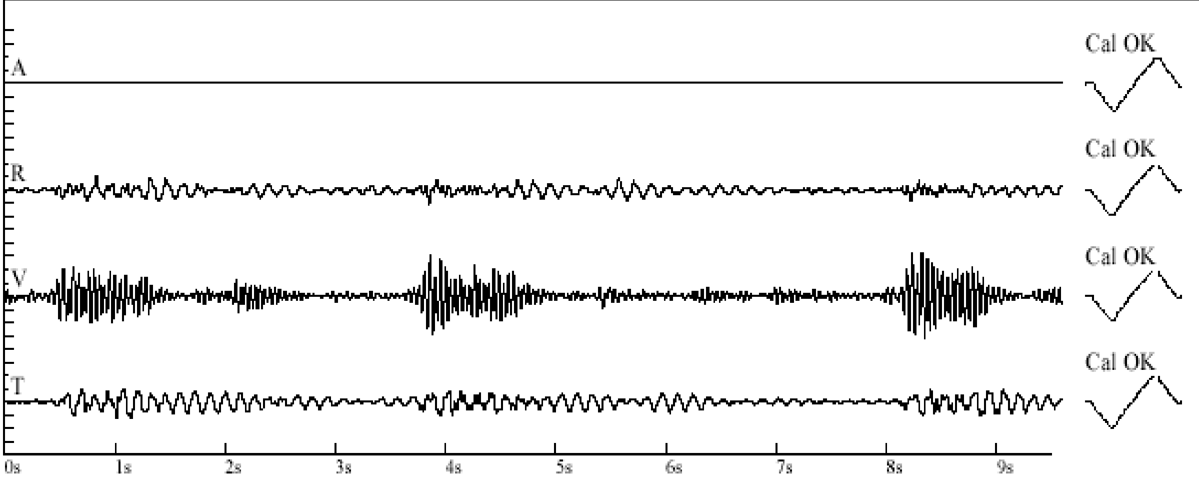


GRAPH OF SEISMS
Die-stamping hammer for mechanical pieces

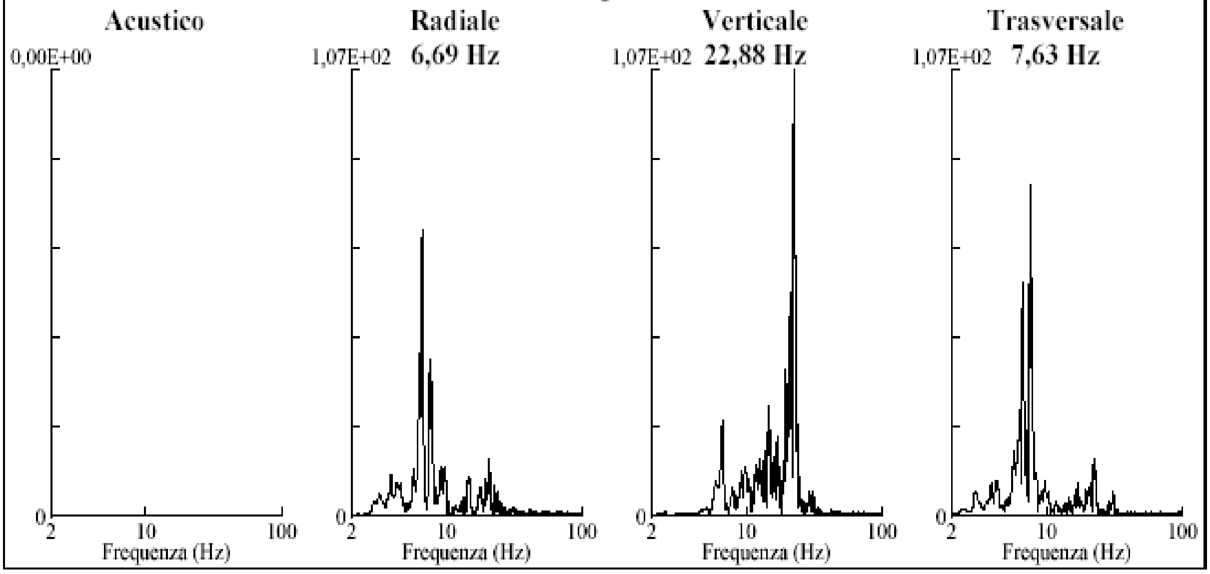
Measurement carried out on the centerline of the floor of a residential building at 70 meters. No acoustic wave was recorded.

(ILLUSTRATION)

Amplitudes and Frequencies	Graph Information
Acustico: <100 dB *Radiale:* 0,0088in/s 0,2223mm/s @ 13,4Hz ***Verticale:* 0,0238in/s 0,6033mm/s @ 19,6Hz** *Trasversale:* 0,0088in/s 0,2223mm/s @ 16,0Hz *Spostamento:*0,000222in 0,005650mm *Accelerazione:*0,008282g's *Data di calibrazione:*20.10.2004	*Durata:*0,000s To: 9,500s *Fondoscala acustico:* 120dB 0,20Mb (0,050Mb/div) *Fondoscala sismico:* 0,03in/s (0,008in/s/div) 0,76mm/s (0,191mm/s/div) *Linee marcatempo ad intervalli di:*1,00 s



Analisi di Fourier (spettro di potenza - finestra di Hanning)



GRAPH OF SEISMS

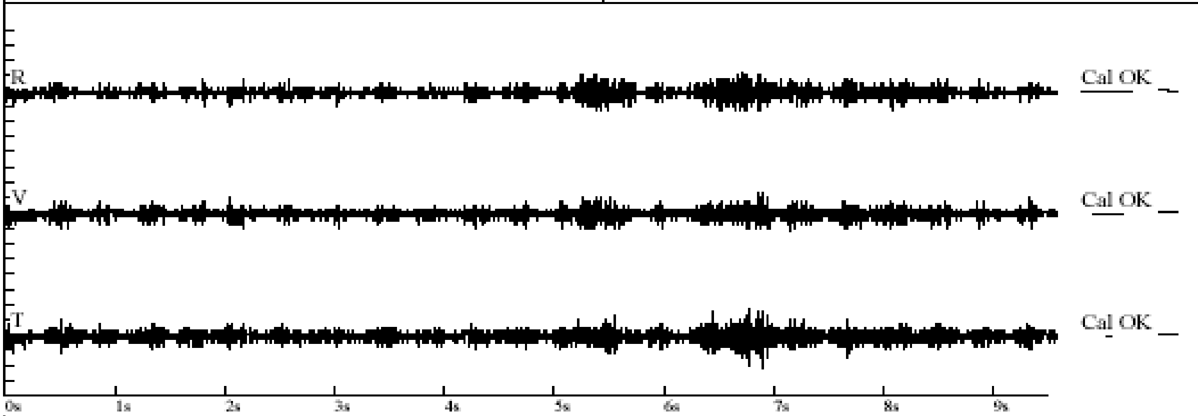
Perforation with raise borer

Measurement carried out at about 10 meters with double monitoring station, one set in "bar graphic" mode and the other in "wave form" graphic.

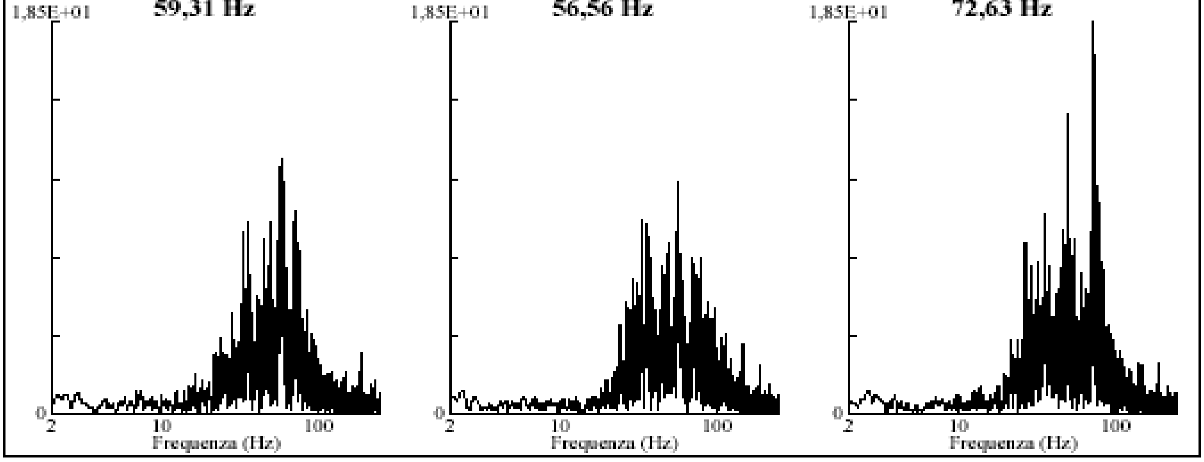
(ILLUSTRATION)

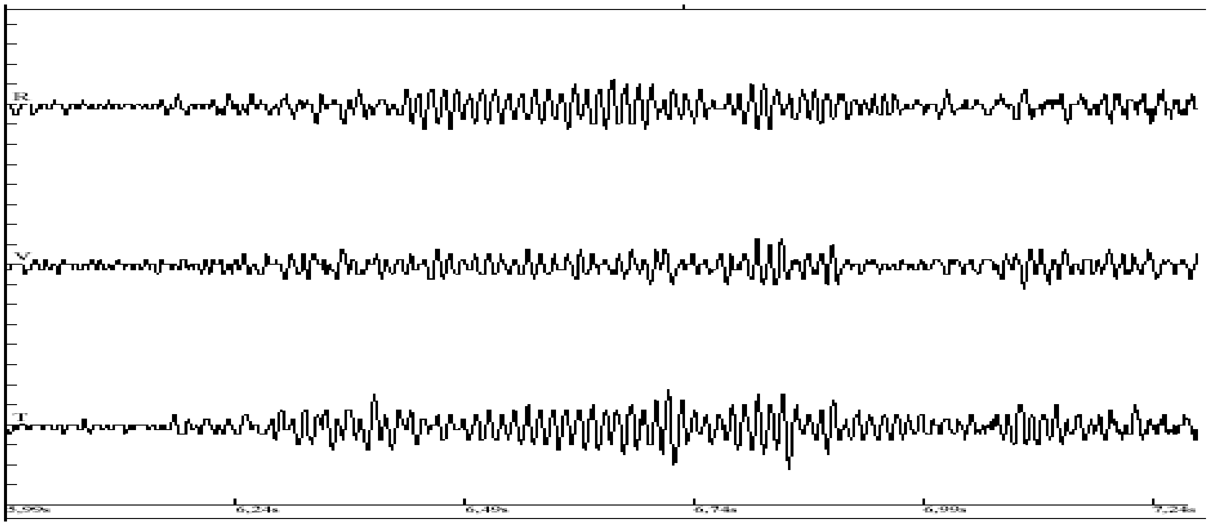
(ILLUSTRATION)

Amplitudes and Frequencies	Graph Information
Radiale: 0,0063in/s 0,1588mm/s @ 85,3Hz	*Durata:* 0,000s To: 9,500s
Verticale: 0,0063in/s 0,1588mm/s @ 102,4Hz	*Fondoscala sismico:* 0,02in/s (0,005in/s/div) 0,51mm/s (0,127mm/s/div)
***Trasversale:* 0,0113in/s 0,2858mm/s @ 64,0Hz**	*Linee marcatempo ad intervalli di:* 1,00 s
Spostamento: 0,000027in 0,000679mm	
Accelerazione: 0,013251g's	
Data di calibrazione: 14.10.2004	



Analisi di Fourier (spettro di ampiezza - finestra di Hanning)



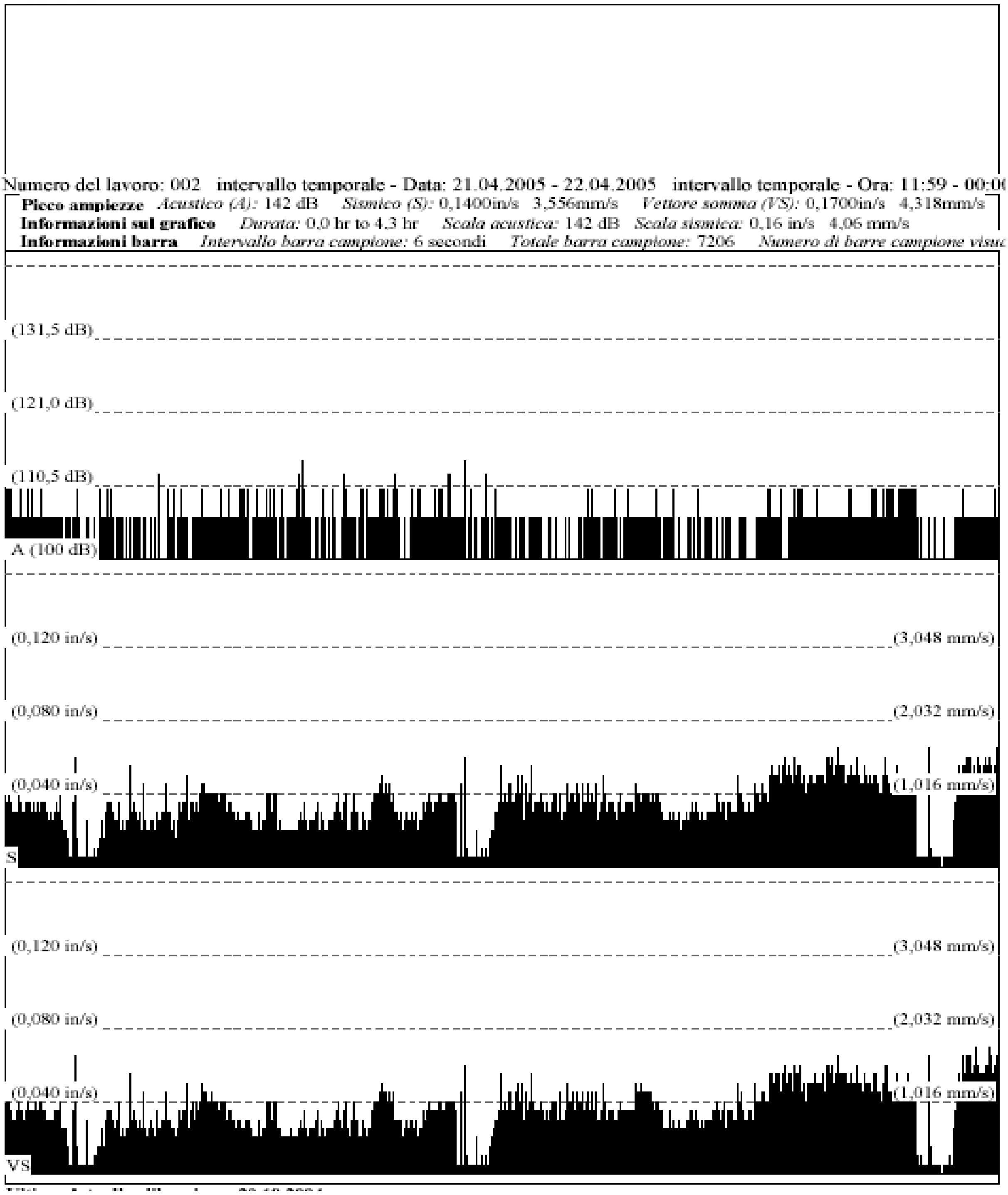


GRAPH OF SEISMS

Perforation with raise borer

Measurement carried out continuously over 4.3 hours with the bar graphic mode.

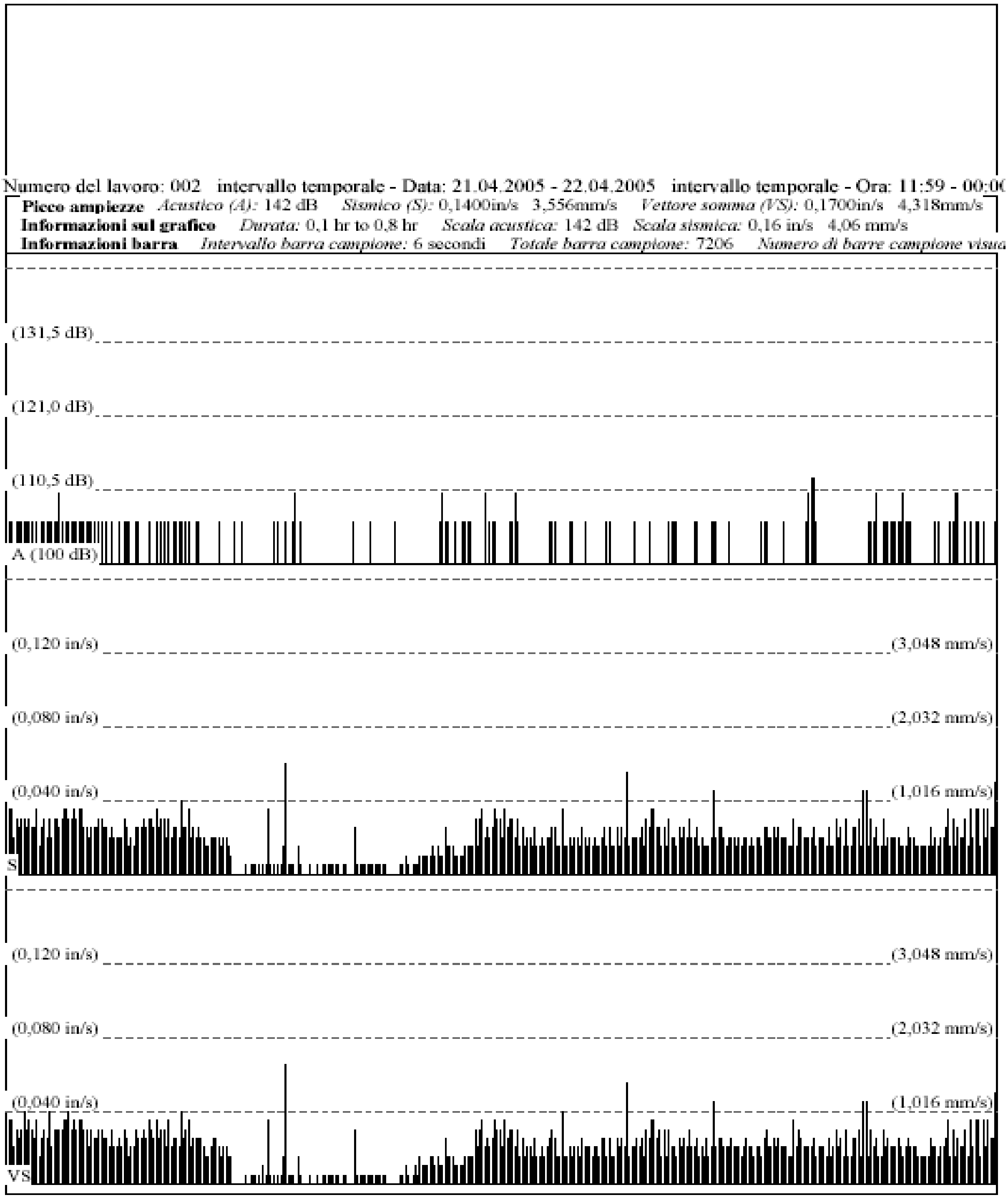
Number of work: 002 time interval - Date 21.04.2005 - 22.04.2005 time interval - 11.59 a.m. - 12.00 midnight
Amplitude peak Acoustic (A) 0.1400dB 3.556mm/s Vector sum (VS) 0.1700in/s4.318 mm/s
Information on graph :*Duration:* 0.0 hr to 4.3 hr Acoustic scale: 142dB Seismic scale : 1.16in/s 4.06 mm/s
Information bar *sample bar interval*: 6 seconds *Total sample bar:* 7206 Number sample bars viewed.



GRAPH OF SEISMS

Perforation with raise borer

Measurement carried out continuously (bar graphic mode) – detail of the representation shown above.
Number of work: 002 time interval - Date 21.04.2005 - 22.04.2005 time interval - 11.59 a.m. – 12.00 midnight
Amplitude peak Acoustic (A) 0.1400dB 3.556mm/s Vector sum (VS) 0.1700in/s4.318 mm/s
Information on graph :*Duration:* 0.01hr to 0.8 hr Acoustic scale: 142dB Seismic scale : 1.16in/s 4.06 mm/s
Information bar *sample bar interval*: 6 seconds *Total sample bar:* 7206 Number sample bars viewed.

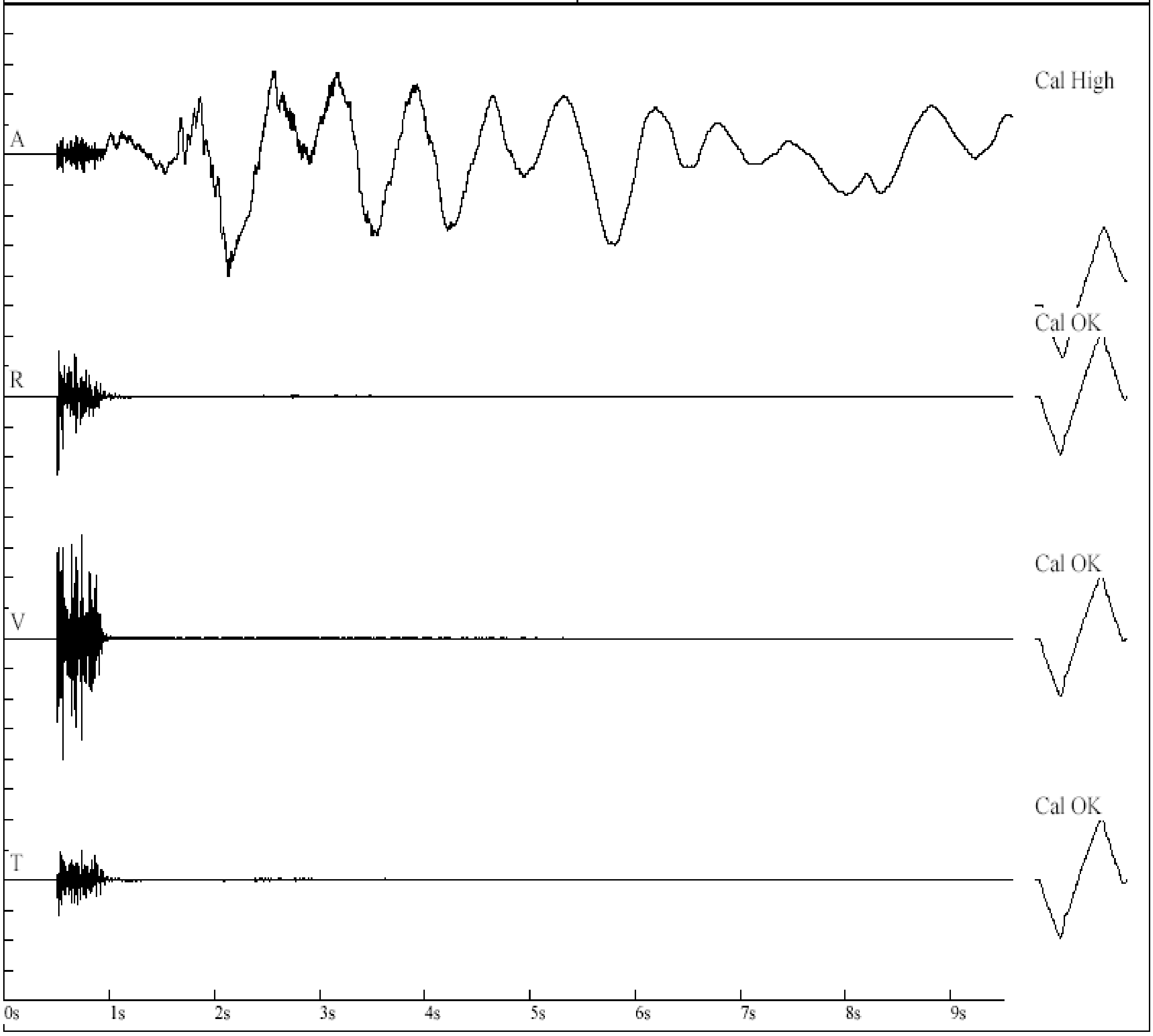


GRAPH OF SEISMS

Sublevel stopping - demolition underground with ray perforation - measured with geophone at bottom of the hole (DTH).

(ILLUSTRATION)

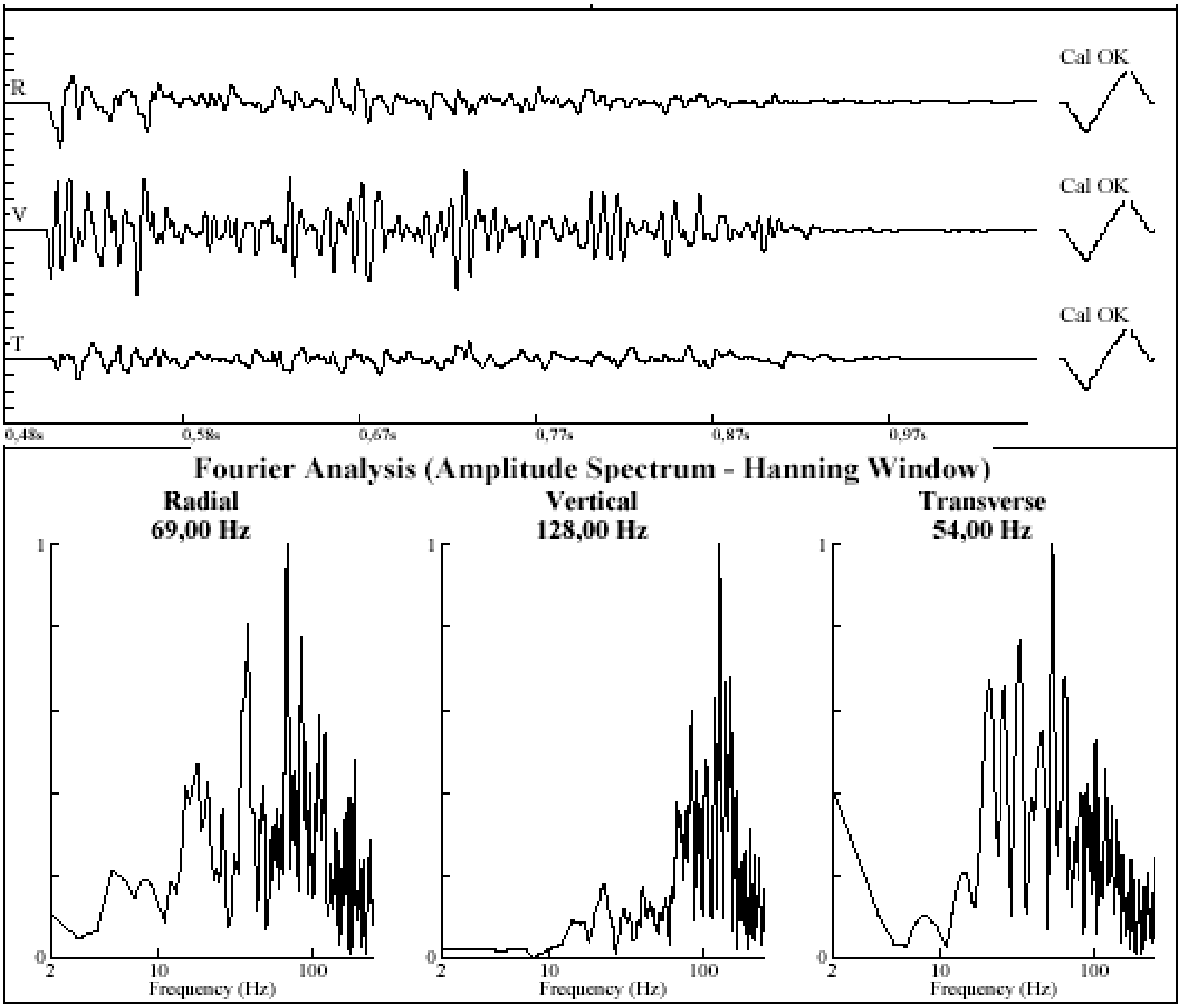
Amplitudes and Frequencies	Graph Information
Acoustic: 146 dB @ 1,1 Hz (4,00Mb 0,0580psi 0,3999kPa) *Radial:* 1,24in/s 31,496mm/s @ 56,8Hz ***Vertical:* 1,92in/s 48,768mm/s @ 128,0Hz** *Transverse:* 0,57in/s 14,478mm/s @ 85,3Hz *Displacement:*0,004093in 0,103950mm *Acceleration:*3,604141g's *Calibration Date:*30.05.2000	*Duration:*0,000s To: 9,500s *Acoustic Scale:* 146dB 3,99Mb (0,998Mb/div) *Seismic Scale:* 1,92in/s (0,480in/s/div) 48,77mm/s (12,192mm/s/div) *Time Line Intervals at:*1,00 s



GRAPH OF SEISMS

Sublevel stopping - demolition underground with ray perforation - measured with geophone at bottom of the hole (DTH).

Detail of wave shown above with expansion of the time scale.

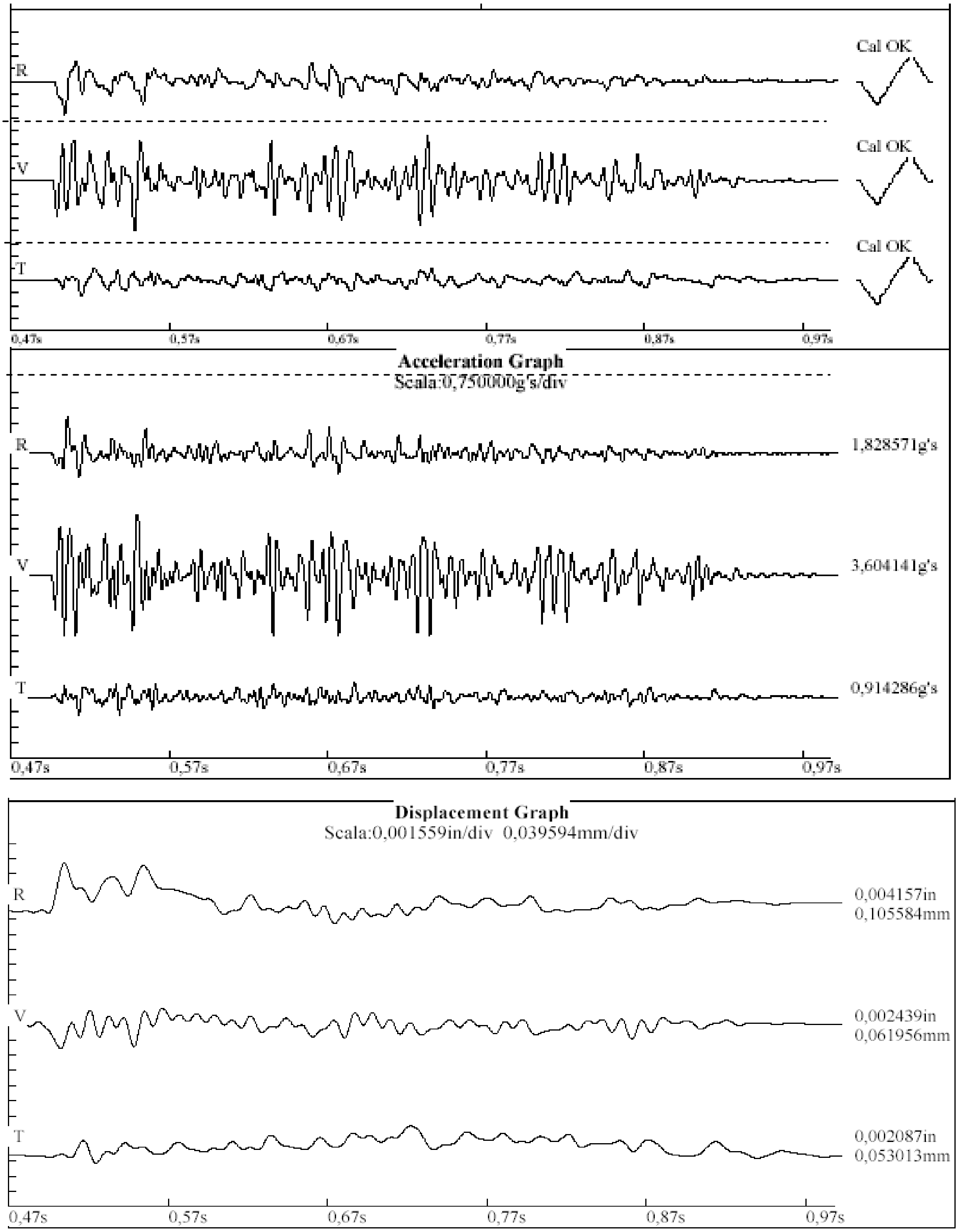


GRAPH OF SEISMS

Sublevel stopping - demolition underground with ray perforation - measured with geophone at bottom of the hole (DTH).

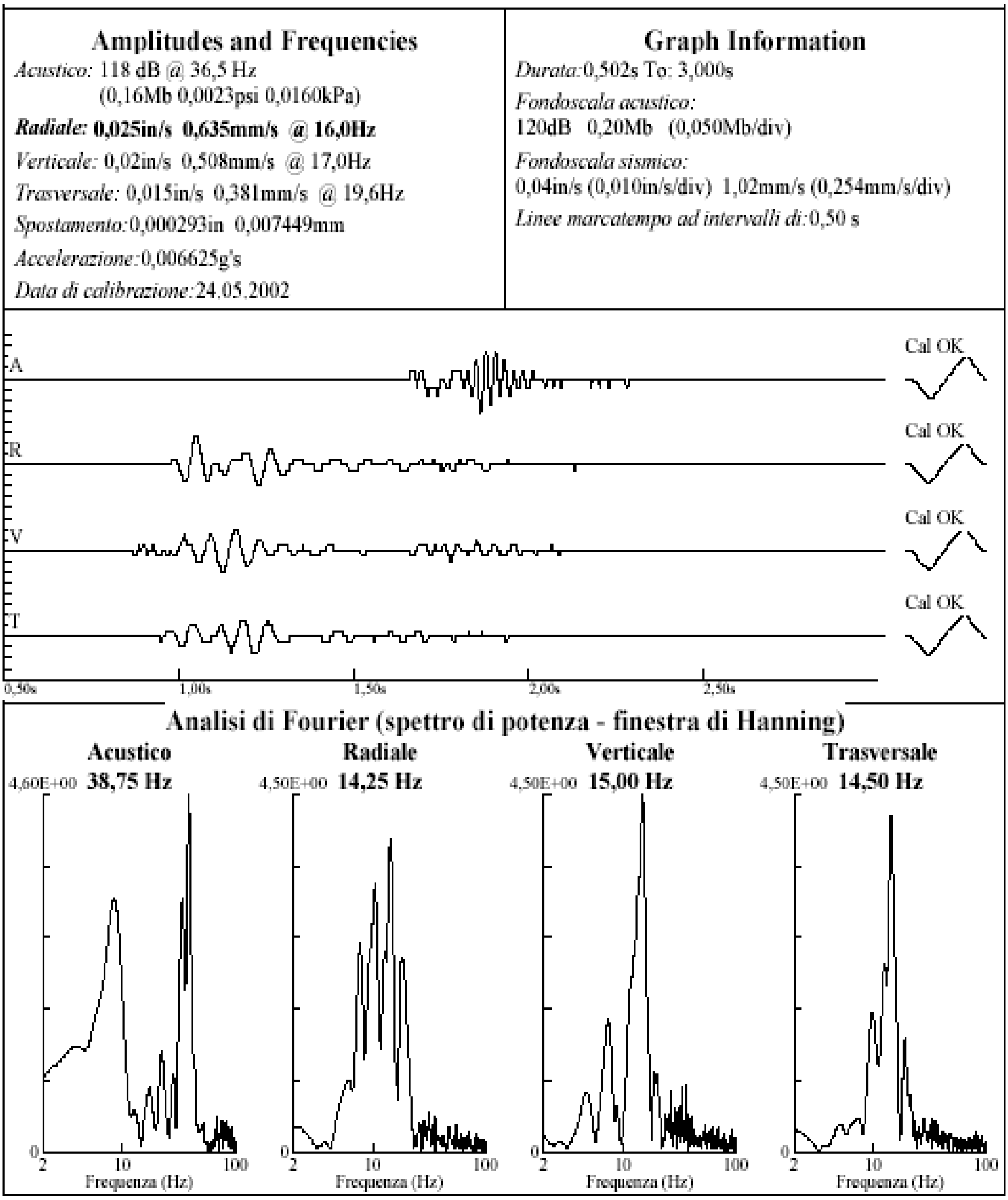
Detail of movements and associated accelerations

SPEED OF VIBRATION

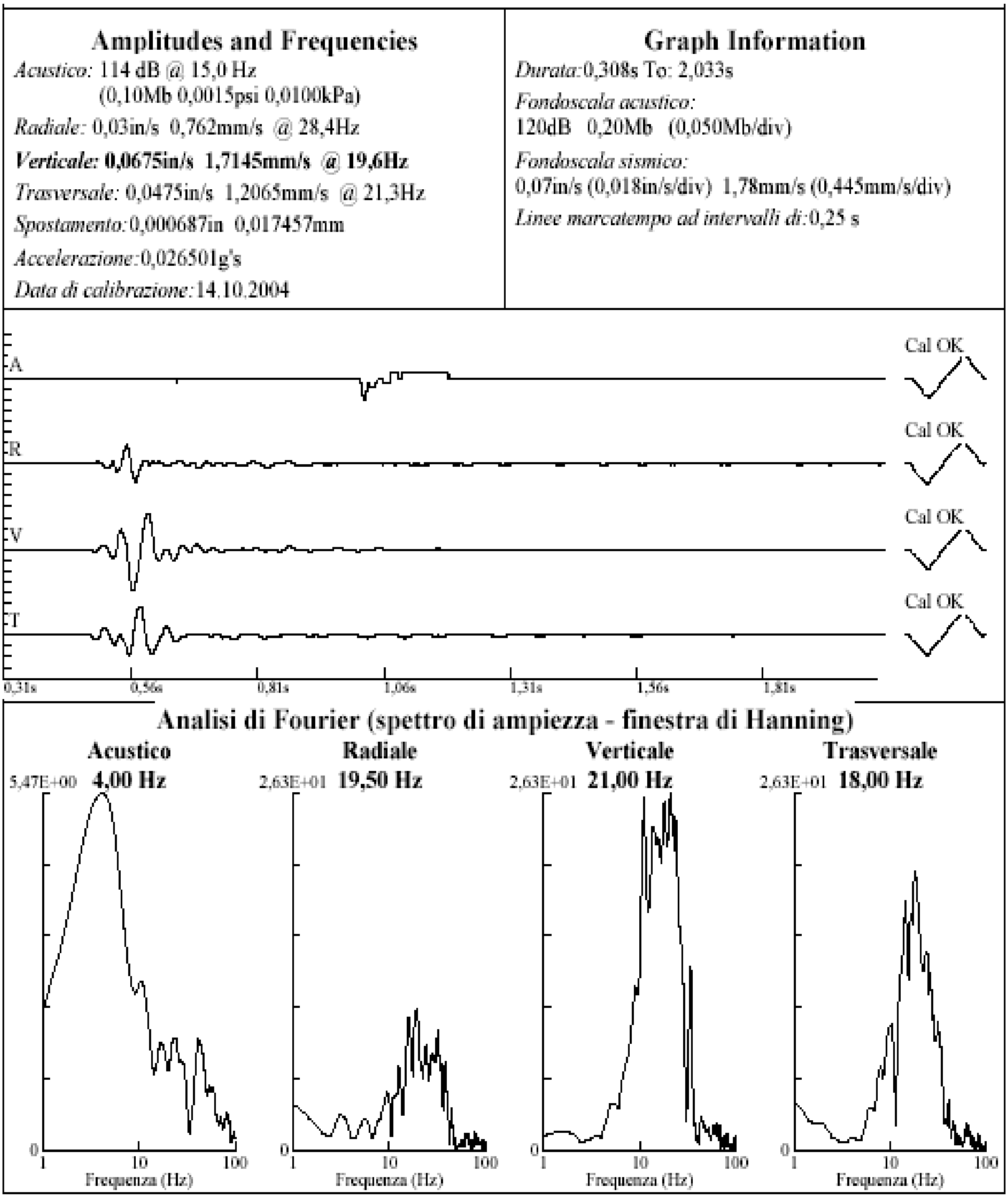


GRAPH OF SEISMS

Cut with detonator fuse 1
Measurement taken at a distance of 60 m from the cut.



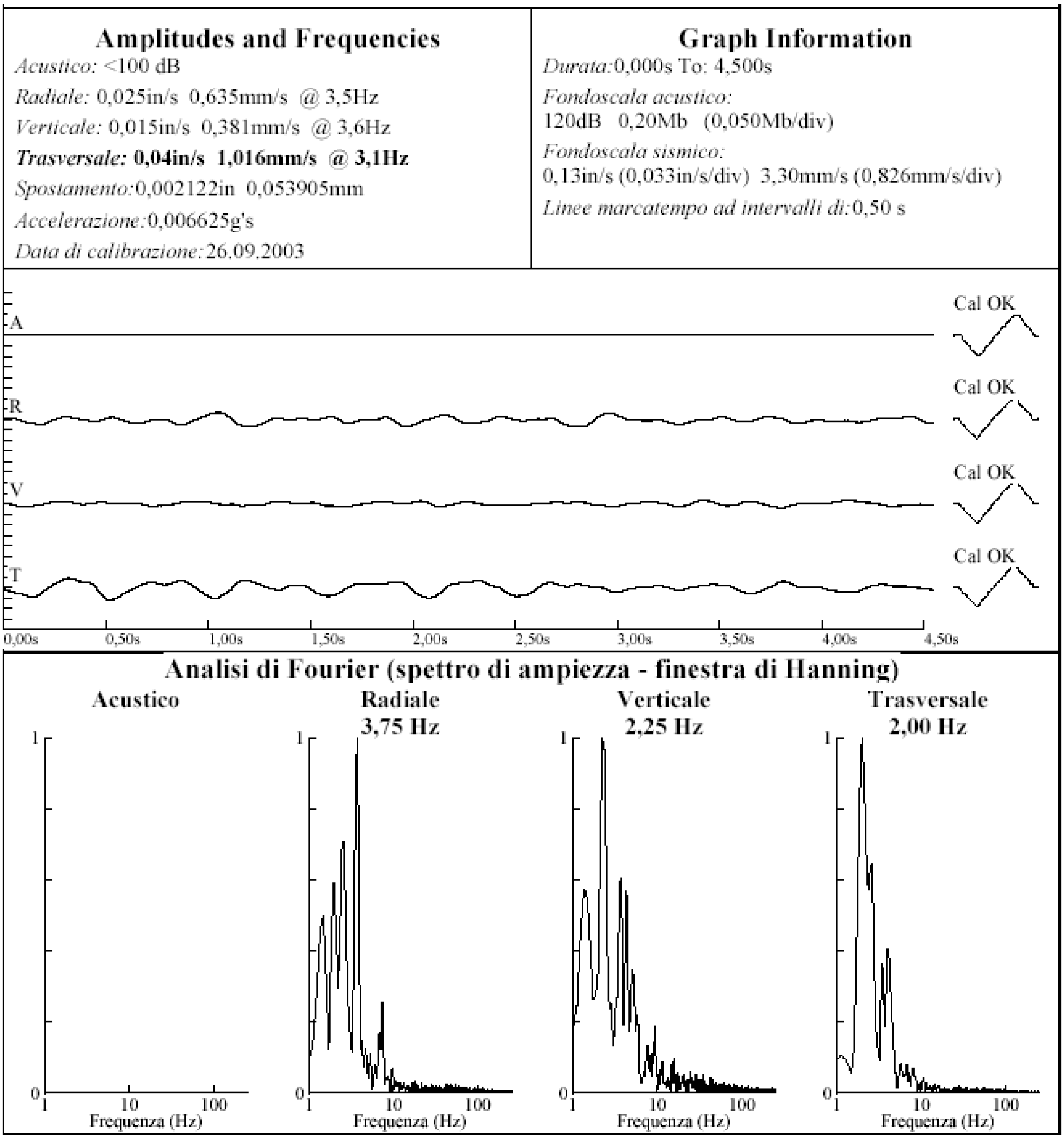
Cut with detonator fuse 2
Measurement taken at a distance of 120 m from the cut.



GRAPH OF SEISMS

Earthquake 1

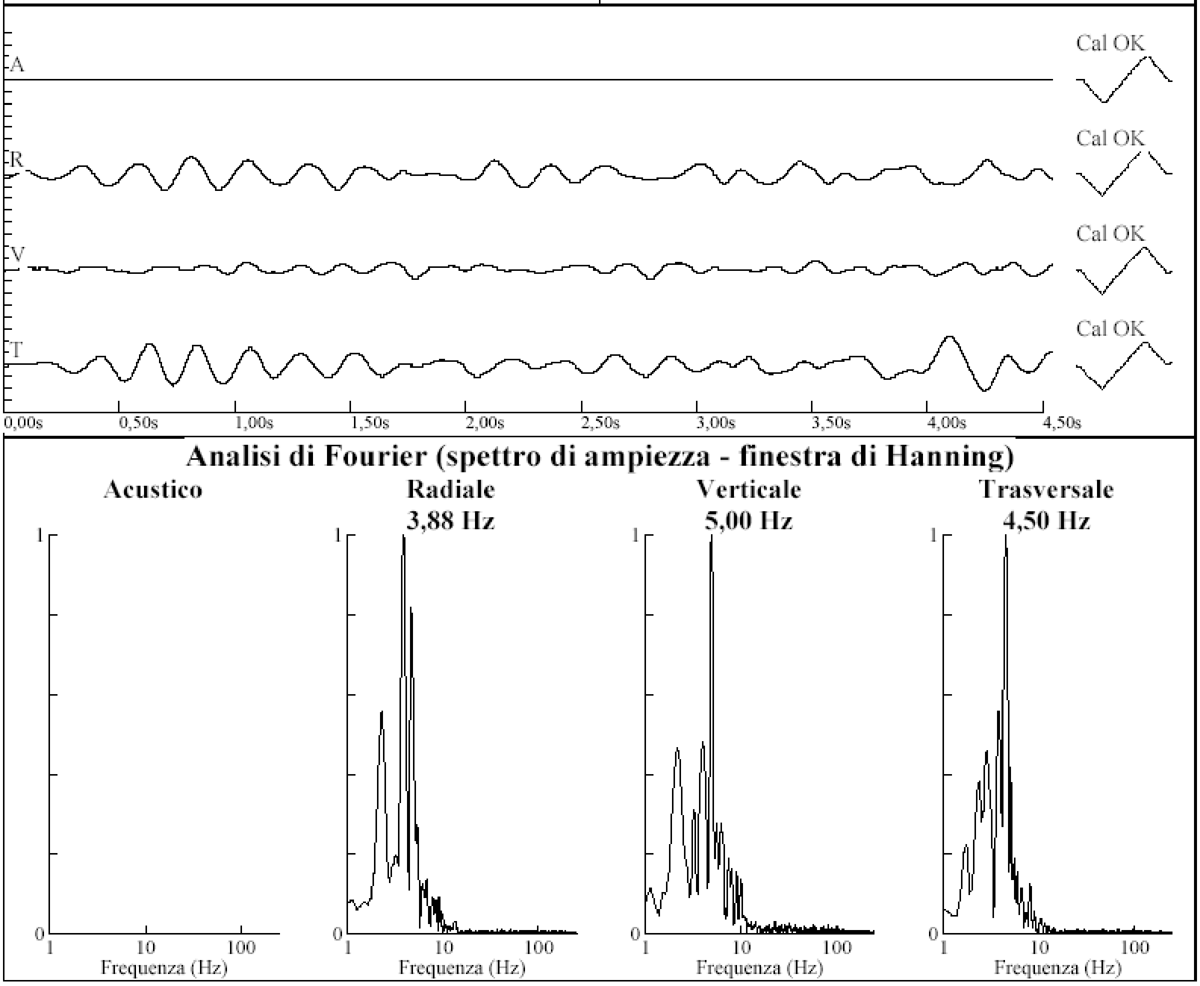
Prevalence of the horizontal component over the vertical, characteristic of the retrograde elliptical movement of the Rayleigh surface waves (earthquake with distant epicenter).
No recording of the overpressure airblast. The earthquake did not produce the “rattle” for the vibration of slabs and thin objects in the property.



GRAPH OF SEISMS

Earthquake 2

Amplitudes and Frequencies	Graph Information
Acustico: <100 dB *Radiale:* 0,05in/s 1,27mm/s @ 4,3Hz *Verticale:* 0,025in/s 0,635mm/s @ 5,2Hz ***Trasversale:* 0,075in/s 1,905mm/s @ 3,3Hz** *Spostamento:*0,003533in 0,089739mm *Accelerazione:*0,013251g's *Data di calibrazione:*22.12.2003	*Durata:*0,000s To: 4,500s *Fondoscala acustico:* 120dB 0,20Mb (0,050Mb/div) *Fondoscala sismico:* 0,13in/s (0,033in/s/div) 3,30mm/s (0,826mm/s/div) *Linee marcatempo ad intervalli di:*0,50 s

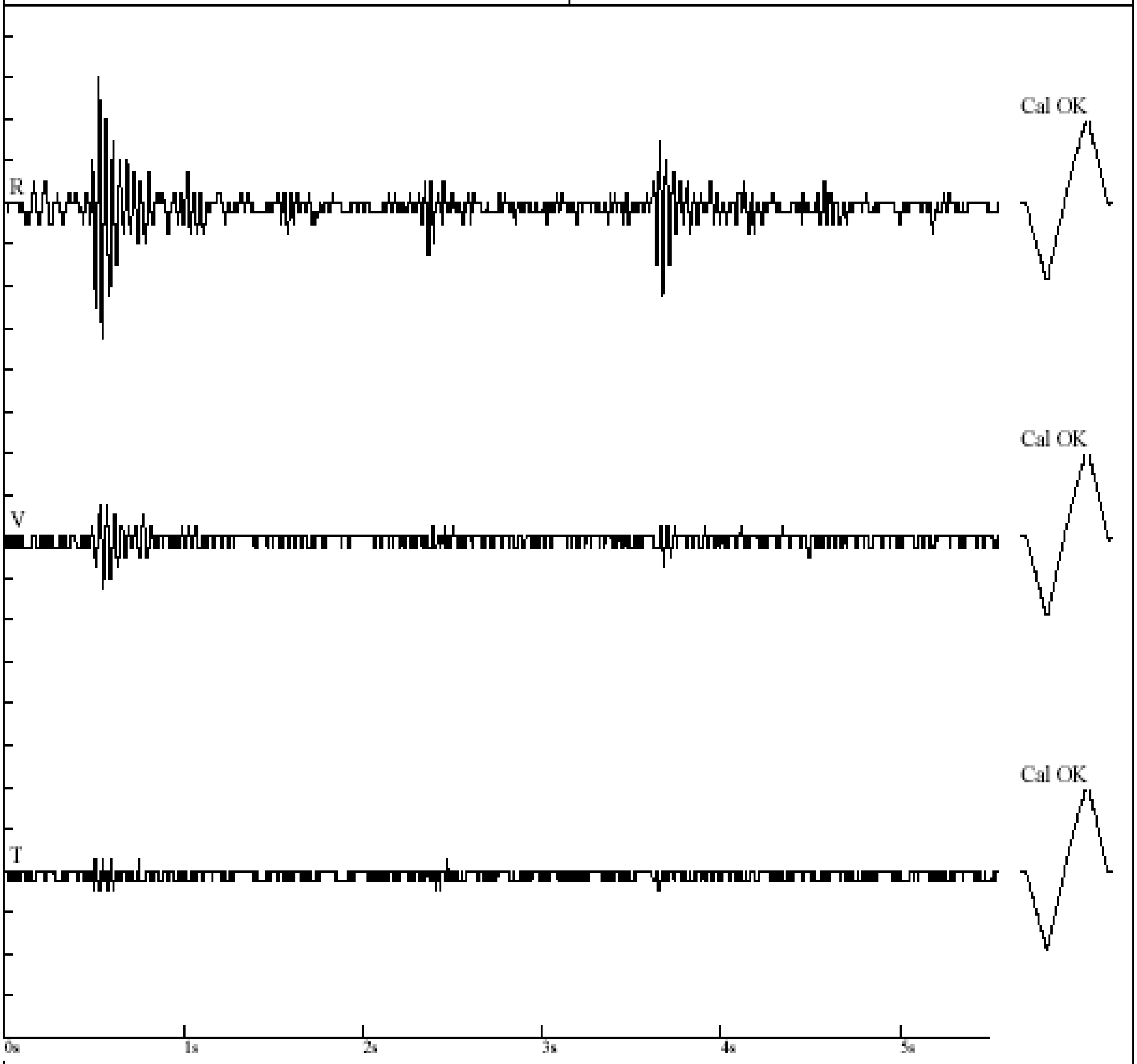


GRAPH OF SEISMS

Vehicle traffic

Measurement taken on an ornamental wall facing the third elevation by the p.c.

Amplitudes and Frequencies	Graph Information
***Radiale:* 0,0163in/s 0,4128mm/s @ 26,9Hz**	*Durata:* 0,000s To: 5,500s
Verticale: 0,0063in/s 0,1588mm/s @ 26,9Hz	*Fondoscala sismico:*
Trasversale: 0,0025in/s 0,0635mm/s @ 0,0Hz	0,02in/s (0,005in/s/div) 0,51mm/s (0,127mm/s/div)
Spostamento: 0,000138in 0,003503mm	*Linee marcatempo ad intervalli di:* 1,00 s
Accelerazione: 0,006625g's	
Data di calibrazione: 20.10.2004	



GRAPH OF SEISMS

Bored hole blast 1 - highway tunnel

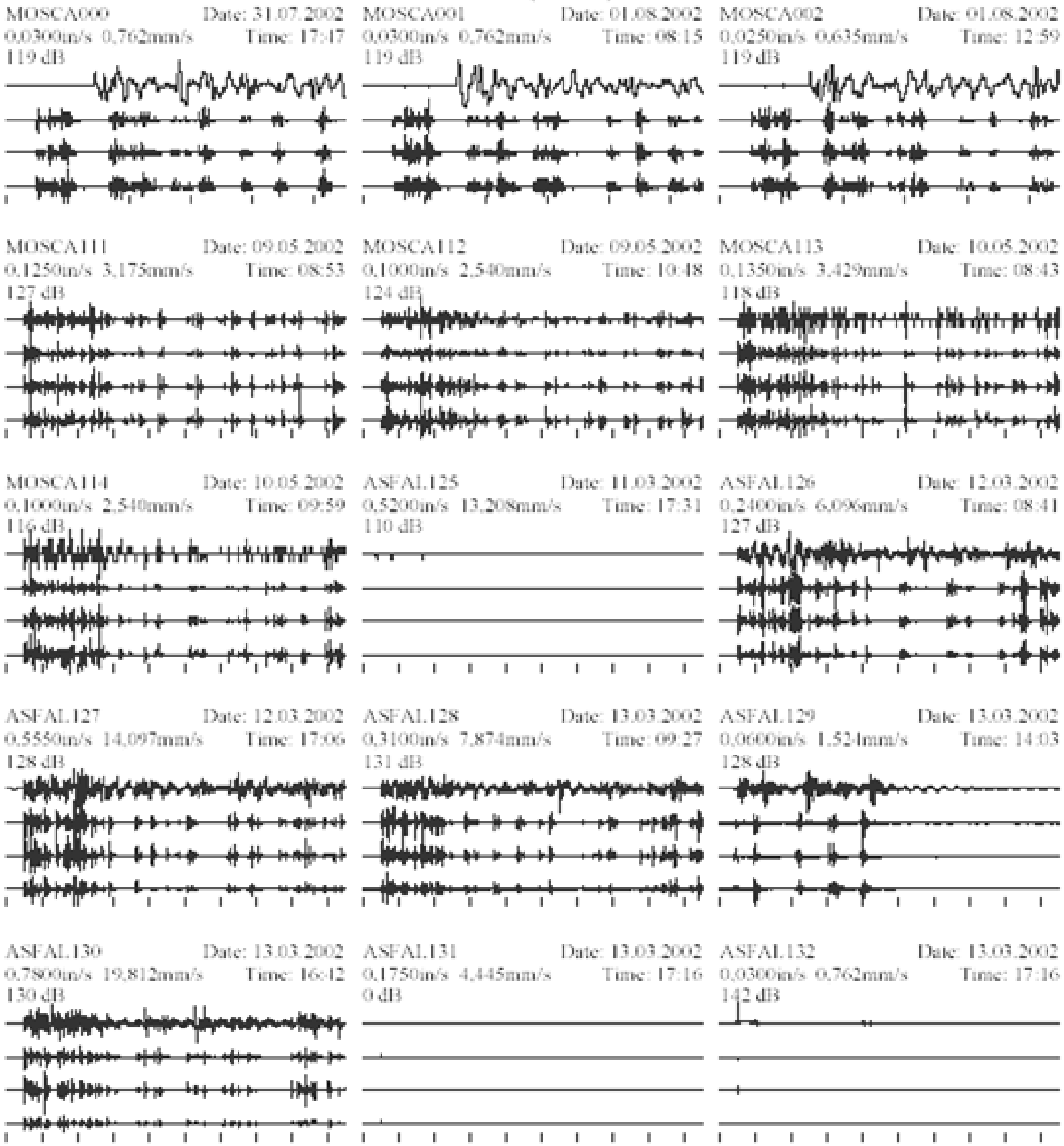
Collection of seisms recorded in continuous monitoring (wave form transcription)

Wave Form Transcription

Page: 1

Galleria Monted'Oro
Comune di Garo Cuno
Punto di misura 4 - Manutaddo Vicenza
- - -
Percorso sismico .... m
Carica massima cooperante .... MJ

Scales (variable)



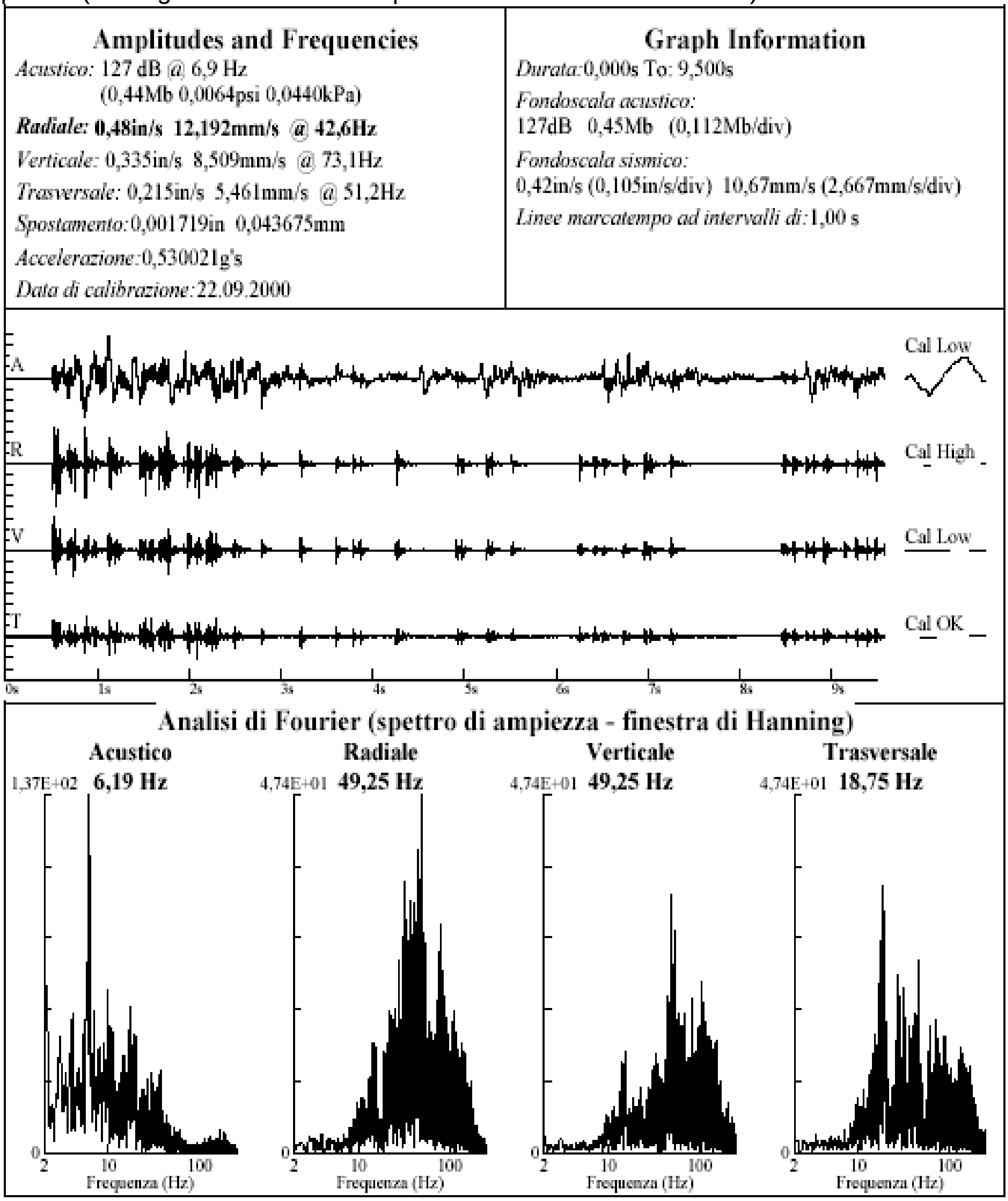
GRAPH OF SEISMS

Bored hole blast 1 - highway tunnel

Geophone placed externally, clamped to building. Succession of blasts with series of brief delay and long delay detonators. Some of the numbers of the series are missing.

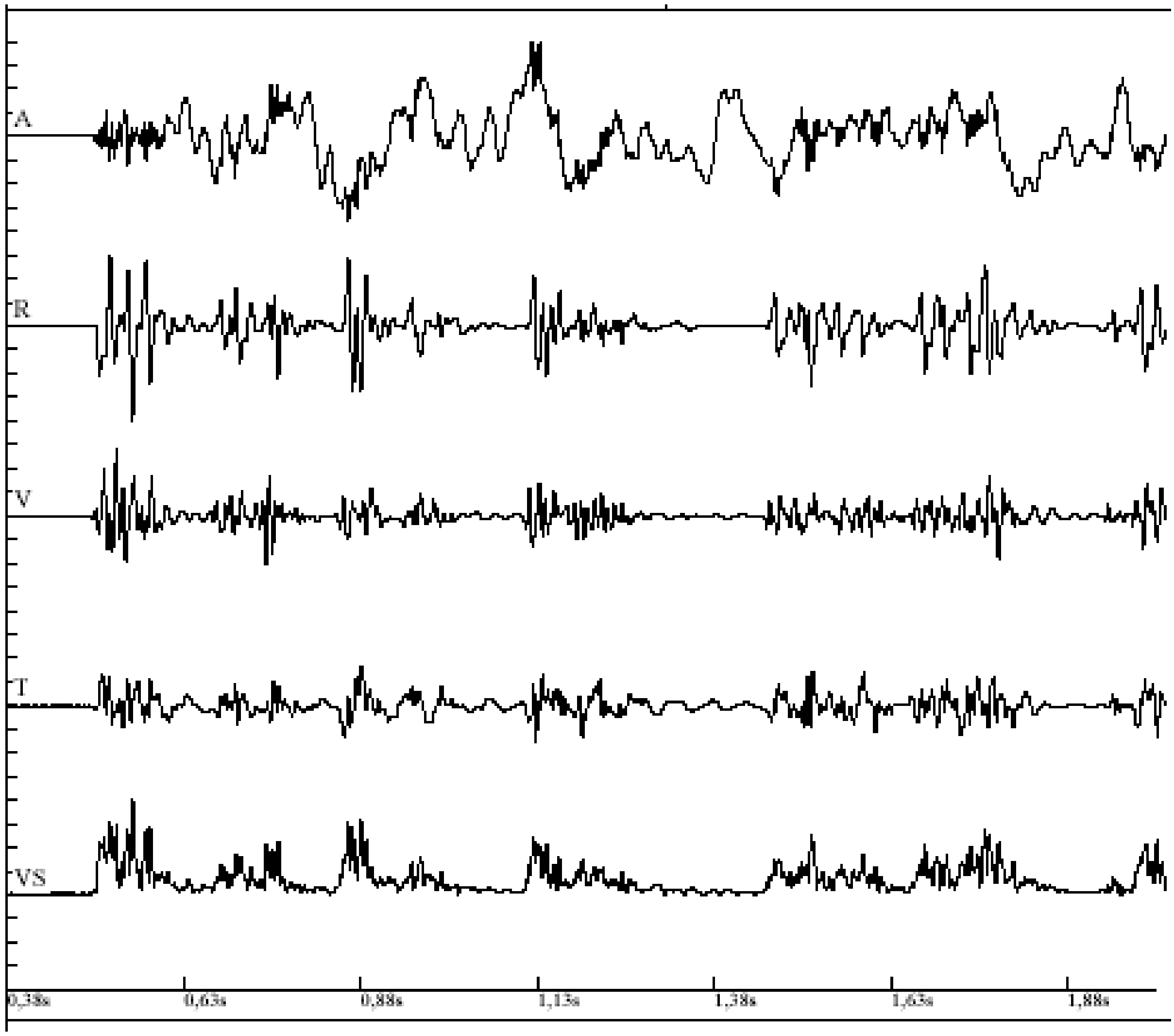
The blast is not balanced and the maximum values take place in the cut and wide holes.

The seism lasts more than 10 seconds and, therefore, continues in the auto-calibration phase (cal High of the radial component and Low of the vertical).



GRAPH OF SEISMS

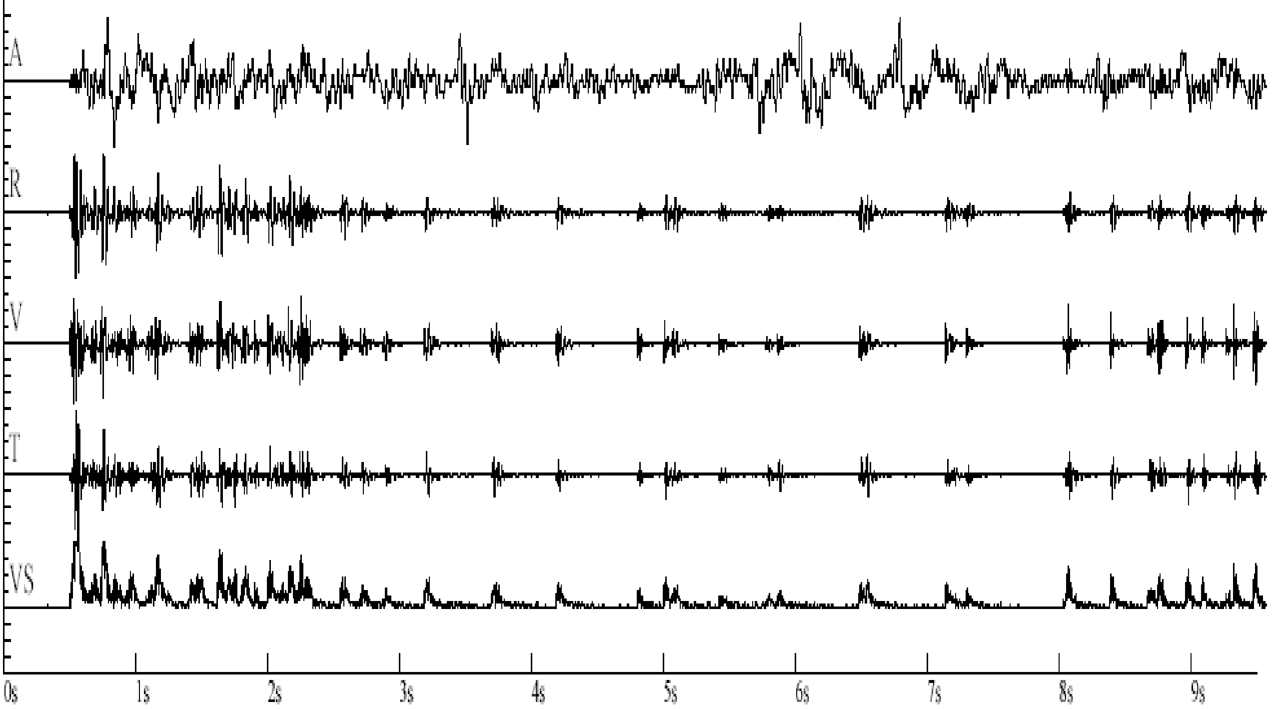
Detail of the wave <u>Bored hole blast 1</u>



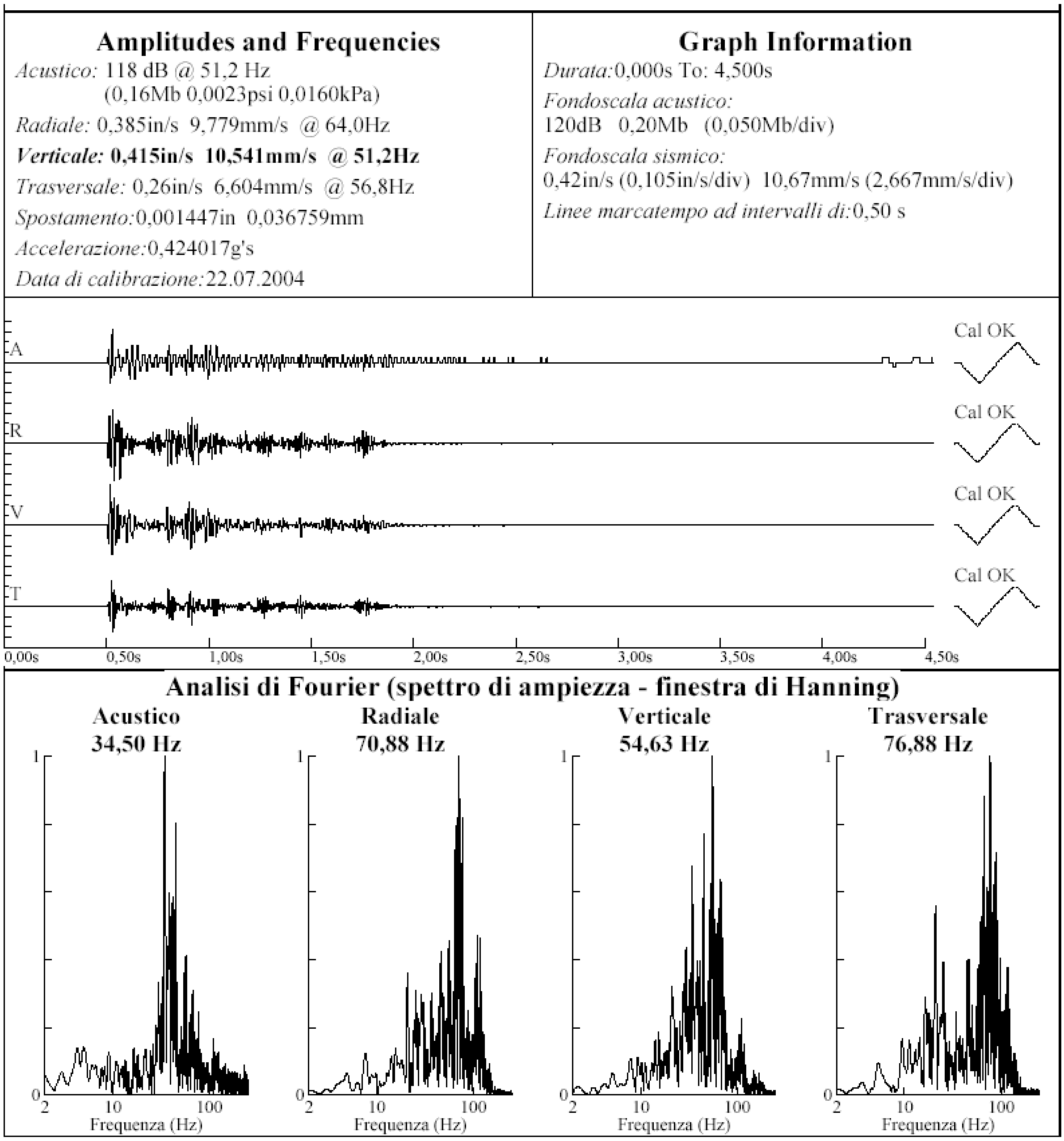
GRAPH OF SEISMS

Bored hole blast 2
Geophone placed externally, clamped to the building. Succession of blasts with series of brief delay and long delay detonators. Net alteration of real explosion times with respect to those nominal. The blast is not balanced and the maximum cooperating values take place only in the cut holes.

Amplitudes and Frequencies	Graph Information
Acoustic: 122 dB @ 6,5 Hz (0,26Mb 0,0038psi 0,0260kPa)	*Duration:* 0,000s To: 9,500s
***Radial:* 0,15in/s 3,81mm/s @ 56,8Hz**	*Acoustic Scale:* 122dB 0,25Mb (0,063Mb/div)
Vertical: 0,135in/s 3,429mm/s @ 73,1Hz	*Seismic Scale:* 0,15in/s (0,038in/s/div) 3,81mm/s (0,953mm/s/div)
Transverse: 0,145in/s 3,683mm/s @ 42,6Hz	*Time Line Intervals at:* 1,00 s
Vector Sum (VS): 0,185in/s 4,699mm/s	
Displacement: 0,000719in 0,018252mm	
Acceleration: 0,205383g's	
Calibration Date: 22.09.2000	

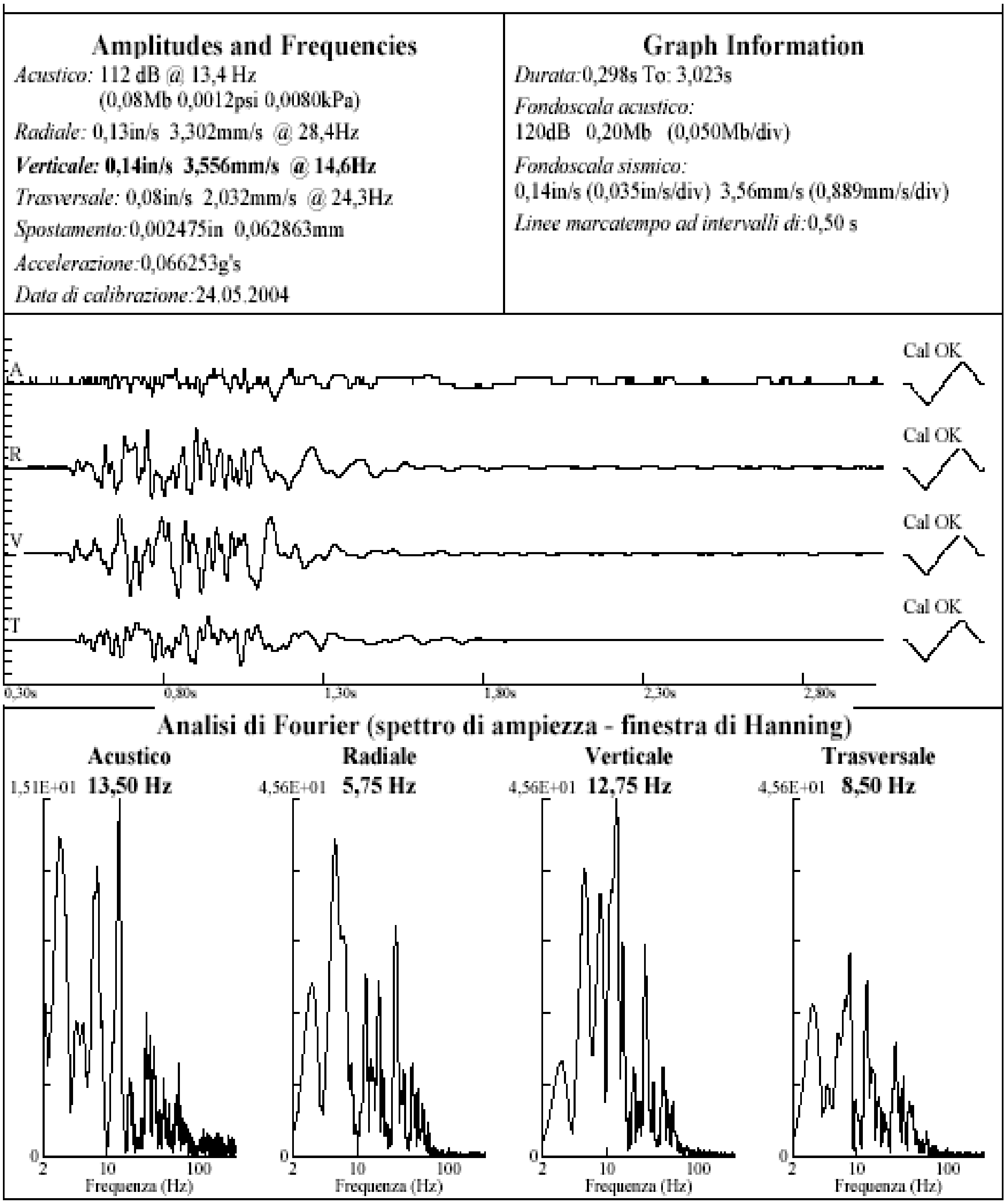


Bored hole blast 3 - hydraulic tunnel
Succession of blows with series of brief delay detonators.



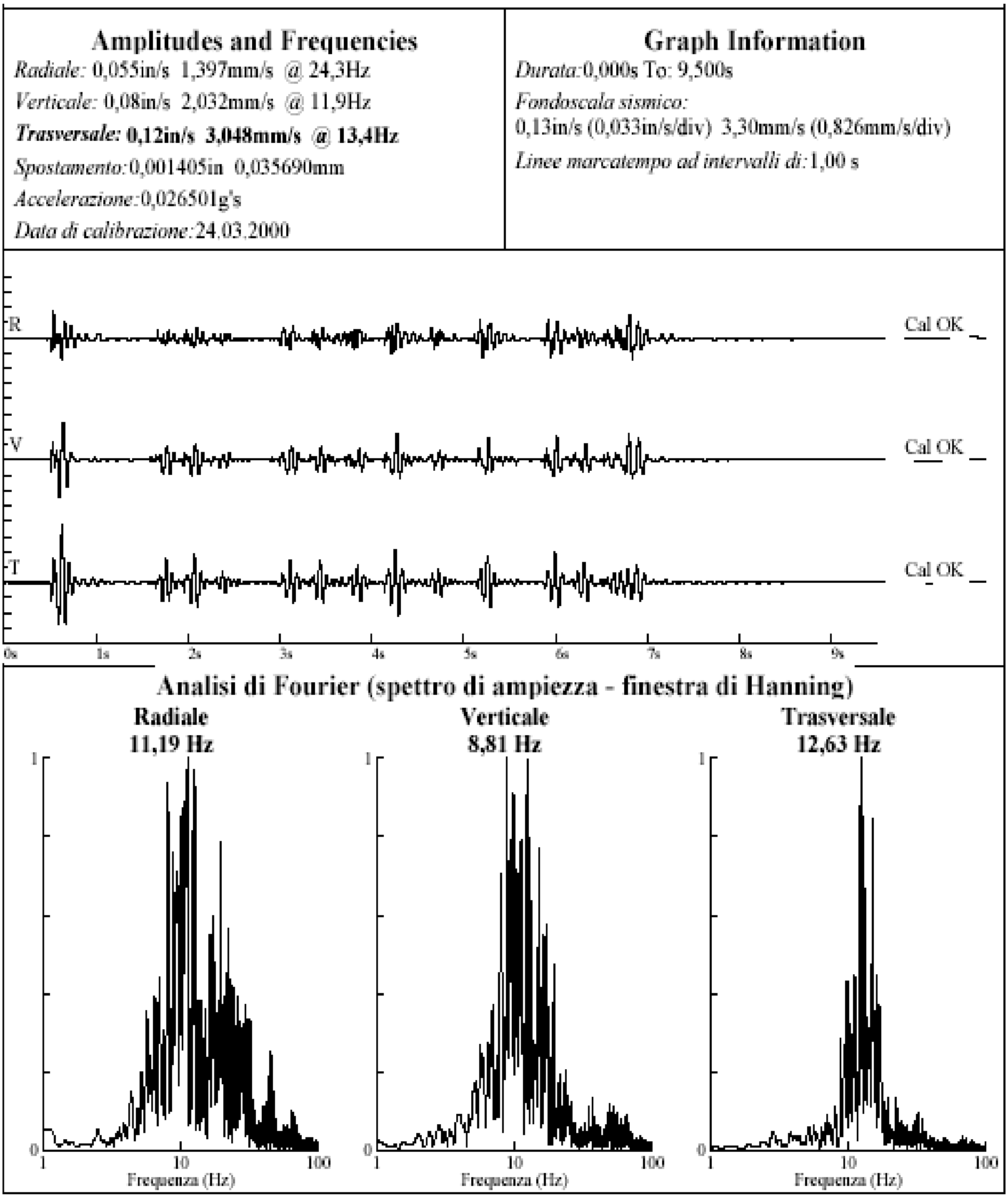
GRAPH OF SEISMS

Step blast 1 – Use of brief delay detonators (25 ms)



GRAPH OF SEISMS

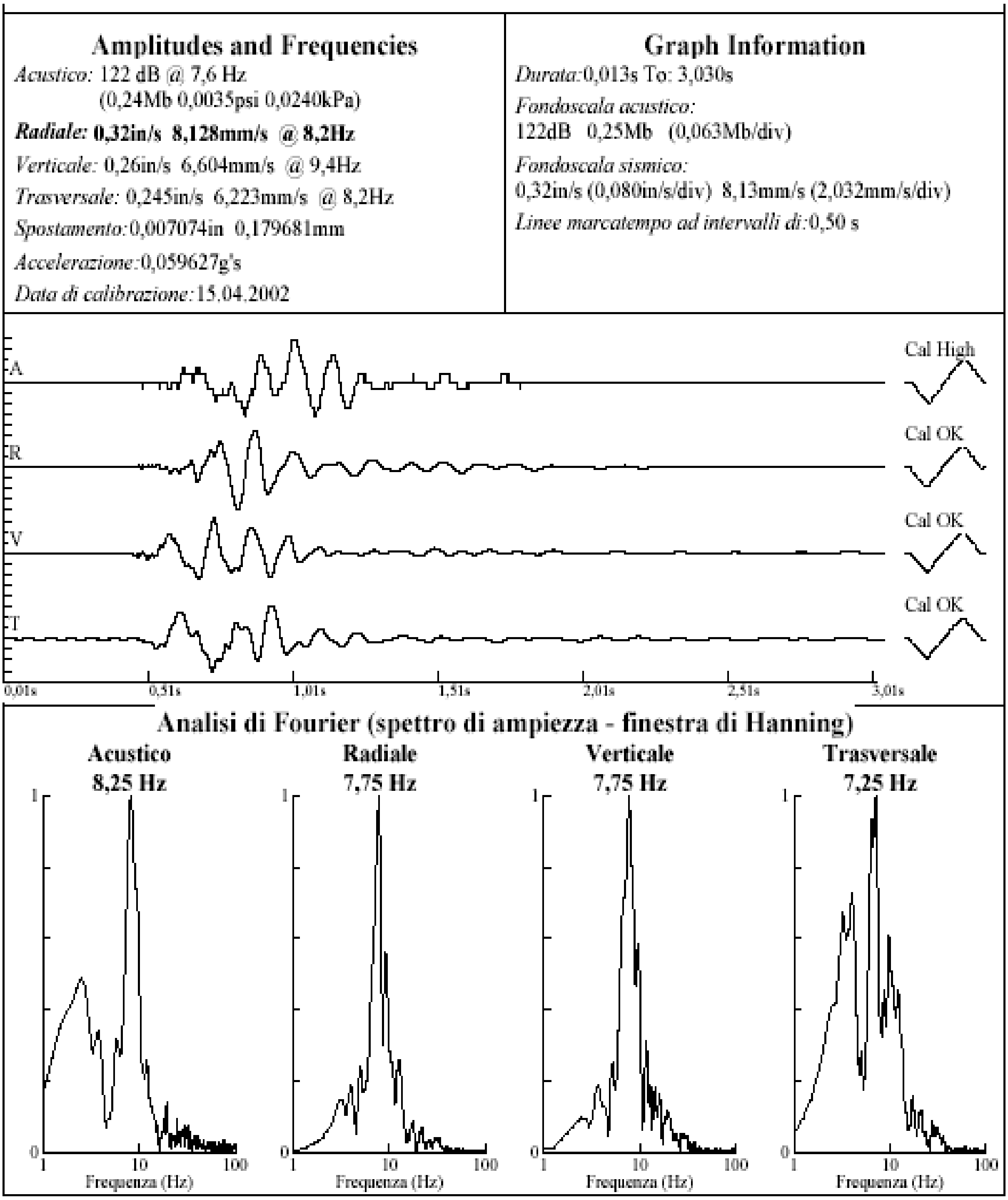
Step blast 2 – Use of long delay detonators (500 ms)



GRAPH OF SEISMS

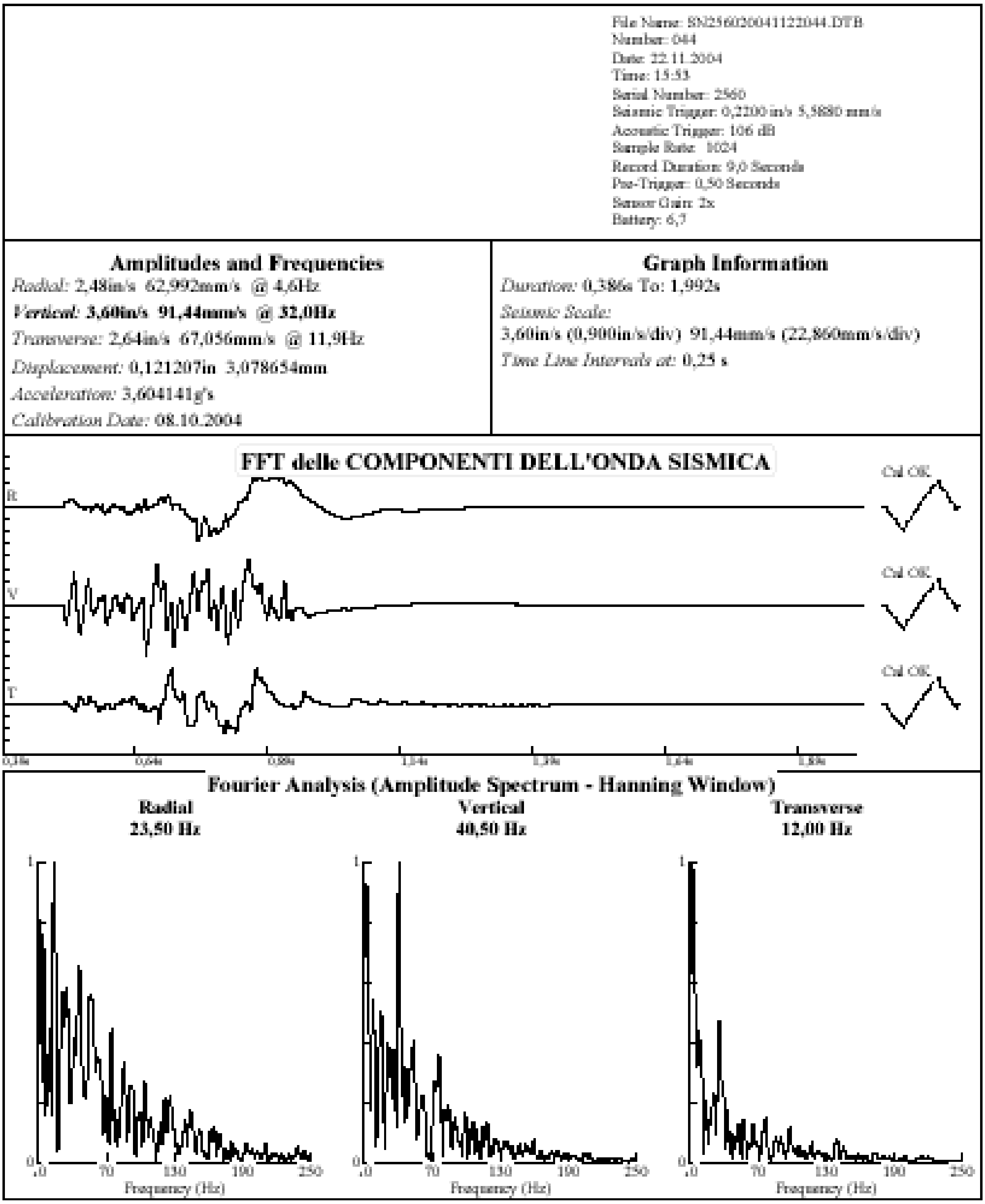
Step blast 3

First arrival of volume waves (P example S) followed by Rayleigh waves.

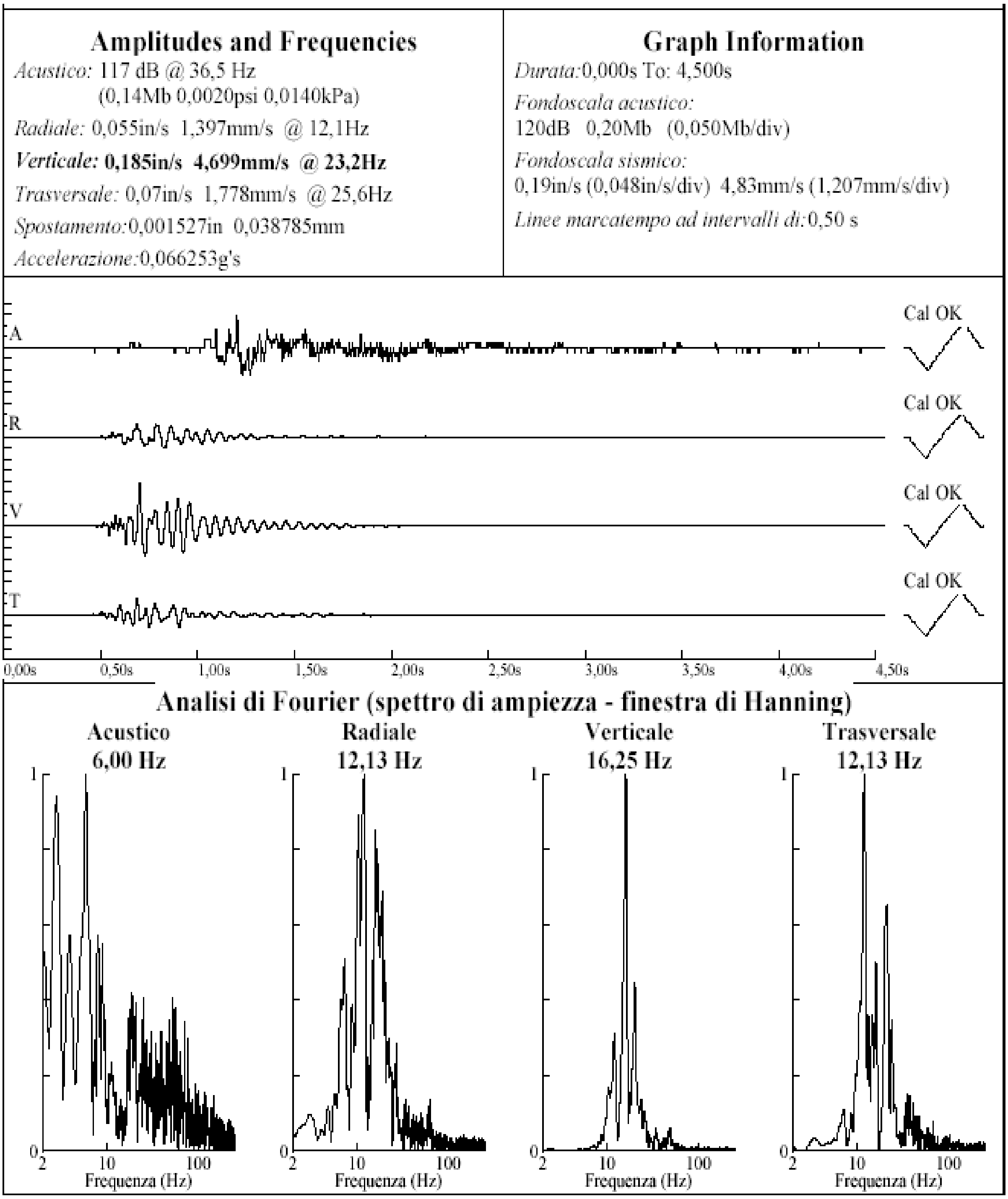


GRAPH OF SEISMS

Step blast 4 - measurement at close distance with geophone at bottom of the hole



Step blast 5 – measurement on the key vault of a medieval bridge in masonry
Vibration tail in free oscillation of the bridge



SIGNIFICANT SEISM

A significant seism is understood as any seism induced by any seismic source whether artificial or natural, with amplitude or frequency relative to the control carried out.

In the case in which, for example, the control carried out is relative to the check of the levels of unease induced by the vibrations to the people residing adjacent, any event that is over the threshold of human perception for amplitude and frequency must be considered significant (SUBJECTIVE RESPONSE OF THE HUMAN BODY TO A VIBRATORY MOVEMENT) .

Sampling extended to all the significant seisms allows framing the environmental seismic context in which vibratory phenomena induced by human activity (e.g. exploding a mine) are inserted and, therefore, defining to what degree they are inserted into this context.

Number of significant seisms recorded	Duration of sampling	Number of significant events per day
80	31	2.9
of which 5 due to the activity of extraction		0.16

Personal form for recording activity of INFORMATION AND TRAINING OF PERSONNEL IN THE USE OF THE SEISMIC-ACOUSTIC MONITORING STATION

Name	Company (only if external)
Activity	TRAINING AND INSTRUCTION in the use of the monitoring station…. - description of the hardware - description of acquisition, analysis and data restitution software introduction to the problems inherent to seismic and acoustic waves induced by setting-off explosive charges - placing the seismograph - characterizing the measurement point - predicting the values of speed of vibration expected - reference regulation; UNI 9916, DIN 4150-3, UNI 9614 - simulating a measurement - carrying out real measurements
Frequency of the activity	Only once/at delivery of the monitoring station
Date and place	
Person in charge of the activity	
Documentation provided	- HARDWARE MANUAL rev… - ANALYSIS AND RESTITUTION GRAPHIC MANUAL rev…. - SEISMIC MEASUREMENT REPORT form rev….. - BLOGORYTHMIC PLAN FORM - Technical documentation - NITREX handbook ☐ attachments
Notes Questions	
Signature of the person in charge of the activity	Signature of the worker

PROBE GIORNAL – form

Days/Months	*Hole*	*i*	*H*	*Notes*

INSTALLATION of the overpressure airblast seismograph

The overpressure airblast seismograph must be mounted at least 1 m ÷1.5 m off the ground, covered by the special foam rubber hood to reduce the apparent overpressure caused by possible wind.

In the case of prolonged installation for measuring, the microphone must be pointed downward in order to avoid damage from rain.

Orienting in the direction of the arrival of the overpressure airblast allows measuring the dynamic overpressure (or rather, also including the component for the movement of the air).
Slant orientation with respect to the direction of the arrival of the overpressure airblast allows measuring the static overpressure (or rather, does not include the component for the movement of the air).

If the overpressure airblast seismograph is mounted inside a structure it can be orientated in any direction.

Inside a structure

Choice of the measurement point

To compare the values of the speed of vibration induced with those envisaged by the regulation, measuring the induced vibrations must preferably be carried out at the level of the foundations, or on a rigid structural component directly connected to the foundations.

Coupling the seismograph to the structure

One of the critical aspects of the instrumental control of vibrations is installing the seismographs on the site. The installation is that much more important the greater is the maximum acceleration of the wave train to be measured.

In the case in which acceleration values less than 0.1 g are envisaged (a tenth of the acceleration of gravity), it is possible to couple the seismograph to a flat surface of the means without anchorage (UNI 9916). To minimize the microphone effect (apparent vibration determined by the impact of the acoustic overpressure wave on the seismograph casing) the geophone must be covered with a sack of dry sand. The sack of sand must not be full but “wrap” the seismograph in a way not to overbalance it at the passage of the transient seism.

Instead, in the case in which values of acceleration greater than 0.1.g are envisaged, it is necessary to fix the seismograph to the measurement point. The fixing point must guarantee mechanical continuity between the structural component and the seismograph, without, however, altering the phenomenon to be measured. Fixing can be carried out by gluing the seismograph to the structure or fixing the seismograph to the measurement point with spikes on the walls to be monitored and the seismograph coupled vertically or horizontally (under the floor or over the foundation beam) by contrasting a perforated plate screwed onto the bar. If measuring is carried out on loose soil the seismograph must be completely buried.

(ILLUSTRATION)

Two spikes fixed on the bearing wall of the structure in rein. con. for coupling the seismograph.

(ILLUSTRATION)

Complement of the measurement station with geophone coupled to wall with spikes and monitoring station in its two containers, supplied from the power, for continuous monitoring.

Outside

Coupling the seismograph to the ground

Also in this case fixing must guarantee mechanical continuity between structural component and ground/rock/structure without, however, altering the size of measurement.

In the case of measuring on soil, it is appropriate to bury the geophone, digging a hole at least 50 centimeters deep, fixing the geophone at the bottom with the supplied pins and then cover it with earth or sand (possibly in sacks).

A common error is to carry out the measurement on the surface of the ground. Fixing on the surface of the ground, less compact than in depth, lacks confinement without layers on top and leads to over-estimating the values of vibration speed.

In the case of measuring on a rock wall, it is possible to use the same method advised for installation inside a structure, fixing with spikes cemented into the wall to be measured.

(ILLUSTRATION)

Simple coupling of the seismograph to the structural element (foundation beam for envisaged speed values under 0.1 g.),

(ILLUSTRATION)

Covering the seismograph with sack of sand, or simple coupling of the seismograph to the structural element (foundation beam for envisaged speed values under 0.1 g.). Monitoring station in its container , supplied by battery (monitoring time limited to one week, 10 days.

(ILLUSTRATION)

Coupling the seismograph to the rocky wall
In a niche with spikes and perforated
plate. The spikes on the outside of
the niche are for applying a protective
cover to the niche.

(ILLUSTRATION)

Detail

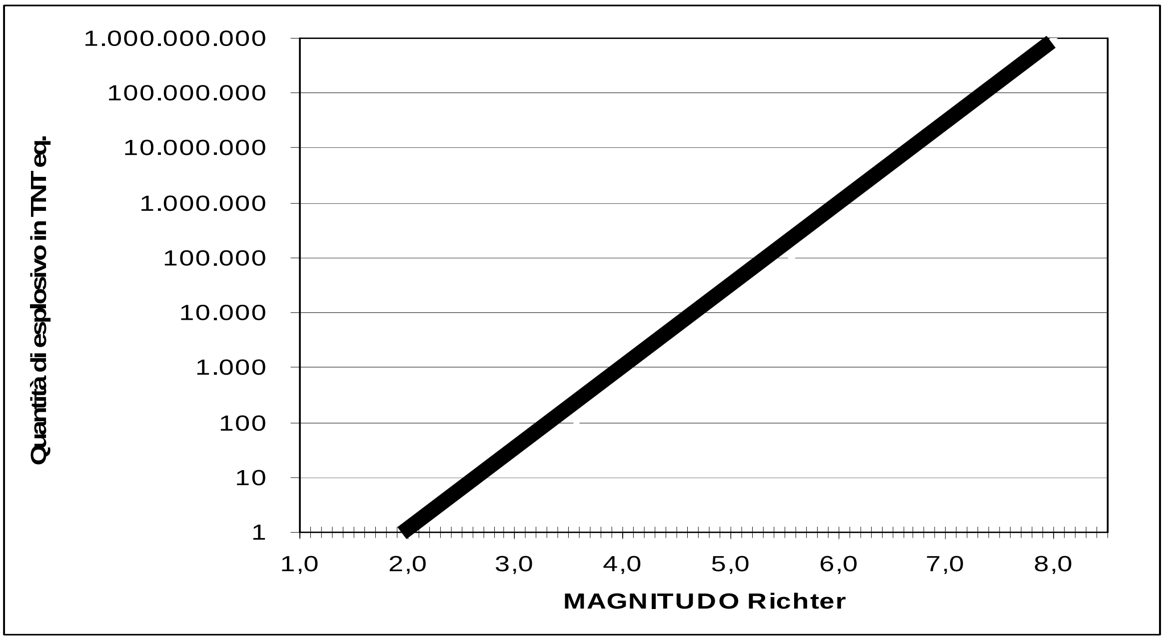
Classification of the INTENSITY OF EARTHQUAKES

RICHTER Scale

The seismic/telluric event is classified by a magnitude in function of the amplitude of the maximum peak of the seismic wave recorded with a Wood-Anderson type seismograph (A, in mm) and by the distance from the epicenter, calculated by the time interval between the first arrival of the pressure wave and the cut wave: (Equations)

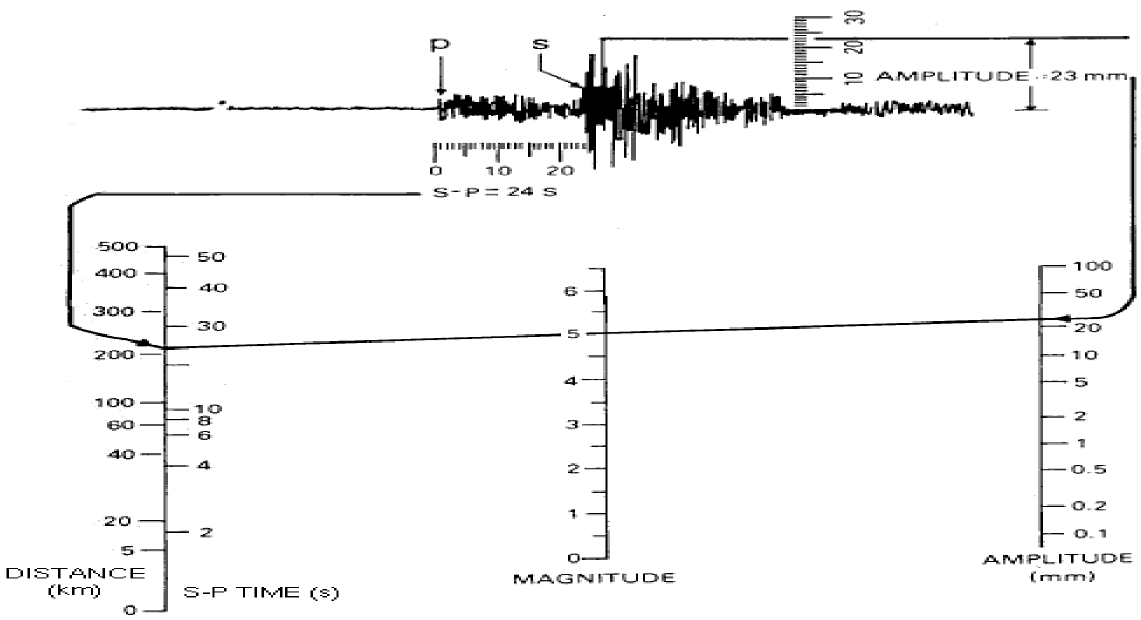
Magnitude	TNT explosive energy	MCS Grade (rough approximation)
2,0	1	
2,5	5	
3,0	29	I
3,5	73	II
4,0	1.000	III
4,5	5.100	IV
5,0	32.000	V
5,5	80.000	VI
6,0	1.000.000	VII
6,5	5.000.000	VIII
7,0	32.000.000	XI
7,5	160.000.000	X
8,0	1.000.000.000	XI
8,5	5.000.000.000	XII

MAGNITUDE Richter	effects
meno di 3,5	Generally recorded but not felt.
3,5 ÷ 5,4	Often felt but not causing damage.
sotto 6,0	At the most, slight damage to solid buildings. Causes greater damage to buildings not in rein. con. built in small regions.
6,1 ÷ 6,9	
7,0 ÷ 7,9	Bigger earthquake. Causes damage over large areas.
8 o maggiore	Huge earthquake. Can cause serious damage over large areas of several hundreds of kg.



Equivalence between energy released by the earthquake (in TNT equivalent) and its Richter magnitude.

Richter diagram for the graphic estimate of the Magnitude - model.



MCS-Mercali, Cancani, Sieberg scale The seismic/telluric event is calculated by a "grade" from one to twelve, increasing as the impact induced on the human context increases.		
grade	**shock**	**description**
I	instrumental	not felt
II	very light	felt only by a few worried people; objects suspended lightly can oscillate
III	light	felt notably by people indoors; especially on the top floors of buildings; stationary cars can oscillate slightly
IV	mediocre	felt by many inside a building in the daytime; by few outside; at night some people are woken-up; stationary cars oscillate notably
V	strong	felt by practically everyone; many are woken-up from sleep,; cracks in the plaster; objects falling; sometimes trees and poles shaken
VI	very strong	felt by all; some very frightened run outside; heavy furniture moved, plaster falls and damage to chimneys; slight damage
VII	extremely strong	all run outside; negligible damage to well designed and constructed buildings; from slight to moderate for well constructed ordinary structures; felt by driven cars
IX	disastrous	damage to anti-seismic structures; loss of verticality to well designed bearing structures; buildings moved from their foundations; cracks in the soil; breaks in buried cables
X	very disastrous	destruction of most part of structures in masonry; notable cracks in the soil; railings bent; notable collapse of river banks or steep slopes
XI	catastrophic	few structures in masonry remain upright: destruction of bridges; wide cracks in the ground; buried conduits out of use; collapse and movement of ground in soft soil
XII	greatly catastrophic	total damage; waves on the surface of the soil; distortion of the visual and level lines; objects thrown into the air

LAW OF MAXIMUM VIBRATION SPEED REDUCTION AT THE VARIANCE OF THE SCALED DISTANCE

General

The amplitude of the vibrations induced by the explosion reduces rapidly at the increase in the distance from the point of the explosion and the decrease in the charge exploded by delayed ignition (sequential explosion), or rather by the cooperating explosive charge.

The maximum speed of vibration "Vmax" at the passage of the transient seism is, therefore, directly proportional to the charge detonated and inversely proportional to the distance from the point of explosion according to an exponential law type:

$$V_{MAX} = K \cdot \frac{Q^{\alpha}}{R^{\beta}} = K \cdot Q^{\alpha} \cdot R^{-\beta} \qquad \text{(eq. 1)}$$

where

"K", "α" e "β" are variable independent parameters in function of the type of blast, explosive and
means of propagation

"R" is the seismic distance (inclined distance) from the explosion point at which the maximum speed Vmax is discoverable.
"Q" is the maximum cooperating explosive charge detonated by delayed ignition.

The parameters "K", "α" e "β" .are calculated for each site and possibly in the same site for various directions of propagation by the regression of power to two independent variables (R and Q) with the data measured in the area with, precisely, "V_{MAX}" as a dependent variable.

To make a bi-dimensional graph easier, the report shown above is normally expressed in the form

$$V_{MAX} = K \cdot (R/Q^{c})^{-\beta} = K \cdot (DS)^{-\beta} \quad \text{(eq. 2)}$$

Where
"c" = α/β

"DS" = R/Q^{c} (normalized or scaled distance on the charge elevated to "C).

Sometimes the parameters "K", "α" e "β" are calculated only by regression of powers to a single independent variable, precisely, "DS" imposing a value of exponent "c" equal to 0.5 (square root of the charge) in case of blasts in the open air and 1/3 (cubic root) in the case of a bored hole blast.
The reliability of the reduction curve calculated with regression to an independent variable (DS) is less than that calculated with two variables (R and Q) but in any case generally accepted.

The maximum speed of vibration, other than the charge and the distance from the energizing point, also depends on the

- elastic and mechanical resistance parameters of the rock (module of elasticity, acoustic impedance, resistance to traction, etc.);
- intensity of fracturing, forms, filling and orientating the interposed points;
- specific demolition charge (the higher the specific charge the lower is the speed of vibration, in equality to the other parameters);
- decoupling of the charge in the hole;
- specific charge;
- relation between back and centerline;
- relation between back and height of the hole;
- etc.

Ignoring the factors shown above together with imprecision in defining the charge associated with the maximum peak of speed of vibration and the relative seismic path makes the data shown in the graph not perfectly aligned in the plan defined in equ.1 of the tri-dimensional space with axes "V_{MAX}", "R" e "Q". The data collected by the measurement are, in fact, dispersed in a cloud. The lesser the variation of the factors shown above, so much greater will be the precision with which the charge and the distance are found and so much less will be the dispersion of the points of measurement around this surface (or rather around the line, in the case of representation in bi-dimensional space with axes "V_{MAX}", "R" e "Q" and the DS line that becomes upright in figure in the BILORYTHMIC PLAN).

The dispersion of the measured data imposes the adoption of a statistical procedure for identifying the reduction trend, so that it becomes possible to predict the speed of vibration at the variance of the distance and the charge.

The statistical procedure used to establish this trend, or rather to calculate the "K", "α" e "β" parameters of equation 1 is that of the REGRESSION OF POWER. It is a method that allows establishing which among all the surface curves of the tri-dimensional space with axes "V_{MAX}", "R" e "Q", whose development is generally defined by equ.1, best approximates the cloud of points. To define this surface we adopt an analytical method that allows identifying, among them all, the one for which the sum of the square of the distance from the various points of the cloud is the least possible and, once this is fixed, the one above, which is present only 5% (85% of probability) or 11% (98% of probability) of the points measured.

Simplified method followed for calculating the regression curve with two independent variables - rec. NTX

Equation of the reduction curve of the scaled (or normalized) distance on the explosive charge.

$V_{MAX}\,(probabile) = \frac{K \cdot Q^{\alpha}}{R^{\beta}} = K \cdot Q^{\alpha} \cdot R^{-\beta}$ equation of the reduction curve or rather the speed with 50% probability of taking place can also be expressed in the form

$$\ln(V_{MAX}) = \ln(K \cdot Q^{\alpha} \cdot R^{-\beta}) = \ln(K) + \ln(Q^{\alpha}) + \ln(R^{-\beta}) = \ln(K) + \alpha \cdot \ln(Q) - \beta \cdot \ln(R).$$

therefore setting:

y = ln(V_{MAX})

b = ln(K

m1 = α

x1= ln(Q)

m2= -β

x2 = ln(R)

obtaining the equation of the upright whose parameters "b", "M1" and "M2" can be defined with the linear regression, or rather with the statistical method of the curve with the minimums squared

y = b + m1·x1 + m2·x2

from the linear regression of the logarithms of the sample variables the values of the parameters "b", "M1" and "M2" are calculated and therefore those of the reduction curve

$K = exp^{b}$

α = m1

β = - m2

From the degree of freedom of the analysis of regression it is possible to calculate the function of allocation (Student's t distribution) for the interval of confidence wanted (typically 97.5% or 99%) and therefore the value of the intercept K' corresponding to the limit curve of trust.

$$V_{MAX}\,(97{,}5\%) = K' \cdot Q^{\alpha} \cdot R^{-\beta}$$

Reliability of the regression curve

1. Predictions for directions different to those in which the reduction curve has been calculated can lead to enormous errors of evaluation. The same site can have different reduction curves for different directions of propagation. This circumstance is even truer the greater the anisotropy of the bedrock concerned is and the more inhomogeneous the geometry of the explosion is with respect to the point for which the prediction must be made.
2. A representative number of data must be used to calculate the reduction curve. Generally, at least 30 samples are necessary for a statically valid analysis.
3. Predictions carried out with distance and charge values outside the sphere of variation of those used for calculating the reduction curve taken as reference can lead to enormous errors of evaluation even if the corresponding scaled distance is included in the interval of variation of those of the sample measurement (under-estimated in the case of scaled distance with a greater seismic path than the maximum of the sample, over-estimated in the case of a lower seismic path).
4. Data that are outside the dispersion cloud must be detected carefully and, possibly, removed from the analysis as they could be affected by a writing error of the distance value or the charge value (e.g. for having considered not only the cooperating charge but also the triggering time of the charge) or by anomalous explosion conditions (e.g. over-confined explosion or back under-dimensioned).

To minimized the vibrations it is necessary to adopt the following measures:

a) Reducing the cooperating charge for delay by lengthening the succession of triggers and/or reducing the instantaneous charge (the time interval between triggers must increase with the increase in the distance of the point at which the vibrations are measured, consequent to the gradual movement of the energy associated with the transient seism from the high frequency and low frequency harmonic components so that the peaks of speed "span" and the effects among near holes exploded in succession add up to "cooperating").

b) Minimizing the demolition back, or rather adopting a low relation between the centerlines of the holes and demolition back.

c) Maximizing the specific demolition charge.

d) Creating "barriers to the vibrations" (e.g. by pre-cutting).

e) Orienting the fronts of the excavations, also in function of the orientation of the tectonic and stratigraphic joints.

f) Precise perforation to minimize the risk of irregularity with over-dimensioning of the back.

Adoption of a procedure aimed at ACOUSTIC SIGNALLING OF A MINE EXPLODING can minimize unease consequent to an unwarned perception of vibrations and associated noise.

MEASURING THE VIBRATIONS INDUCED BY EXPLODING MINES

INTERNATIONAL SOCIETY OF EXPLOSIVES ENGINEERS

BLAST VIBRATIONS AND SEISMOGRAPH SECTION

ISEE Field Practice Guidelines for Blasting Seismographs

Disclaimer: These field practice recommendations are intended to serve as general guidelines, and cannot describe all types of field conditions. It is incumbent on the operator to evaluate these conditions and to obtain good coupling between monitoring instrument and the surface to be monitored. In all cases, the operator should describe the field conditions and setup procedures in the permanent record of each blast.

Preface: Seismographs are used to establish compliance with regulations and evaluate explosive performance.

Laws and regulations have been established to prevent damage to property and injury to people. The disposition of the rules is strongly dependant on the reliability and accuracy of ground vibration and airblast data. In terms of explosive performance the same holds true. One goal of the ISEE Blast Vibrations and Seismograph Section is to ensure reliable and consistent recording of ground vibrations and air blasts between all blasting seismographs.

Part I. General Guidelines

Seismographs are deployed in the field to record the levels of blast-induced ground vibration and airblast.

Accuracy of the recordings is essential. These guidelines define the user’s responsibilities when deploying seismographs in the field.

1. Read the instruction manual. Every seismograph comes with an instruction manual. Users are responsible for reading the appropriate sections before monitoring a blast.

2. Seismograph calibration. Annual calibration of the seismograph is recommended.

3. Keep proper records. A seismograph user’s log should note: the user’s name, date, time, place and other pertinent data.

4. Record the blast. When seismographs are deployed in the field, the time spent deploying the unit justifies recording an event. As practical, set the trigger levels low enough to record each blast.

5. Record the full waveform. It is not recommended that the continuous recording option available on many seismographs be used for monitoring blast generated vibrations.

6. Document the location of the seismograph. This includes the name of the structure and where the seismograph was placed on the property relative to the structure. Any person should be able to locate and identify the exact monitoring location at a future date.

7. Know and record the distance to the blast. The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 feet would be measured to the nearest tens of feet and a blast within 10,000 feet would be measured to the nearest hundreds of feet.

Where elevation changes exceed 2.5h:1v, slant distances or true distance should be used.

8. Know the data processing time of the seismograph. Some units take up to 5 minutes to process and print data. If another blast occurs within this time the second blast may be missed.

9. Know the memory or record capacity of the seismograph. Enough memory must be available to store the event. The full waveform should be saved for future reference in either digital or analog form.

10. Know the nature of the report that is required. For example, provide a hard copy in the field, keep digital data as a permanent record or both. If an event is to be printed in the field, a printer with paper is needed.

11. Allow ample time for proper setup of the seismograph. Many errors occur when seismographs are hurriedly set-up. Generally, more than 15 minutes for set-up should be allowed from the time the user arrives at the monitoring location until the blast.

12. Know the temperature. Seismographs have varying manufacturer specified operating temperatures.

13. Secure cables. Suspended or freely moving cables from the wind or other extraneous sources, can produce false triggers due to microphonics.

Part II. Ground Vibration Monitoring

Placement and coupling of the vibration sensor are the two most important factors to ensure accurate ground vibration recordings.

A. Sensor Placement

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure. Sensor placement should ensure that the data obtained adequately represents the vibration levels received at the structure being protected. The sensor should be placed within 10 feet of the structure or less than 10% of the distance from the blast, whichever is less.

2. Soil density evaluation. The soil density should be greater than or equal to the sensor density. Fill material, sand, unconsolidated soils, flower-bed mulch or other unusual mediums may have an influence on the recording accuracy if not properly dealt with during geophone installation.

3. The sensor must be nearly level.

4. The longitudinal channel should be pointing directly at the blast and the bearing should be recorded.

5. Where access to the structure and/or property is not available, the sensor should be placed closer to the blast in undisturbed soil.

B. Sensor coupling

If the acceleration exceeds 0.2 g, slippage of the sensor may be a problem. Depending on the anticipated acceleration levels spiking, burial, or sandbagging of the geophone to the ground may be appropriate.

1. If the acceleration is expected to be:

a. less than 0.2 g, no burial or attachment is necessary

b. between 0.2 and 1.0 g, burial or attachment is preferred. Spiking may be acceptable.

c. greater than 1.0 g, burial or firm attachment is required (USBM RI 8506).

The following table exemplifies the particle velocities and frequencies where accelerations are 0.2 g and 1.0 g.

Frequency, Hz	4	10	15	20	25	30	40	50	100	200
Particle Velocity - in/s at 0.2 g	78.1	31.2	20.8	15.6	12.5	10.4	7.8	6.2	3.1	1.6
Particle Velocity - in/s at 1.0 g	390.3	156.1	104.1	78.1	82.5	52.0	39.0	31.2	15.6	7.8

Burial or attachment methods.

a. The preferred burial method is excavating a hole that is no less than three times the height of the sensor (ANSI S2.47-1990, R1997), spiking the sensor to the bottom of the hole, and firmly compacting soil around and over the sensor.

b. Attachment to bedrock is achieved by bolting, clamping or gluing the sensor to the rock surface.

c. The sensor may be attached to the foundation of the structure if it is located within +/- 1-foot of ground level (USBM RI 8969). This should only be used if burial, spiking or sandbagging is not practical.

3. Other sensor placement methods.

a. Shallow burial is anything less than described at 2a above.

b. Spiking entails removing the sod, with minimal disturbance of the soil and firmly pressing the sensor with the attached spike(s) into the ground.

c. Sand bagging requires removing the sod with minimal disturbance to the soil and placing the sensor on the bare spot with a sand bag over the top. Sandbags should be large and loosely filled with about 10 pounds of sand.

When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.

d. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

C. Programming considerations

Site conditions dictate certain actions when programming the seismograph.

1. Ground vibration trigger level. The trigger level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 0.05 in/s.

2. Dynamic range and resolution. If the seismograph is not equipped with an auto-range function, the user should estimate the expected vibration level and set the appropriate range. The resolution of the printed waveform should allow verification of whether or not the event was a blast.

3. Recording duration - Set the record time for 2 seconds longer than the blast duration plus 1 second for each 1100 feet from the blast.

Part III Airblast Monitoring

Placement of the microphone relative to the structure is the most important factor.

A. Microphone placement

The microphone should be placed along the side of the structure nearest the blast.

1. The microphone should be mounted near the geophone with the manufacturer's wind screen attached.

2. The preferred microphone height is 3 feet above the ground or within 1.2 inches of the ground.

Other heights may be acceptable for practical reasons. (ANSI S12.18-1994, ANSI S12.9-1992/Part2) (USBM RI 8508)

3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.

4. If placed too close to a structure, the airblast may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Reflection can be minimized by placing the microphone near a corner of the structure. (RI 8508).

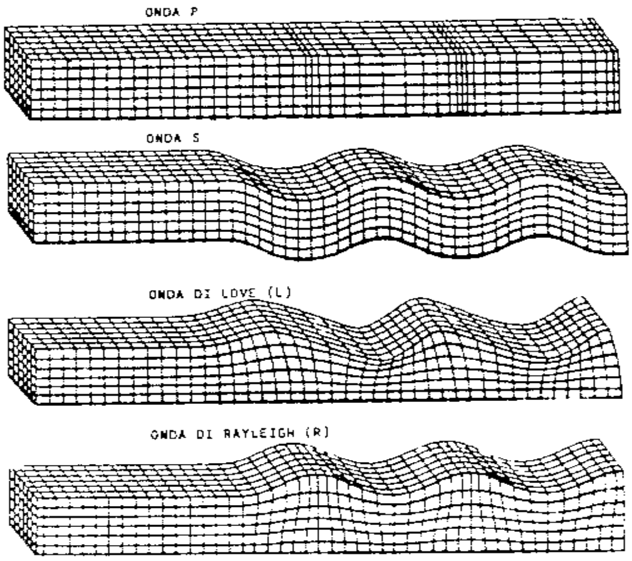
Programming considerations

1. Trigger level. When you want to measure only the overpressure airblast. the acoustic trigger level must be set sufficiently low to record the event but sufficiently high to avoid false starts. The trigger level must be set slightly higher than the bottom of the site. On average, a good starting level is 120 db.

2. Recording duration. When only recording airblast, set the recording time for at least two seconds more than the blast duration. When ground vibrations and airblast measurements are desired on the same record, follow the guidelines for ground vibration programming (Part II C.3).

Elementary wave components

Two main types of waves are generated from the explosion of a mine (in general from any kind of impulsive energizing a solid means): volume waves and surface waves.
Volume waves consist of pressure or compression P waves and S waves, cutting waves.
Surface waves consist of R (Rayleigh and L Love).
R and L surface waves have a lesser speed of propagation than volume waves so that, at a certain distance from the point of explosion, they can be distinguishable in the tail and train of the seismic wave.



Volume waves propagate around a spherical front and when they intercept the surface of the ground or interface between two means with different elastic characteristics, or a joint in a bedrock, they generate cutting waves and surface waves.
The surface waves move with a wave front that can be approximately cylindrical.

Characteristic parameters and their functional connections

Among the characteristic parameters of seismic waves and the vibrations associated with them, those relevant in terms of safety and unease are:

- speed of propagation of the train of wave “C” (depending on the physical and geo-mechanical characteristics of the means of propagation and the type of wave);
- movement “s”, speed “v” and acceleration “a” of the ground at the passage of the transient seism;
- dominant frequency of the train of seismic wave “f”;
- relation between predominant wave “f” and frequency of the oscillating building.

Approximating the vibrations to a sinusoidal oscillatory movement, we have the following functional connection: $v = 2 \cdot \pi \cdot f \cdot s$; $a = 2 \cdot \pi \cdot f \cdot v$.

Usually the acceleration is given in units of acceleration of gravity “g” with g = 9814 mm/s^2.
It follows that an acceleration of 2,000 mm/s is equal to: 2,000/9814 =0.2g.

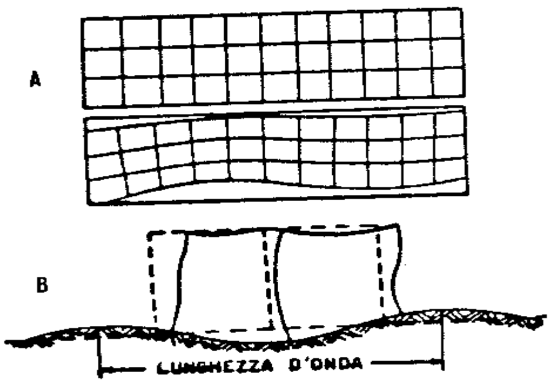
The frequency of agitation induced in the structure is determined by the evaluation of the stress it is subjected to and it is, therefore, necessary to record the entire form of the wave to identify it. Adopting criteria about the effects induced by the vibrations based upon the frequency imposes particular care in estimating and calculating the dominant or main frequency. The dominant frequency can be estimated through the visual analysis of the form of the wave (CALCULATION OF THE FREQUENCY ASSOCIATED WITH THE PEAK - zero crossing) or calculated through the spectrum of response (SPETRUM OF RESPONSE) or the spectrum of Fourier's frequency (CALCULATION OF FOURIER'S TRANSFORMATION).
The best approach for calculating determination of the dominant frequency is the spectrum of response. The spectrum of response is to be preferred to Fourier's spectrum because it can be correlated to the movements of the structure and, therefore, to the deformations.

Transient and prolonged seismic waves

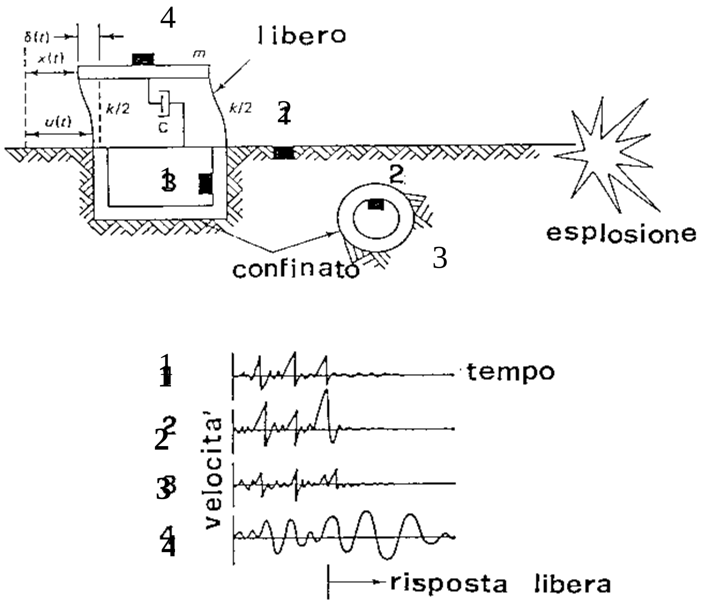
As a first approximation vibrations can be divided into "transient" or "prolonged" types (**DIN 4150-3** regulation).
By "transient" we mean those vibrations that take place with insufficient repetition to provoke effects of fatigue in the materials or whose dominant or recurrent frequency does not provoke agitation in the specific structure. In this case the effects are essentially connected to the stresses transmitted directly to the structure and absorbed by inertia (figure).

Transient vibrations on structures smaller than the wavelength of the seismic impulse (consequent stresses)

those indirect because of oscillation of the structure itself and/or because of differentiated movements by the component parts. (figure). For this latter type relevance, for safety, also assumes the degree of freedom of the structure (figure).



Effect of prolonged vibrations. Different response to transient seism of structures with various



Different type of response of the structures to seismic waves.

As a first approximation, the stresses associated with a transient seism in the means can be calculated with the formula:

$\sigma X = \rho \cdot C_P \cdot vX$; $\tau XY = \rho \cdot C_S \cdot vXY$ [Kolsky 1963].

- where (letter) is the density of the means of propagation
- (letters) are respectively the speed of propagation of the seismic waves of compression (letter) and cut (letter);
- vX and vXY are respectively the speed of oscillation of the particles in the longitudinal (X) and transversal (XY) direction with respect to that of the propagation of the wave.

(ILLUSTRATION)

Direction of propagation parallel to stratigraphic joints
channeling the waves - Love waves) -
less rapid reduction of the amplitude
of the waves.

Direction of slant propagation to stratigraphic joints
- greater rapidity in reduction of the amplitude
of the waves.

A part of the energy released by the explosion of the charge in the bedrock to demolish disperses into the air. The fraction of energy that disperses into the air increases with the decrease in the confinement of the charge in the bedrock and is at maximum in explosions in the open air, away from the soil (figure 1 [Baker 1973].
As for vibrations induced in the ground, overpressure airblast waves can also be described in the form of a wave (amplitude varying over time) as shown. A fraction of the highest frequency of overpressure enters into the range of hearable frequency (noise). Lesser fractions of frequency are less hearable but agitate the structure provoking movements, which, in their turn, produce a characteristic shaking noise (rattling), causing many complaints. The agitation of the masonry due to the airblast wave is visible comparing the agitation from the airblast with the response of the masonry at the extreme right part of the vibrogram, where there is no long movement of the ground. Different to the movement of the ground, the airblast wave can be completely described by measurement with a single seismograph because the value of airblast overpressure at any point is equal in each of the three slant directions.

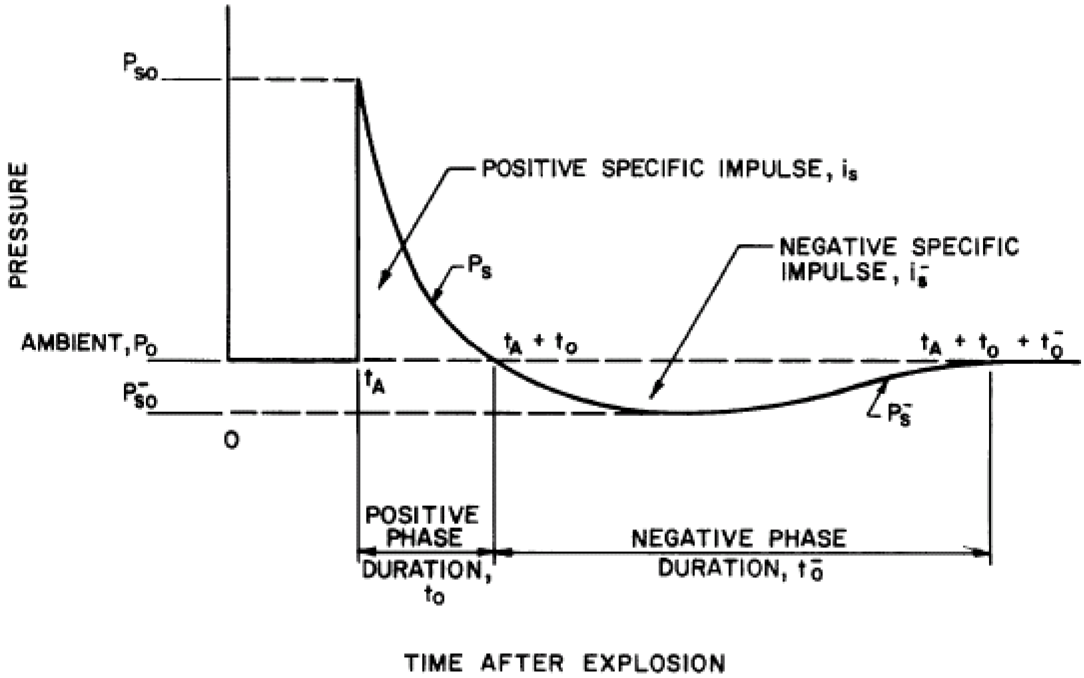
The propagation of the overpressure wave is generally indicated by a normalization of the distance from the point of explosion on the cube of the charge rather than the square. The peak of the pressure is shown in decibels "Db" that are defined as $dB = 20 \log_{10}(P/P_0)$, where P is the peak of over pressure and P_0 is a pressure of reference equal to $2x10^{-7}$ Pa.

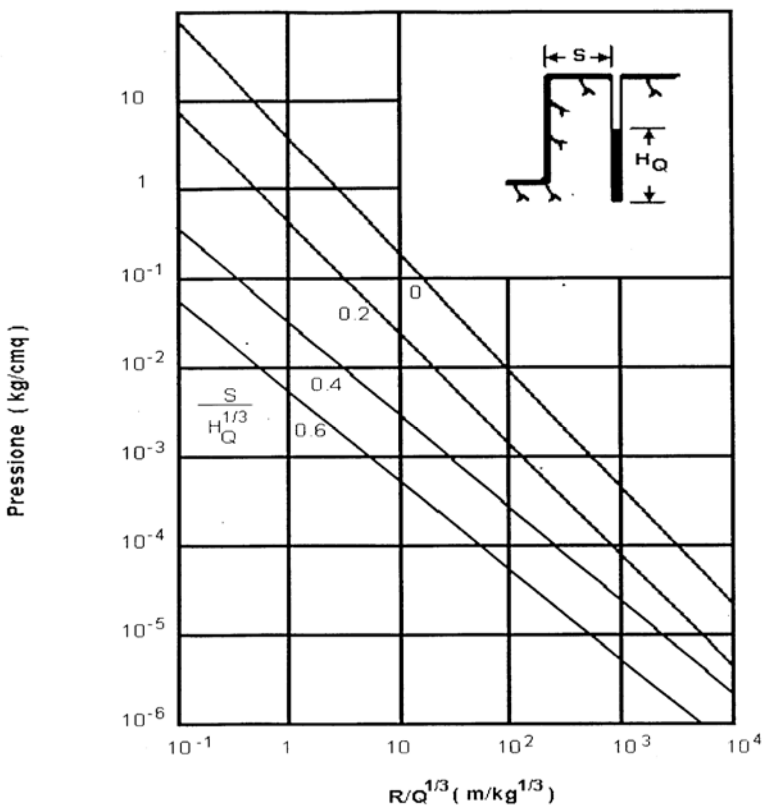
To calculate a first approximation, the values of the peak of airblast overpressure induced by the explosion of the charge in function of the distance from the point of the blast, the quantity of explosive and the confinement of the bedrock, refer to the graph in figure 2 [Hoek 1977], 3, 4 and 5 [Siskind 1980].

"The tolerability to noise", or rather the peak of airblast overpressure induced by the explosion of the explosive charge depends on the amplitude of the overpressure, the number of daily repetitions and the predominant frequency of the overpressure impulse.

In figure 5 are shown the guideline values established experimentally by the CHBA Committee on Hearing Bioacoustics and Biomechanics, Washington D.C., USA [Siskind, 1980].

Form of overpressure waves induced by the detonation. The duration of the negative phase (?), or rather the time of return to environmental pressure, increases progresively with the increase in distance from the point of detonation.





Explosive charges in function of distance from the point of demolition "S" (Hoek 1977)

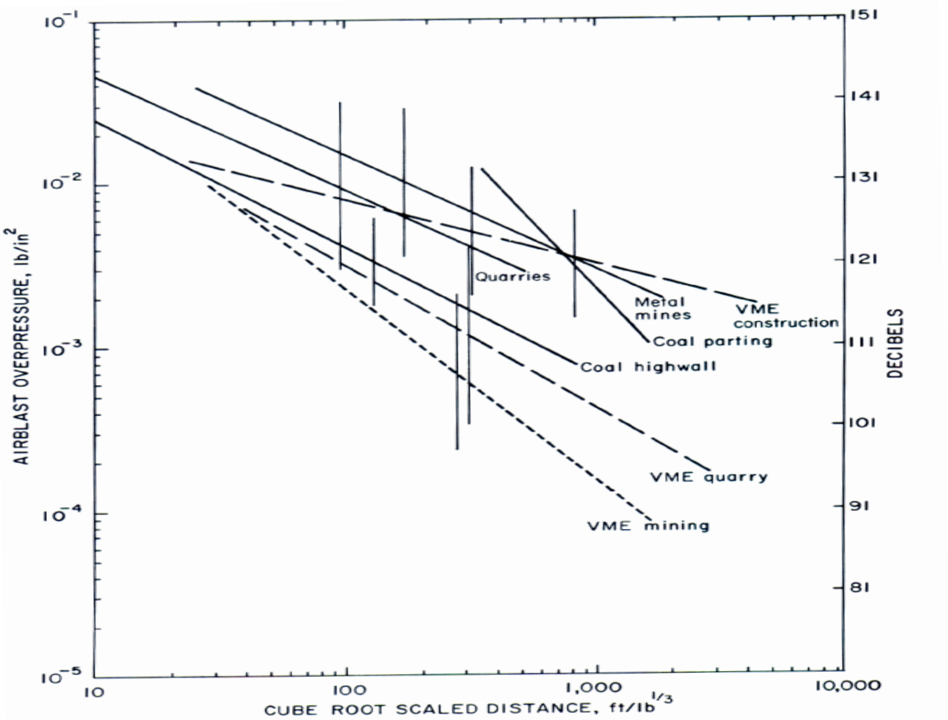


FIGURE B-3. - Airblasts from various types of mining, 0.1-Hz high-pass.

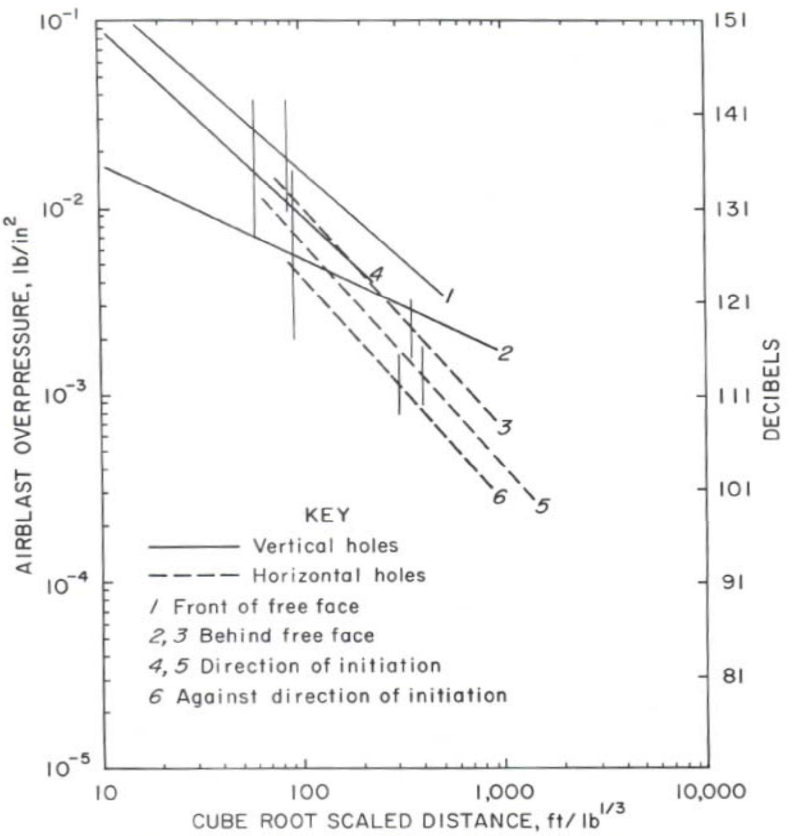


FIGURE B-4. - Airblast propagation from various face orientations.

Graph – in inglese

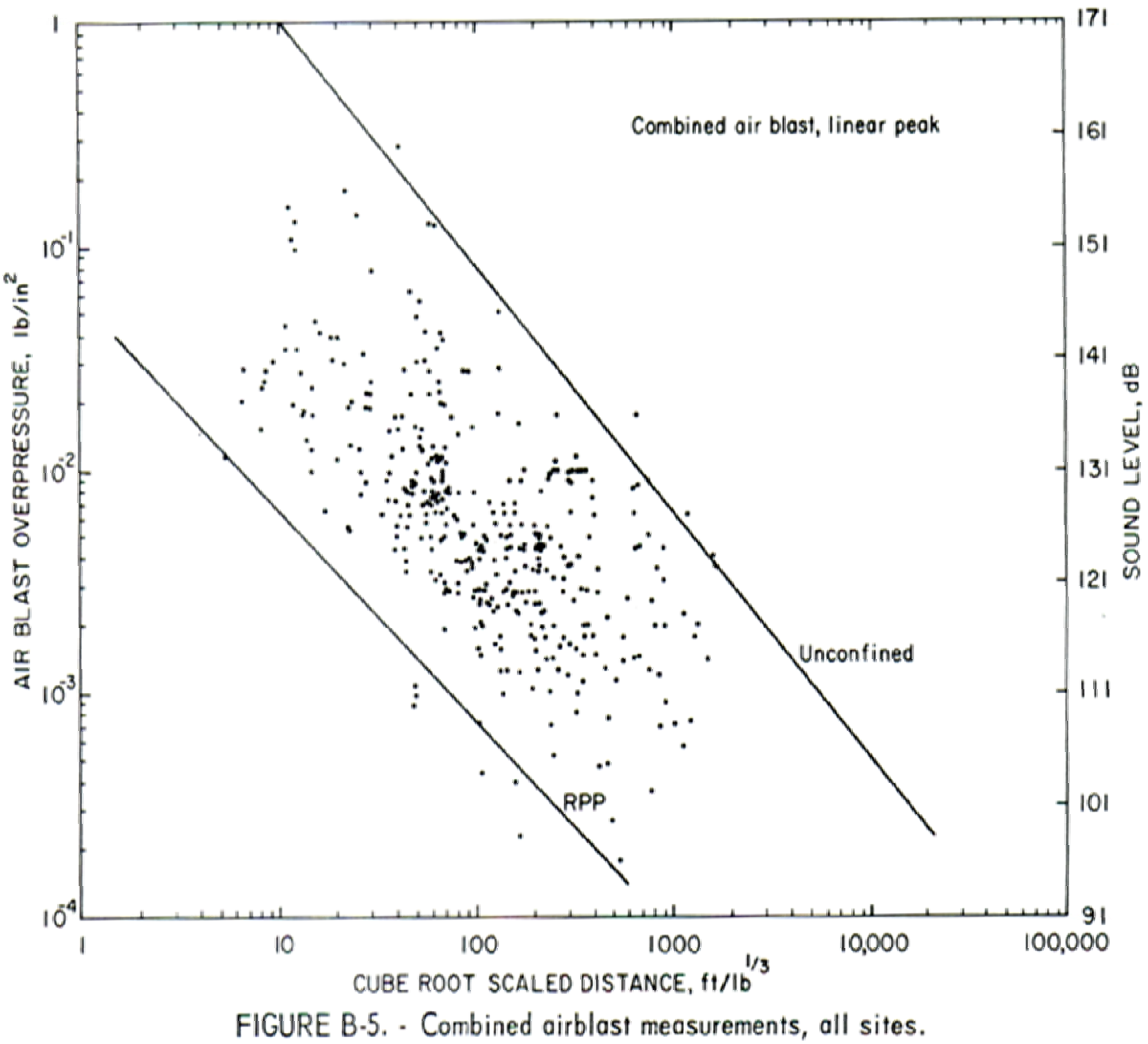


Figure 5 – range of variation of demolition curves from airblast waves induced by the explosion of explosive charges in various types of mining. (Siskind 1980)

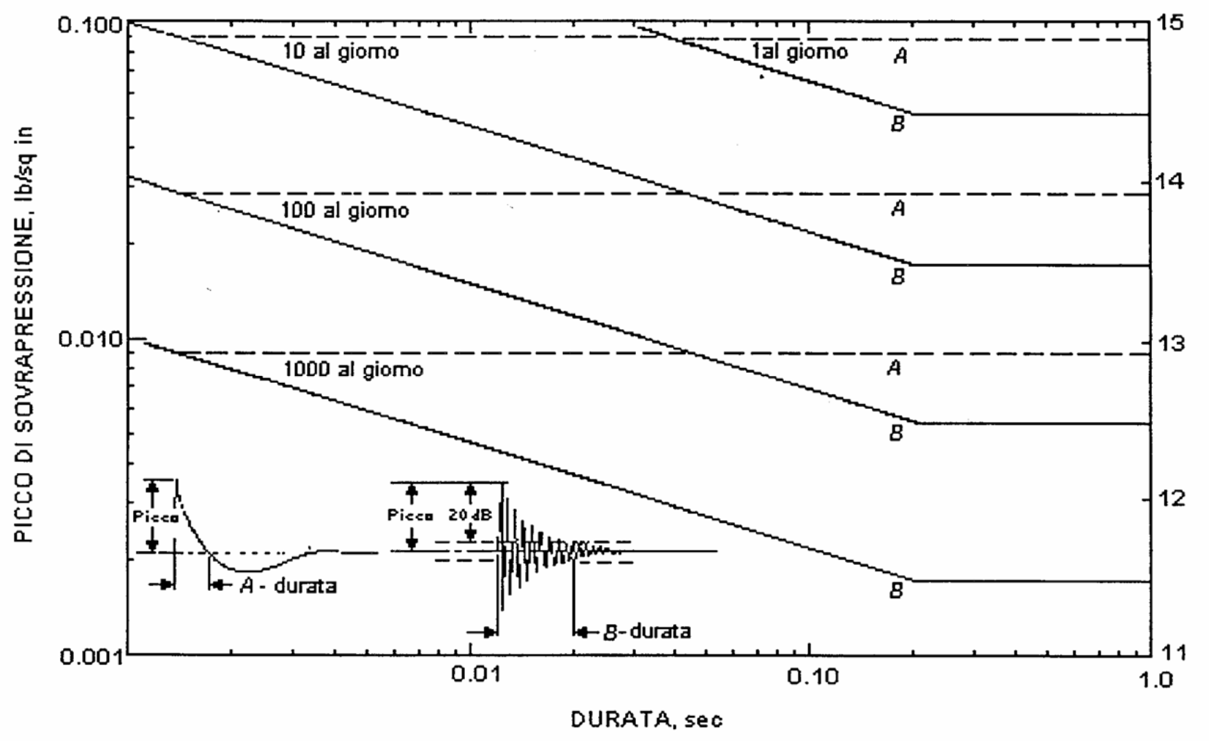


Figure 5 – Value guide for being able to bear the peaks of airblast as established experimentally by the CHBA Committee on Hearing Bioacoustics and Biomechanics, Washington D.C.,USA (Siskind, 1980).

OVERPRESSURE WAVES IN WATER

Part of the energy freed by the explosion disperses in water as overpressure waves. The fraction of energy that it transmits in water depends on the confinement of the charge and is at maximum for free charge explosions in water and far from the bottom.
Stress associated with overpressure waves in water gives rise to resentment among the nearby buildings.
To check the safety of the surrounding buildings, lacking specific regulation, stresses and impulses produced by explosions can be calculated using the following graphs.
To reduce the pressure on nearby buildings a wall of buoys can be built, releasing

$0.004 m^3/s$ per linear meter of tubing (reduction of stress by about 1/10)
$0.008 m^3/s$ per linear meter of tubing (reduction of stress by about 1/40)

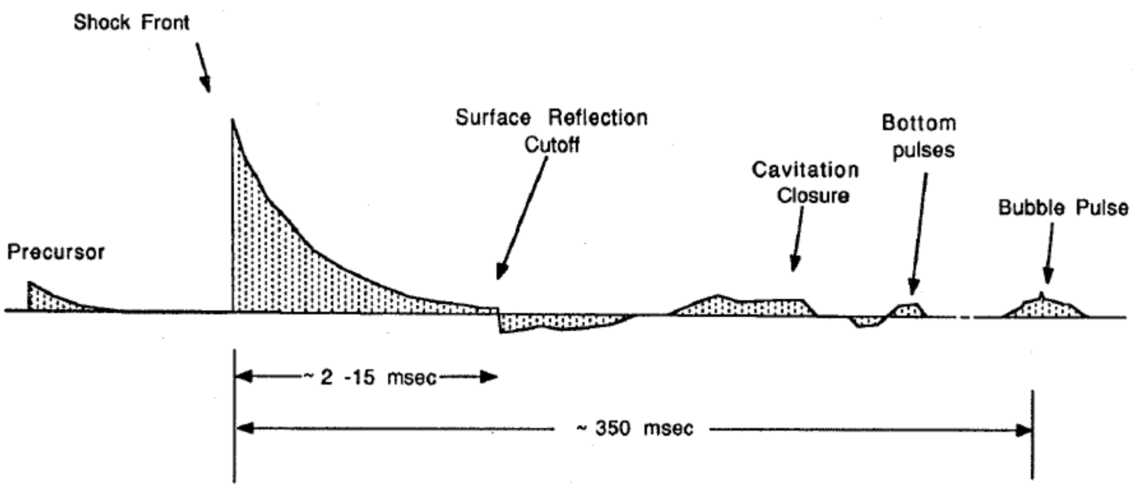
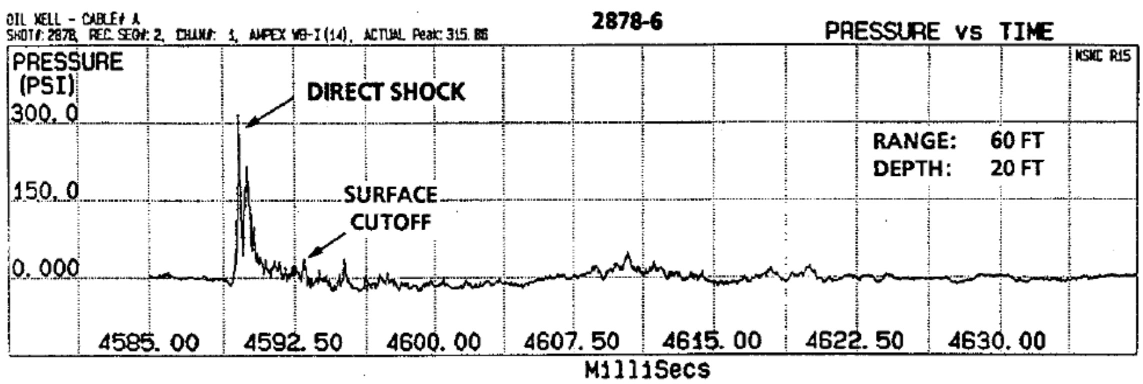


FIGURE 3-3. IDEALIZED UNDERWATER EXPLOSION PRESSURE SIGNATURE



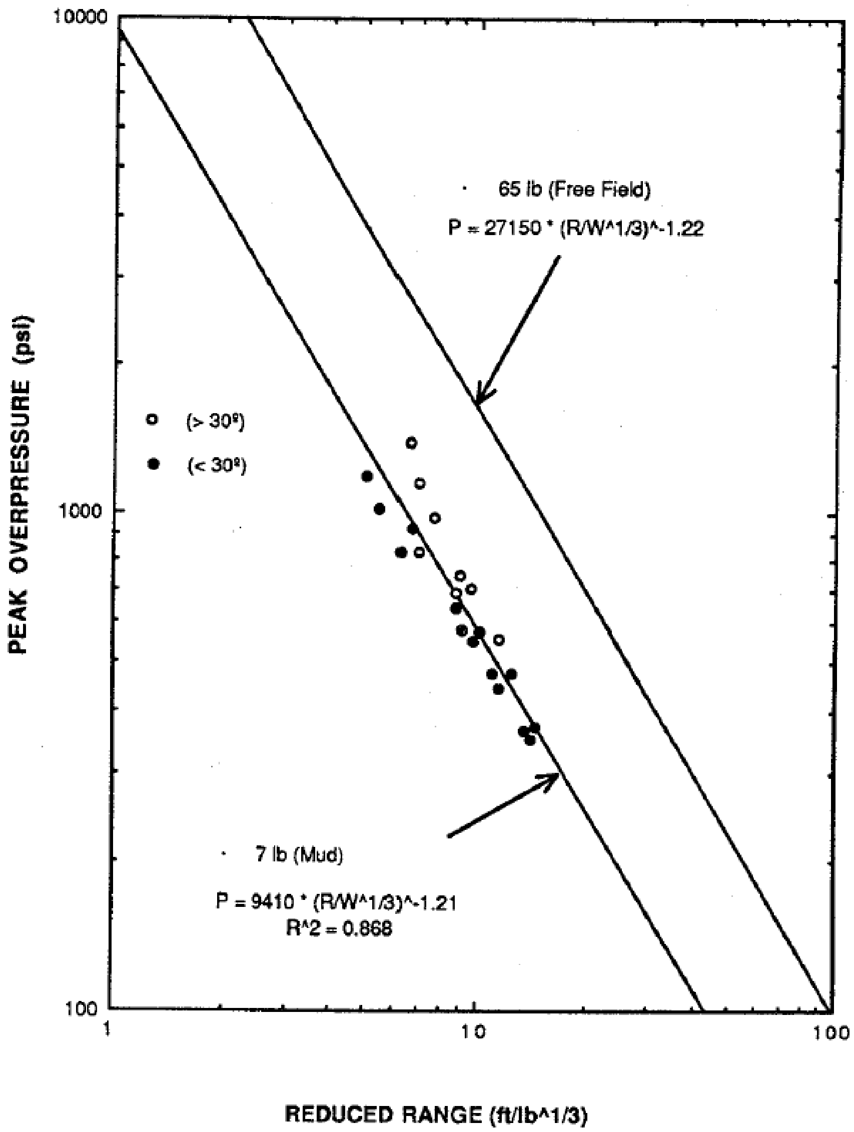


FIGURE 2-3. PEAK PRESSURE FROM HALF-SCALE BURIED CHARGE TESTS

Peak of overpressure in water at variation of distance scaled on the cube of the charge, consequent to the detonation of charges of TNT equ: (4.52 kg) exploded both freely and confined under the bottom of the sea mud (Condor G.J. "Underwater blast effects from explosive severance of offshore platform legs and well conductors". Naval Surface Welfare Center TR:80-532, Maryland, USA, 1990).

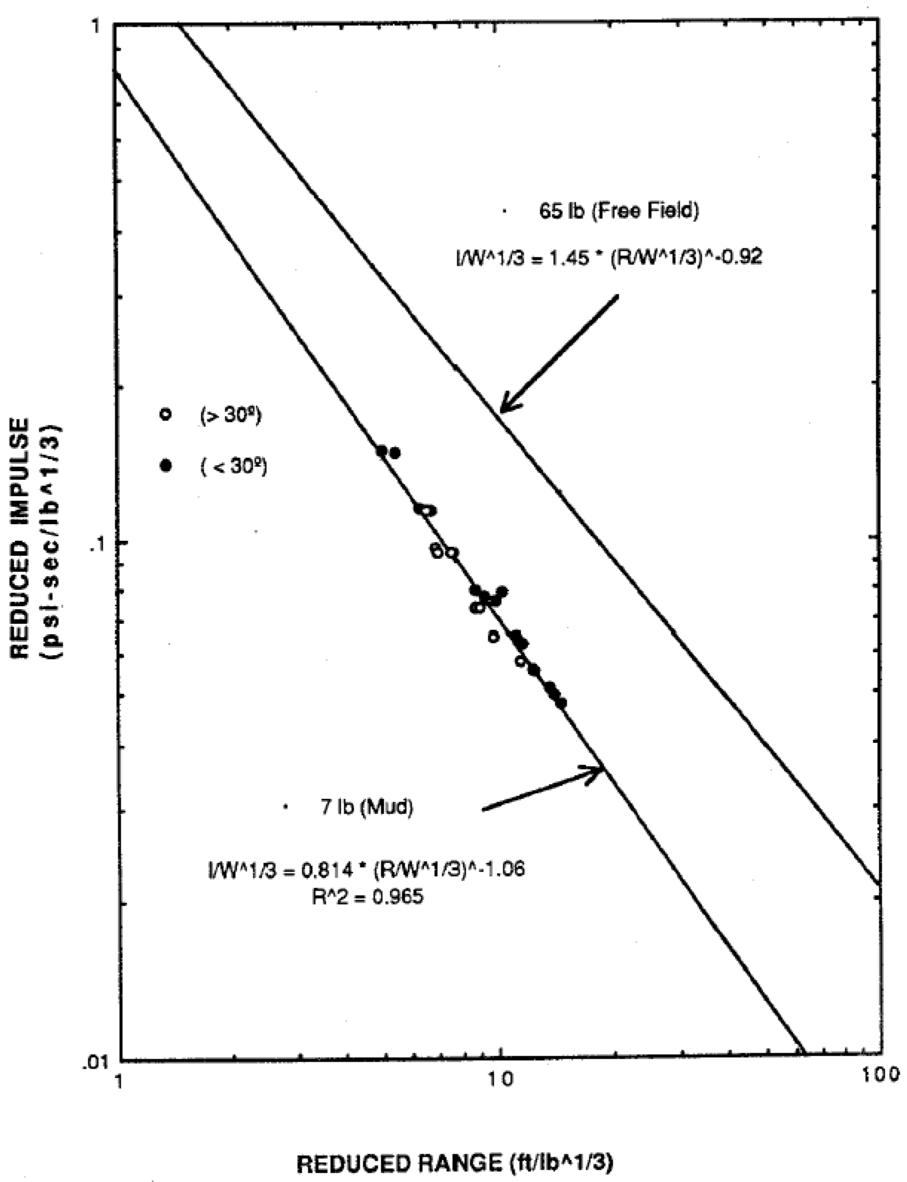


FIGURE 2-4. REDUCED IMPULSE FROM HALF-SCALE BURIED CHARGE TESTS

Impulse scaled on the charge at variation of the scaled distance on the cube of the charge consequent to the detonation of charges of TNT equ: (4.52 kg) exploded both freely and confined under the bottom of the ea mud (Condor G.J. "Underwater blast effects from explosive severance of offshore platform legs and well conductors". Naval Surface Welfare Center TR:80-532, Maryland, USA, 1990).

The demolition blast must be targeted at optimizing the best safety, technically efficiency and economic conditions.
It is necessary to design, perform, collect data and technical-economic data by intervening on the following parameters to optimize;

- acting on the perforation (choice of diameter of perforation, aiming at the reduction of the specific perforation);
- seabed insertion (choice of a suitable relation between practical demolition back and centerpiece);
- Charging blast time (choice of perforation diameter, type of explosive, and charging system, the number of holes for the blast, the number of blasts to explode a year….;)
- Safety in carrying out demolitions (minimizing noise, launches, vibrations, back-fracturing of the bedrock-overbreak);
- Incidence of explosives and fires (size of transport, cost-efficiency relation, type of explosives….:)

To optimize the technical-economic parameters of a demolition blast with sequential explosion of several holes, above all if in different files, you must have precise information available about the work carried out on each single hole. Organoleptic control does not allow an analysis in depth in view of the rapidity of the succession of explosions, so it becomes necessary to integrate it with instrumental controls – high-speed video and seismic monitoring;

It is appropriate to use at least three monitoring stations with digital recording, each equipped with tri-axial seismographs (x,y,z) of vibration speed for measuring the horizontal radial, horizontal transversal and vertical components and a microphone for measuring the airblast.

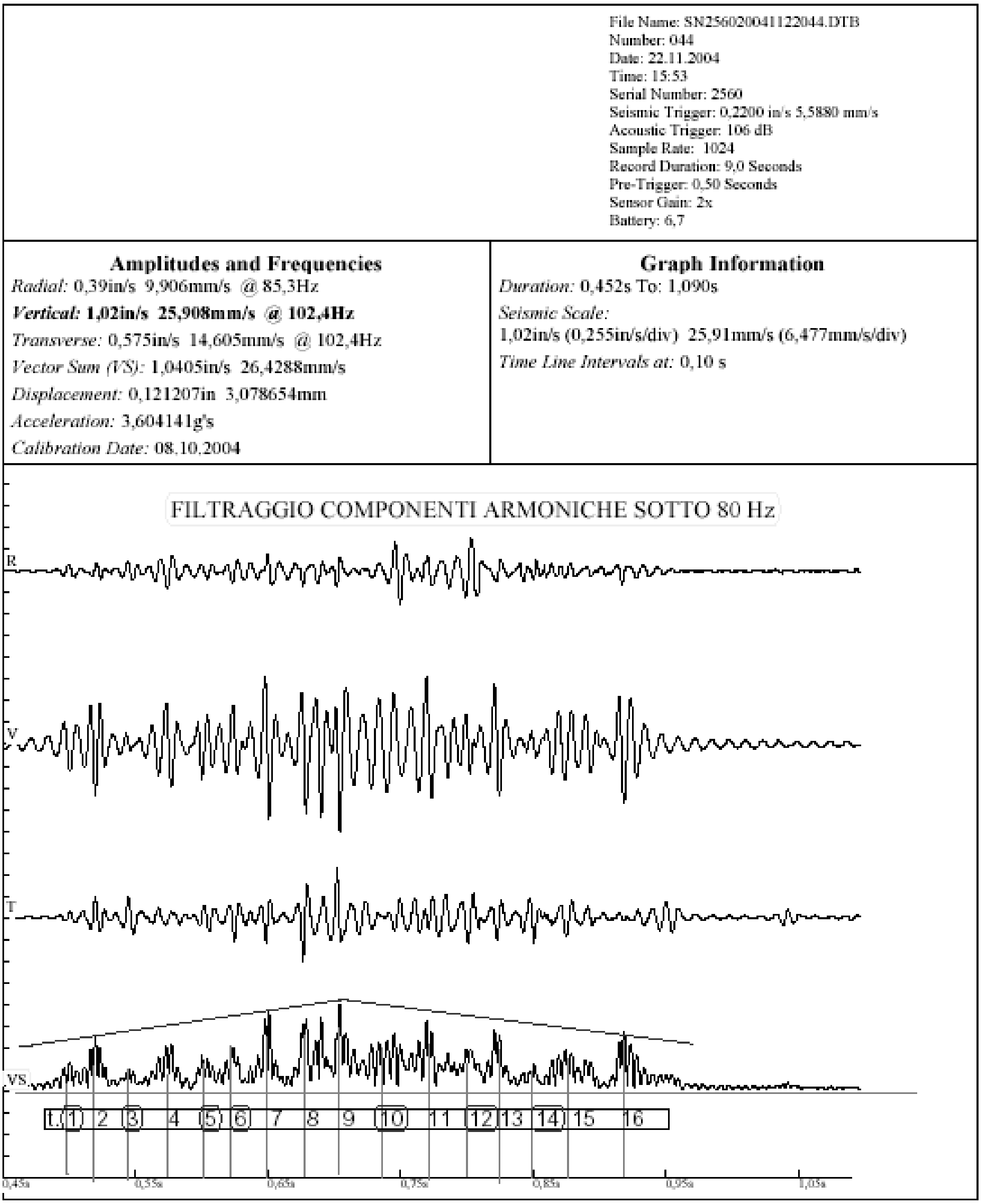
<u>The first point of measurement</u> should be chosen close to the blast (about 3-10 cm) deep in the bedrock, not less than a meter, so as to minimize the interference determined by refraction on the free surface of the seismic wave. In the case of open-air blasts with step demolition it is appropriate to place a GEOPHONE AT THE BOTTOM OF THE HOLE held to the wall with double wedges. Alternatively, a geophone for measuring surfaces could be used clamped to the bedrock with spikes so as not to be thrown up because of the high acceleration. In addition, it must be covered with sacks of sand for both mechanical protection and minimizing the “microphone effect” (apparent seismic waves determined by the impact of the acoustic wave on the wall of the geophone).
The acquisition of the signal must be made with sampling frequently equal to not less than a 2kHz/channel, in order to be able to distinguish with sufficient definition the peaks due to sequential explosions of each charge, even in the case of successive closeness of blasts (e.g. 25mm).

The second point of measurement should be chosen at a distance of about twice the size of the blast so that it is reduced but not completely eliminated. The interference of the effect of scale of the blast (e.g. for blast with step 10 m and alignment of 20 m), the point of measurement could be chosen around 30 ÷50 m from the blast.

The third point of measurement should be chosen at a distance equal to 5 times the size of the blast so that interference is eliminated by the effect of the scaled blast.
The interference of the effect of scale of the blast (e.g. for blast with step 10 m and alignment of 20 m), the point of measurement could be chosen around 80 ÷120m from the blast.

If possible, the various points of measurement should be aligned and the measurements must be synchronized (start of the measurement in the three stations commanded by exceeding the threshold of the trigger of the nearest station) so that it is possible to obtain a good level of approximation in estimating the significant geo-mechanical parameters of the bedrock: (module of the elasticity of the bedrock, index of fracturing of the mass of rock, etc.).

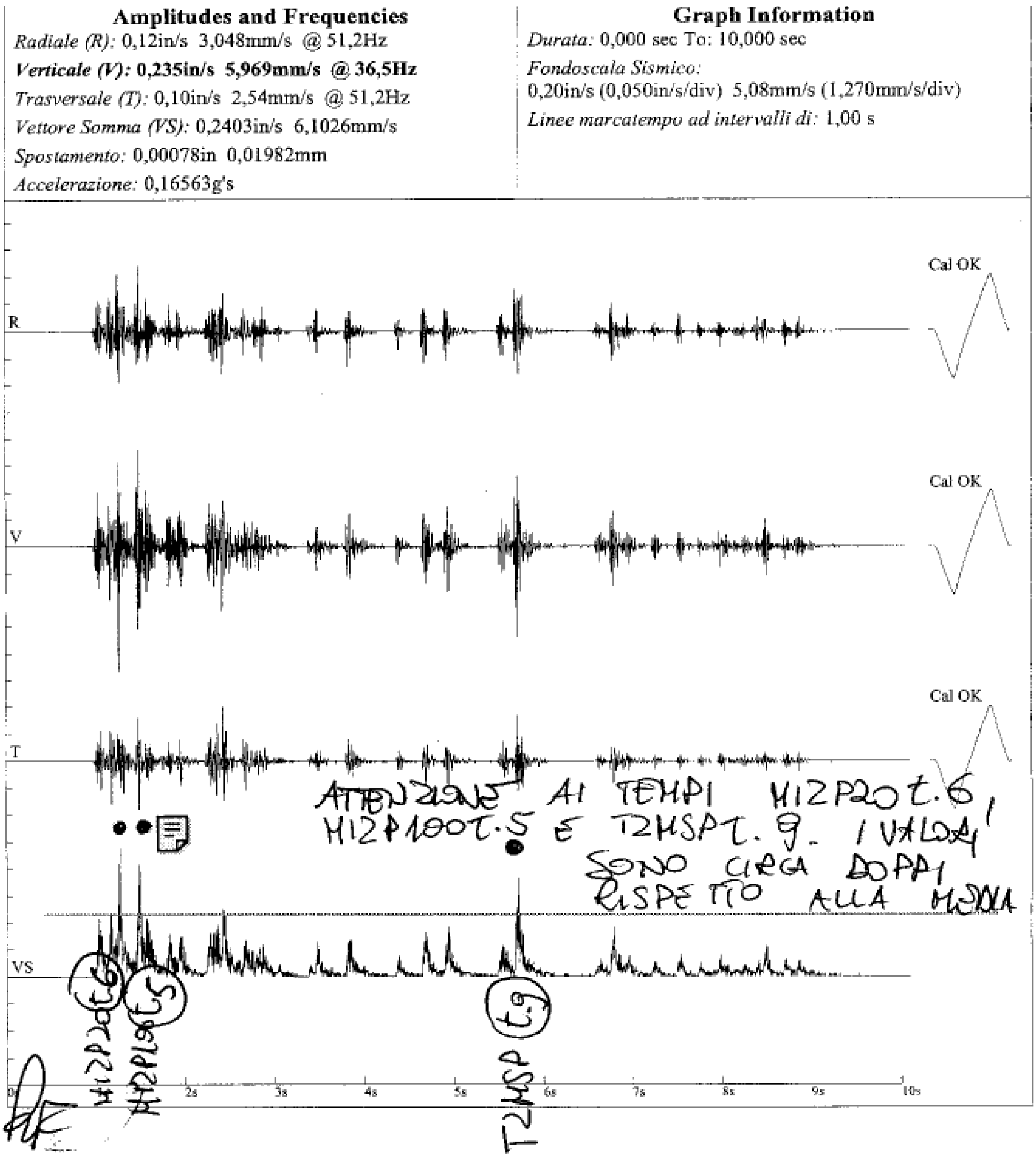
Example of analysis of seisms induced by each demolition hole in step blasts



From the analysis of the graph we find that holes exploded with timing 1, 3, 5, and 6, 10, 12, 14 induced less seismic energy in the bedrock with respect to other holes. It follows that the volume of rock demolished has opposed less resistance (presumably because part of the volume of influence of the hole has been demolished by previous holes). The energy released by the explosion did not, therefore, have efficient use as it was used to demolish a volume of rock inferior to what would have been possible.

From the analysis of this blast it might therefore be proposed adjusting the next blast with an increase in the area of influence of the holes.

Example of analysis of seisms induced by each series of bored demolition holes



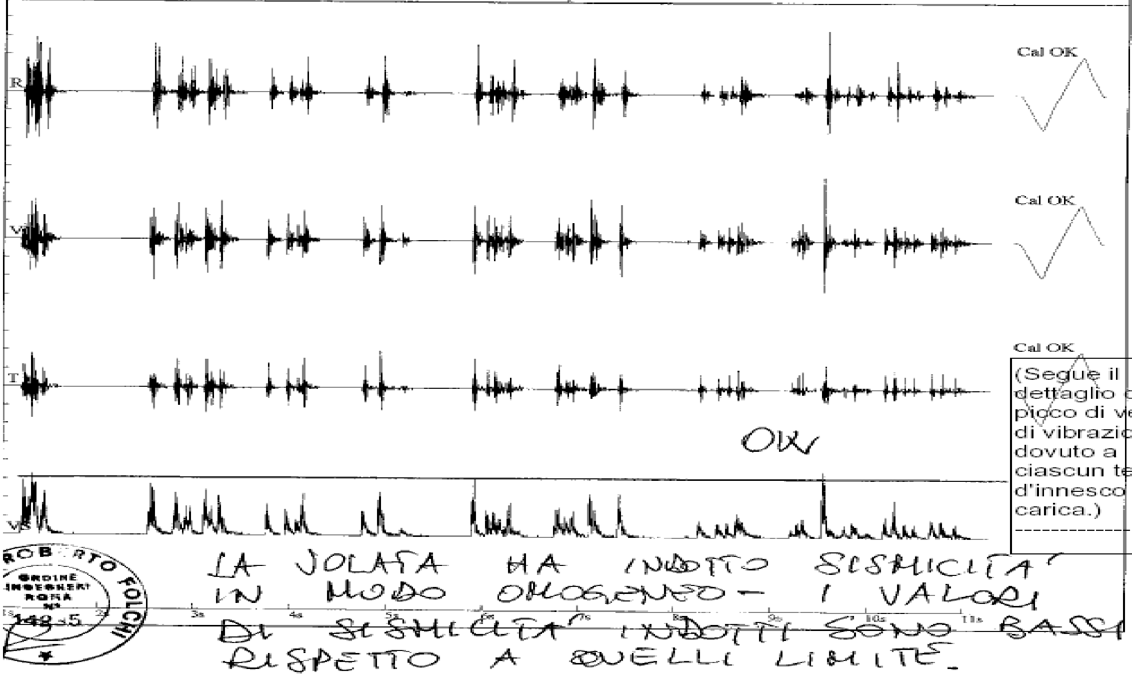
From the analysis of the graph we find that the holes exploded in 6-series, 20 ms, 5-series, 100 ms and 9-series, 500 ms time induced in the bedrock almost double the seismic energy with respect to the other holes, therefore, maintaining respect for the value limit and safety and unease, the average seismic level can be increased, concentrating the charge In a fewer number of holes with larger charge to reduce the incidence in perforation and charging time.

Amplitudes and Frequencies

Radiale (R): 0,17in/s 4,318mm/s @ 64,0Hz
Verticale (V): **0,175in/s 4,445mm/s @ 64,0Hz**
Trasversale (T): 0,10in/s 2,54mm/s @ 85,3Hz
Vettore Somma (VS): 0,1757in/s 4,4631mm/s
Spostamento: 0,00044in 0,01124mm
Accelerazione: 0,20538g's

Graph Information

Durata: 0,801 sec To: 11,000 sec
Fondoscala Sismico:
0,20in/s (0,050in/s/div) 5,08mm/s (1,270mm/s/div)
Linee marcatempo ad intervalli di: 1,00 s



(Segue il dettaglio di del picco di velocità di vibrazione dovuto a ciascun tempo d'innesco della carica.) ------------------->

Amplitudes and Frequencies

Vettore Somma (VS): 0,1757in/s 4,4631mm/s
Spostamento: 0,00044in 0,01124mm
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Graph Information

Durata: 0,801 sec To: 11,000 sec
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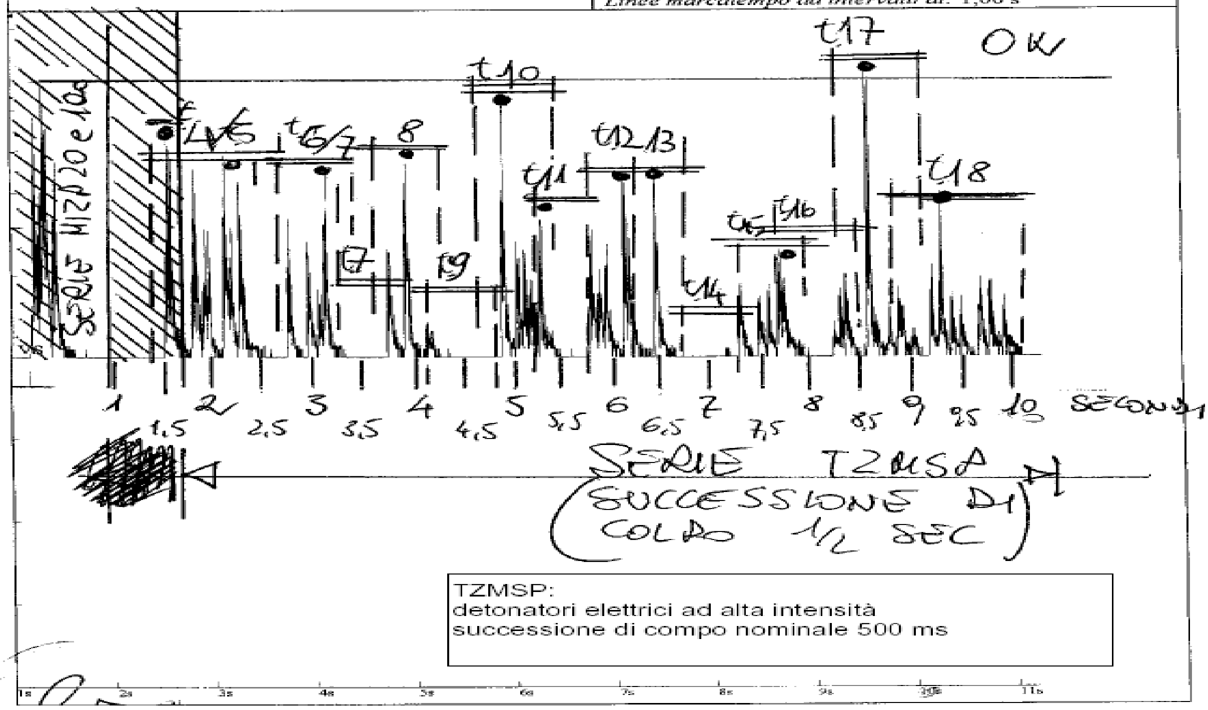
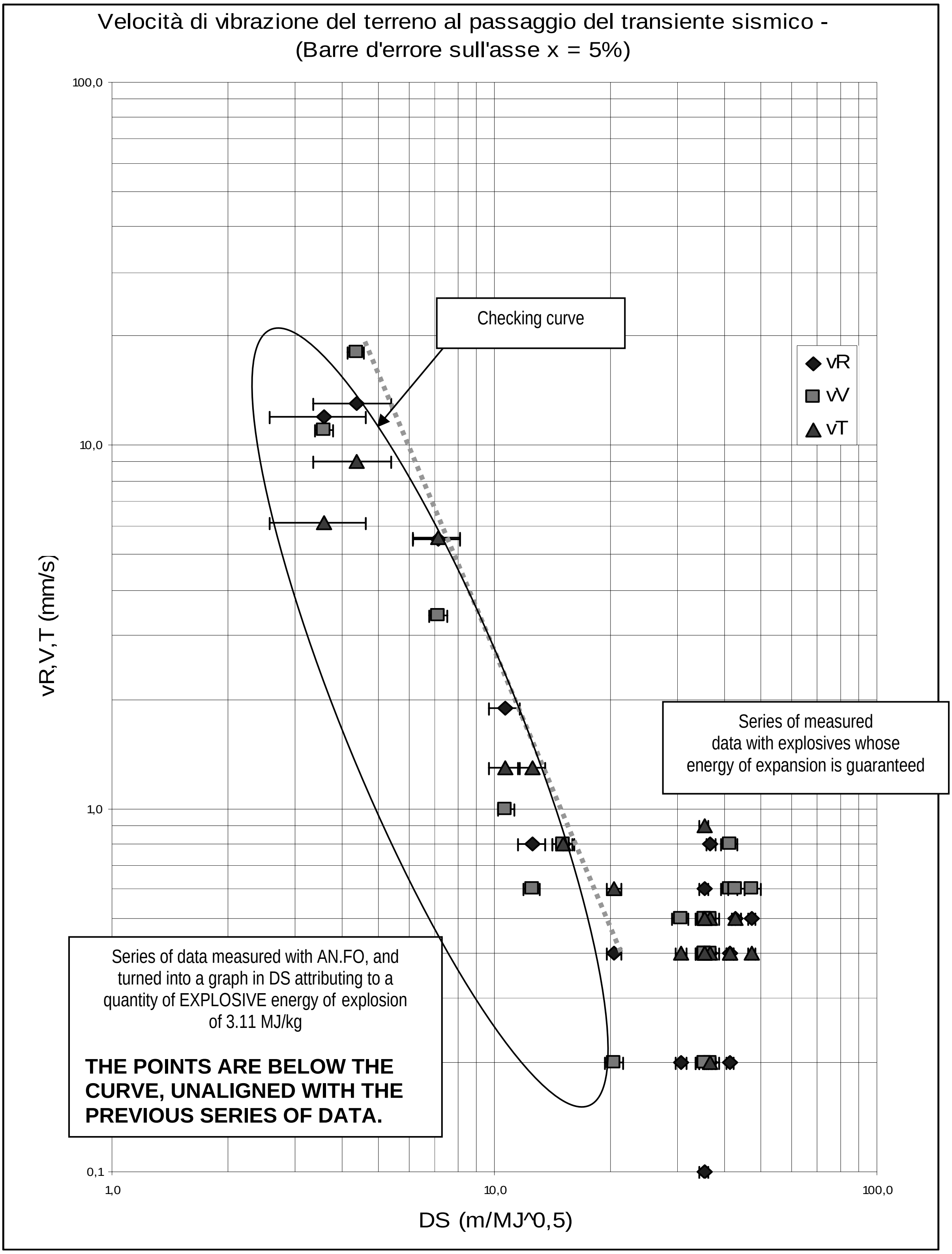
0,20in/s (0,050in/s/div) 5,08mm/s (1,270mm/s/div)
Linee marcatempo ad intervalli di: 1,00 s



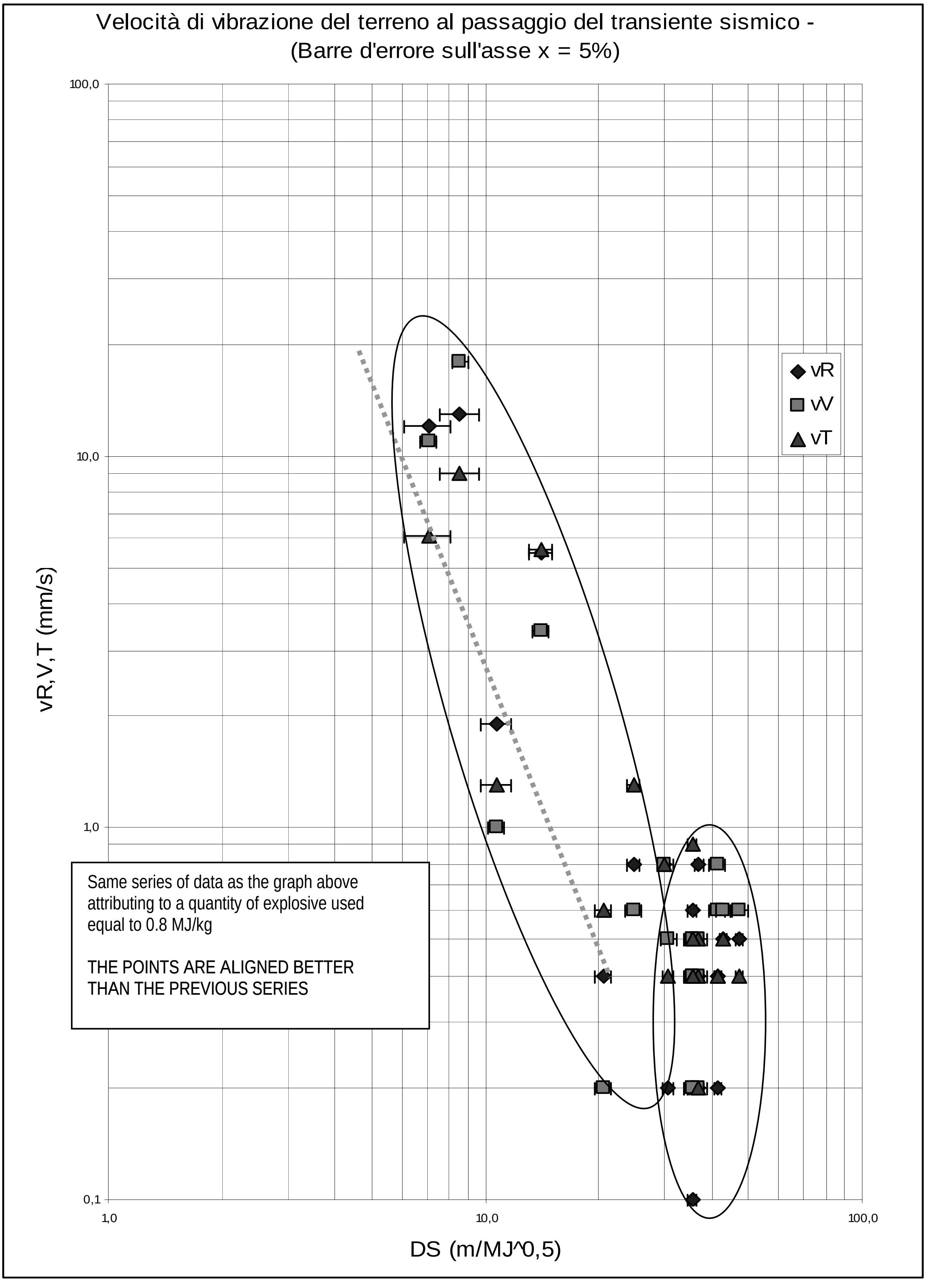
TZMSP:
detonatori elettrici ad alta intensità
successione di compo nominale 500 ms

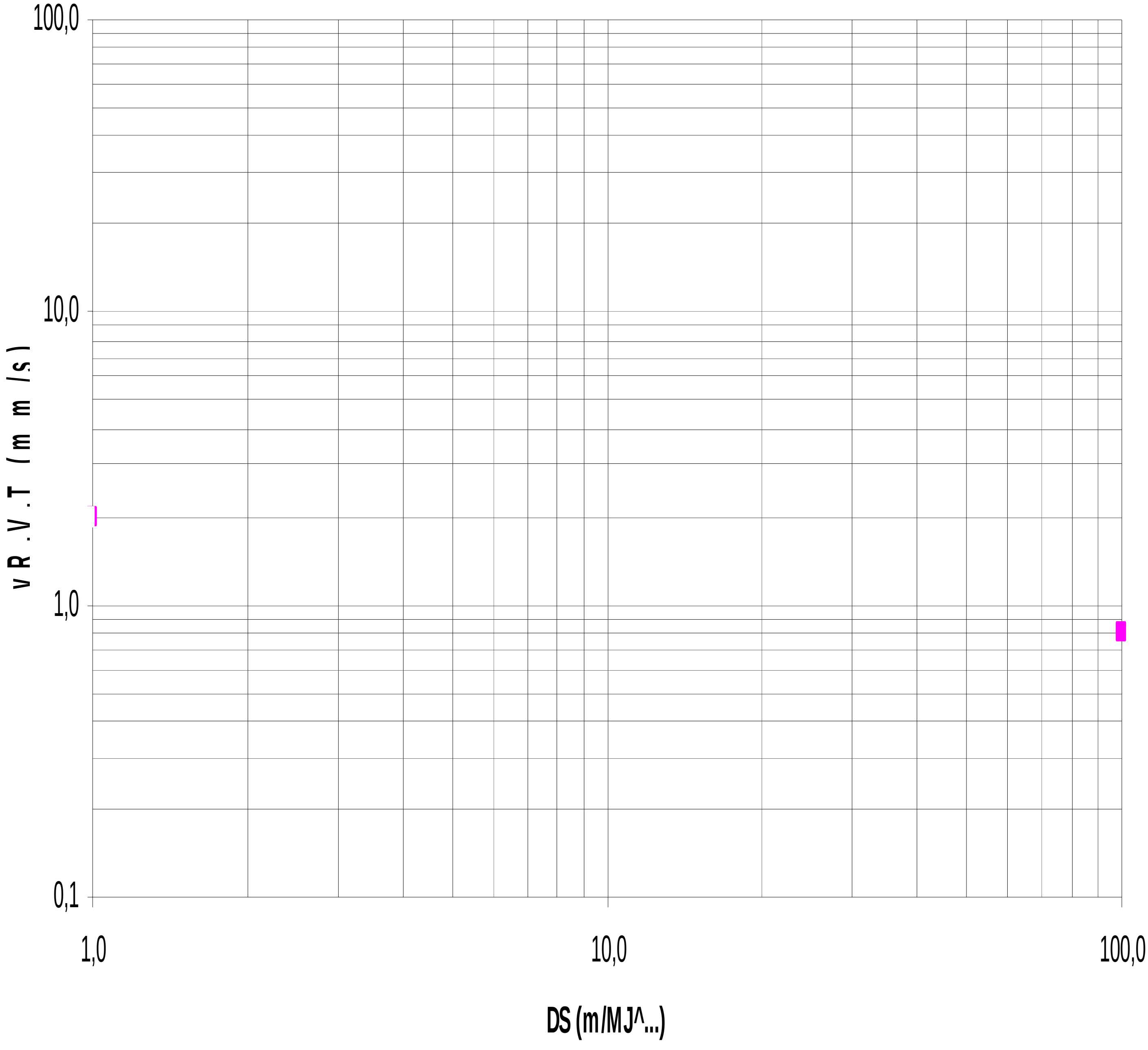
<u>Check of the yield of the An.Fo. - rec. NTX</u>
OR THE SPECIFIC CHARGE OF THE EXPLOSION

The measured data are shown in the following bilogarythmic graphs, attributing a specific energy of explosion like that of the technical diagram = 3.11 MJ/kg.



The measured data are shown in the following bilogarythmic graph, attributing a quantity of explosive used equal to 0.8 MJ/kg




100,0
10,0
1,0
0,1
1,0
10,0
100,0
DS (m/MJ^...)
v R . V . T (m m / s)

Collection of data for the MEASUREMENT REPORT model DN 4150-3

Ref.

---

progressive number of the measurement date / / hour :

value of speed component peak

horizontal longitudinal mm/s | horizontal transversal mm/s | vertical mm/s

frequency of the peak value of the horizontal longitudinal component of the speed

horizontal longitudinal Hz | horizontal transversal Hz | vertical Hx

time interval between the first seismic and the first acoustic arrival ms

duration of the transient seism ms

distance from the point of explosion/seismic path ms

quantity of explosive exploded in correspondence to the peak value of the component

horizontal longitudinal kg | horizontal transversal kg | vertical kg

type of explosive exploded specific energy MJ/kg

description of the measurement point and its position attachment

type and number of seismograph series used for the measurements

blast diagram (e.g. type A, B. etc.)

attachments

possible notes

attachments

:

UNI 9916 "Measurement and evaluation criteria of the effects of vibrations on buildings"

- Reference to the regulation
- Target of the activity carried out
- Description of the structure being studied
- Description of possible damage revealed
- Aim of the research
- Date (or period) of carrying out the activity
- Names of those in charge of the activity
- Reference to documents and names applicable to the single activities
- Description of the source of vibrations
- Description of the environmental conditions that might influence the measurements performed
- Measurements performed
- Position and type of seismographs used
- Method of fixing the seismographs
- Criteria and method of acquiring data
- Criteria and method of elaborating data
- Evaluation of the base noise
- Evaluation of errors
- Evaluation of the uncertainty of the measurements
- Results obtained
- Conclusive judgment

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LEGISLATIVE REFERENCES

- L.R. 8.8.1988 n.14 “New regulations for disciplining mining cave mineral substances”

- D.G.R: 25.1.2002 – n. 7/7857 Determining the criteria and methods of exercising the function of delegates with reference to the 1st paragraph of art. 42 of the L.R. 8.8.1988 n.14 “New regulations for disciplining mining cave mineral substances”

- **Legislative Decree 1 9 August 2005 n.187 actuating the 2002//44/CE directive on the minimum safety and health instructions for workers at risks deriving from mechanical vibrations.**

Directive 2002/44/EC of the European Parliament and of the Council

of 25 June 2002

on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 137(2) thereof,

Having regard to the proposal from the Commission [1], submitted after consultation with the Advisory Committee on Safety, Hygiene and Health Protection at Work,

Having regard to the opinion of the Economic and Social Committee [2],

Having consulted the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty [3], in the light of the joint text approved by the Conciliation Committee on 8 April 2002,

Whereas:

(1) Under the Treaty the Council may, by means of directives, adopt minimum requirements for encouraging improvements, especially in the working environment, to guarantee a better level of protection of the health and safety of workers. Such directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized undertakings.

(2) The communication from the Commission concerning its action programme relating to the implementation of the Community Charter of the Fundamental Social Rights of Workers provides for the introduction of minimum health and safety requirements regarding the exposure of workers to the risks caused by physical agents. In September 1990 the European Parliament adopted a resolution concerning this action programme [4], inviting the Commission in particular to draw up a specific directive on the risks caused by noise and vibration and by any other physical agent at the workplace.

(3) As a first step, it is considered necessary to introduce measures protecting workers from the risks arising from vibrations owing to their effects on the health and safety of workers, in particular muscular/bone structure, neurological and vascular disorders. These measures are intended not only to ensure the health and safety of each worker on an individual basis, but also to create a minimum basis of protection for all Community workers in order to avoid possible distortions of competition.

(4) This Directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more favourable provisions for the protection of workers, in particular the fixing of lower values for the daily action value or the daily exposure limit value for vibrations. The implementation of this Directive should not serve to justify any regression in relation to the situation which already prevails in each Member State.

(5) A system of protection against vibration must limit itself to a definition, free of excessive detail, of the objectives to be attained, the principles to be observed and the fundamental values to be used, in order to enable Member States to apply the minimum requirements in an equivalent manner.

(6) The level of exposure to vibration can be more effectively reduced by incorporating preventive measures into the design of work stations and places of work and by selecting work equipment, procedures and methods so as to give priority to reducing the risks at

source. Provisions relating to work equipment and methods thus contribute to the protection of the workers involved.

(7) Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to vibration, with a view to improving the safety and health protection of workers.

(8) In the case of sea and air transport, given the current state of the art it is not possible to comply in all circumstances with the exposure limit values for whole-body vibration; provision should therefore be made for duly justified exemptions in some cases.

(9) Since this Directive is an individual Directive within the meaning of Article 16(1) of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work [5], that Directive therefore applies to the exposure of workers to vibration, without prejudice to more stringent and/or specific provisions contained in this Directive.

(10) This Directive constitutes a practical step towards creating the social dimension of the internal market.

(11) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission [6],

HAVE ADOPTED THIS DIRECTIVE:

SECTION I

GENERAL PROVISIONS

Article 1

Aim and scope

1. This Directive, which is the 16th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC, lays down minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to mechanical vibration.

2. The requirements of this Directive shall apply to activities in which workers are or are likely to be exposed to risks from mechanical vibration during their work.

3. Directive 89/391/EEC shall apply fully to the whole area referred to in paragraph 1, without prejudice to more stringent and/or more specific provisions contained in this Directive.

Article 2

Definitions

For the purposes of this Directive, the following terms shall mean:

(a) "hand-arm vibration": the mechanical vibration that, when transmitted to the human hand-arm system, entails risks to the health and safety of workers, in particular vascular, bone or joint, neurological or muscular disorders;

(b) "whole-body vibration": the mechanical vibration that, when transmitted to the whole body, entails risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine.

Article 3

Exposure limit values and action values

1. For hand-arm vibration:

(a) the daily exposure limit value standardised to an eight-hour reference period shall be 5 m/s2;

(b) the daily exposure action value standardised to an eight-hour reference period shall be 2,5 m/s2.

Workers' exposure to hand-arm vibration shall be assessed or measured on the basis of the provisions of Point 1 of Part A of the Annex.

2. For whole-body vibration:

(a) the daily exposure limit value standardised to an eight-hour reference period shall be 1,15 m/s2 or, at the choice of the Member State concerned, a vibration dose value of 21 m/s1,75;

(b) the daily exposure action value standardised to an eight-hour reference period shall be 0,5 m/s2 or, at the choice of the Member State concerned, a vibration dose value of 9,1 m/s1,75.

Workers' exposure to whole-body vibration shall be assessed or measured on the basis of the provisions of Point 1 of Part B of the Annex.

SECTION II

OBLIGATION OF EMPLOYERS

Article 4

Determination and assessment of risks

1. In carrying out the obligations laid down in Article 6(3) and Article 9(1) of Directive 89/391/EEC, the employer shall assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed. Measurement shall be carried out in accordance with Point 2 of Part A or Point 2 of Part B of the Annex to this Directive, as appropriate.

2. The level of exposure to mechanical vibration may be assessed by means of observation of specific working practices and reference to relevant information on the probable magnitude of the vibration corresponding to the equipment or the types of equipment used in the particular conditions of use, including such information provided by the manufacturer of the equipment. That operation shall be distinguished from measurement, which requires the use of specific apparatus and appropriate methodology.

3. The assessment and measurement referred to in paragraph 1 shall be planned and carried out by competent services at suitable intervals, taking particular account of the provisions of Article 7 of Directive 89/391/EEC concerning the necessary competent services or persons. The data obtained from the assessment and/or measurement of the level of exposure to mechanical vibration shall be preserved in a suitable form so as to permit consultation at a later stage.

4. Pursuant to Article 6(3) of Directive 89/391/EEC, the employer shall give particular attention, when carrying out the risk assessment, to the following:

(a) the level, type and duration of exposure, including any exposure to intermittent vibration or repeated shocks;

(b) the exposure limit values and the exposure action values laid down in Article 3 of this Directive;

(c) any effects concerning the health and safety of workers at particularly sensitive risk;

(d) any indirect effects on worker safety resulting from interactions between mechanical vibration and the workplace or other work equipment;

(e) information provided by the manufacturers of work equipment in accordance with the relevant Community Directives;

(f) the existence of replacement equipment designed to reduce the levels of exposure to mechanical vibration;

(g) the extension of exposure to whole-body vibration beyond normal working hours under the employer's responsibility;

(h) specific working conditions such as low temperatures;

(i) appropriate information obtained from health surveillance, including published information, as far as possible.

5. The employer shall be in possession of an assessment of the risk in accordance with Article 9(1)(a) of Directive 89/391/EEC and shall identify which measures must be taken in accordance with Articles 5 and 6 of this Directive. The risk assessment shall be recorded on a suitable medium, according to national law and practice; it may include a justification by the employer that the nature and extent of the risks related to mechanical vibration make a further detailed risk assessment unnecessary. The risk assessment shall be kept up-to-date on a regular basis, particularly if there have been significant changes which could render it out-of-date, or when the results of health surveillance show it to be necessary.

Article 5

Provisions aimed at avoiding or reducing exposure

1. Taking account of technical progress and of the availability of measures to control the risk at source, the risks arising from exposure to mechanical vibration shall be eliminated at their source or reduced to a minimum.

The reduction of such risks shall be based on the general principles of prevention set out in Article 6(2) of Directive 89/391/EEC.

2. On the basis of the risk assessment referred to in Article 4, once the exposure action values laid down in Article 3(1)(b) and (2)(b) are exceeded, the employer shall establish and implement a programme of technical and/or organisational measures intended to reduce to a minimum exposure to mechanical vibration and the attendant risks, taking into account in particular:

(a) other working methods that require less exposure to mechanical vibration;

(b) the choice of appropriate work equipment of appropriate ergonomic design and, taking account of the work to be done, producing the least possible vibration;

(c) the provision of auxiliary equipment that reduces the risk of injuries caused by vibration, such as seats that effectively reduce whole-body vibration and handles which reduce the vibration transmitted to the hand-arm system;

(d) appropriate maintenance programmes for work equipment, the workplace and workplace systems;

(e) the design and layout of workplaces and work stations;

(f) adequate information and training to instruct workers to use work equipment correctly and safely in order to reduce their exposure to mechanical vibration to a minimum;

(g) limitation of the duration and intensity of the exposure;

(h) appropriate work schedules with adequate rest periods;

(i) the provision of clothing to protect exposed workers from cold and damp.

3. In any event, workers shall not be exposed above the exposure limit value.

If, despite the measures taken by the employer to comply with this Directive, the exposure limit value is exceeded, the employer shall take immediate action to reduce exposure below the exposure limit value. He shall identify the reasons why the exposure limit value has been exceeded, and shall amend the protection and prevention measures accordingly in order to prevent it being exceeded again.

4. Pursuant to Article 15 of Directive 89/391/EEC, the employer shall adapt the measures referred to in this Article to the requirements of workers at particular risk.

Article 6

Worker information and training

Without prejudice to Articles 10 and 12 of Directive 89/391/EEC, the employer shall ensure that workers who are exposed to the risks from mechanical vibration at work and/or their representatives receive information and training relating to the outcome of the risk assessment provided for in Article 4(1) of this Directive, concerning in particular:

(a) the measures taken to implement this Directive in order to eliminate or reduce to a minimum the risks from mechanical vibration;

(b) the exposure limit values and the exposure action values;

(c) the results of the assessment and measurement of the mechanical vibration carried out in accordance with Article 4 of this Directive and the potential injury arising from the work equipment in use;

(d) why and how to detect and report signs of injury;

(e) the circumstances in which workers are entitled to health surveillance;

(f) safe working practices to minimise exposure to mechanical vibration.

Article 7

Consultation and participation of workers

Consultation and participation of workers and/or of their representatives shall take place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by this Directive.

SECTION III

MISCELLANEOUS PROVISIONS

Article 8

Health surveillance

1. Without prejudice to Article 14 of Directive 89/391/EEC, Member States shall adopt provisions to ensure the appropriate health surveillance of workers with reference to the outcome of the risk assessment provided for in Article 4(1) of this Directive where it indicates a risk to their health. Those provisions, including the requirements specified for health records and their availability, shall be introduced in accordance with national laws and/or practice.

Health surveillance, the results of which are taken into account in the application of preventive measures at a specific workplace, shall be intended to prevent and diagnose rapidly any disorder linked with exposure to mechanical vibration. Such surveillance shall be appropriate where:

- the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health,

- it is probable that the illness or the effects occur in a worker's particular working conditions, and

- there are tested techniques for the detection of the illness or the harmful effects on health.

In any event, workers exposed to mechanical vibration in excess of the values stated in Article 3(1)(b) and (2)(b) shall be entitled to appropriate health surveillance.

2. Member States shall establish arrangements to ensure that, for each worker who undergoes health surveillance in accordance with paragraph 1, individual health records are made and kept up-to-date. Health records shall contain a summary of the results of the health surveillance carried out. They shall be kept in a suitable form so as to permit any consultation at a later date, taking into account any confidentiality.

Copies of the appropriate records shall be supplied to the competent authority on request. The individual worker shall, at his request, have access to the health records relating to him personally.

3. Where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect which is considered by a doctor or occupational health-care professional to be the result of exposure to mechanical vibration at work:

(a) the worker shall be informed by the doctor or other suitably qualified person of the result which relates to him personally. He shall, in particular, receive information and advice regarding any health surveillance which he should undergo following the end of exposure;

(b) the employer shall be informed of any significant findings from the health surveillance, taking into account any medical confidentiality.

(c) the employer shall:

- review the risk assessment carried out pursuant to Article 4,

- review the measures provided for to eliminate or reduce risks pursuant to Article 5,

- take into account the advice of the occupational health-care professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risk in accordance with Article 5, including the possibility of assigning the worker to alternative work where there is no risk of further exposure, and

- arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health care professional or the competent authority may propose that exposed persons undergo a medical examination.

Article 9

Transitional periods

With regard to implementation of the obligations laid down in Article 5(3), Member States, after consultation of the two sides of industry in accordance with national legislation or practice, shall be entitled to make use of a maximum transitional period of five years from 6 July 2005 where work equipment is used which was given to workers before 6 July 2007 and which does not permit the exposure limit values to be respected, taking into account the latest technical advances and/or the organisational measures taken. With regard to equipment used in the agriculture and forestry sectors, Member States shall be entitled to extend the maximum transitional period by up to four years.

Article 10

Derogations

1. In compliance with the general principles of health and safety protection for workers, Member States may, in the case of sea and air transport, derogate from Article 5(3) in duly justified circumstances with respect to whole-body vibration where, given the state of the art and the specific characteristics of workplaces, it is not possible to comply with the exposure limit value despite the technical and/or organisation measures taken.

2. In a case where the exposure of a worker to mechanical vibration is usually below the exposure action values given in Article 3(1)(b) and (2)(b) but varies markedly from time to time and may occasionally exceed the exposure limit value, Member States may also grant derogations from Article 5(3). However, the exposure value averaged over 40 hours must be less than the exposure limit value and there must be evidence to show that the risks from the pattern of exposure to the work are lower than those from exposure at the exposure limit value.

3. The derogations referred to in paragraphs 1 and 2 shall be granted by Member States after consultation of the two sides of industry in accordance with national laws and practice. Such derogations must be accompanied by conditions which guarantee, taking into account the special circumstances, that the resulting risks are reduced to a minimum and that the workers concerned are subject to increased health surveillance. Such derogations shall be reviewed every four years and withdrawn as soon as the justifying circumstances no longer obtain.

4. Every four years Member States shall forward to the Commission a list of derogations as referred to in paragraphs 1 and 2, indicating the exact reasons and circumstances which made them decide to grant the derogations.

Article 11

Technical amendments

Amendments to the Annex of a strictly technical nature in line with:

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(a) the adoption of Directives in the field of technical harmonisation and standardisation with regard to the design, building, manufacture or construction of work equipment and/or workplaces;

(b) technical progress, changes in the most appropriate harmonised European standards or specifications and new findings concerning mechanical vibration;

shall be adopted in accordance with the regulatory procedure laid down in Article 12(2).

Article 12

Committee

1. The Commission shall be assisted by the Committee referred to in Article 17(2) of Directive 89/391/EEC.

2. Where reference is made to this paragraph, Articles 5 and 7 of Decision 1999/468/EC shall apply, having regard to the provisions of Article 8 thereof.

The period referred to in Article 5(6) of Decision 1999/468/EC shall be set at three months.

3. The Committee shall adopt its rules of procedure.

SECTION IV

FINAL PROVISIONS

Article 13

Reports

Every five years Member States shall provide a report to the Commission on the practical implementation of this Directive, indicating the points of view of the two sides of industry. It shall contain a description of best practice for preventing vibrations with a harmful effect on health and of other forms of work organisation, together with the action taken by the Member States to impart knowledge of such best practice.

On the basis of those reports, the Commission shall carry out an overall assessment of the implementation of the Directive, including implementation in the light of research and scientific information, and shall inform the European Parliament, the Council, the Economic and Social Committee and the Advisory Committee on Safety, Hygiene and Health Protection at Work thereof and, if necessary, propose amendments.

Article 14

Transposition

1. The Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive no later than 6 July 2005. They shall forthwith inform the Commission thereof. They shall also include a list, giving detailed reasons, of the transitional arrangements which the Member States have adopted in accordance with Article 9.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by Member States.

2. Member States shall communicate the provisions of national law which they adopt or have already adopted in the field covered by this Directive to the Commission.

Article 15

Entry into force

This Directive shall enter into force on the day of its publication in the Official Journal of the European Communities.

Article 16

Addressees

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This Directive is addressed to the Member States.

Done at Luxembourg, 25 June 2002.

For the European Parliament

The President

P. Cox

For the Council

The President

J. Matas I Palou

[1] OJ C 77, 18.3.1993, p. 12.OJ C 230, 19.8.1994, p. 3.

[2] OJ C 249, 13.9.1993, p. 28.

[3] Opinion of the European Parliament of 20 April 1994 (OJ C 128, 9.5.1994, p. 146) confirmed on 16 September 1999 (OJ C 54, 25.2.2000, p. 75), Council Common Position of 25 June 2001 (OJ C 301, 26.10.2001, p. 1) and Decision of the European Parliament of 23 October 2001 (not yet published in the Official Journal). Decision of the European Parliament of 25 April 2002 and Council Decision of 21 May 2002.

[4] OJ C 260, 15.10.1990, p. 167.

[5] OJ L 183, 29.6.1989, p. 1.

[6] OJ L 184, 17.7.1999, p. 23.

ANNEX

A. HAND-ARM VIBRATION

1. Assessment of exposure

The assessment of the level of exposure to hand-arm vibration is based on the calculation of the daily exposure value normalised to an eight-hour reference period A(8), expressed as the square root of the sum of the squares (rms) (total value) of the frequency-weighted acceleration values, determined on the orthogonal axes ahwx, ahwy, ahwz as defined in Chapters 4 and 5 and Annex A to ISO standard 5349-1(2001).

The assessment of the level of exposure may be carried out on the basis of an estimate based on information provided by the manufacturers concerning the level of emission from the work equipment used, and based on the observation of specific work practices or on measurement.

2. Measurement

When measurement is employed in accordance with Article 4(1):

(a) the methods used may include sampling, which must be representative of the personal exposure of a worker to the mechanical vibration in question; the methods and apparatus used must be adapted to the particular characteristics of the mechanical vibration to be measured, to ambient factors and to the characteristics of the measuring apparatus, in accordance with ISO standard 5349-2(2001);

(b) in the case of devices which need to be held with both hands, measurements must be made on each hand. The exposure is determined by reference to the higher value of the two; information for the other hand shall also be given.

3. Interference

Article 4(4)(d) will apply, in particular where the mechanical vibration interferes with the proper handling of controls or reading of indicators.

4. Indirect risks

Article 4(4)(d) will apply in particular when the mechanical vibration interferes with the stability of structures or the security of joints.

5. Individual protectors

Personal protective equipment against hand-arm vibration may contribute to the programme of measures referred to in Article 5(2).

B. WHOLE-BODY VIBRATION

1. Assessment of exposure

The assessment of the level of exposure to vibration is based on the calculation of daily exposure A(8) expressed as equivalent continuous acceleration over an eight-hour period, calculated as the highest (rms) value, or the highest vibration dose value (VDV) of the frequency-weighted accelerations, determined on three orthogonal axes (1,4awx, 1,4awy, awz for a seated or standing worker) in accordance with Chapters 5, 6 and 7, Annex A and Annex B to ISO standard 2631-1(1997).

The assessment of the level of exposure may be carried out on the basis of an estimate based on information provided by the manufacturers concerning the level of emission from the work equipment used, and based on observation of specific work practices or on measurement.

In the case of maritime shipping, Member States may consider only vibrations of a frequency exceeding 1 Hz.

2. Measurement

When measurement is employed in accordance with Article 4(1), the methods used may include sampling, which must be representative of the personal exposure of a worker to the mechanical vibration in question. The methods used must be adapted to the particular characteristics of the mechanical vibration to be measured, to ambient factors and to the characteristics of the measuring apparatus.

3. Interference

Article 4(4)(d) will apply, in particular where the mechanical vibration interferes with the proper handling of controls or reading of indicators.

4. Indirect risks

Article 4(4)(d) will apply, in particular when the mechanical vibration interferes with the stability of structures or the security of joints.

5. Extension of exposure

Article 4(4)(g) will apply, in particular where, owing to the nature of the activity, a worker benefits from the use of rest facilities supervised by the employer; exposure to whole-body vibration in those facilities must be reduced to a level compatible with their purpose and conditions of use, except in cases of "force majeure".

Joint Statement by the European Parliament and the Council

The European Parliament and the Council reaffirm their commitment to continue examining the Commission's proposal on the other physical agents (audible acoustic fields, electric or magnetic fields or combinations thereof). However, in view of the technical difficulties with regard to the other physical agents, priority has been given to vibrations. The European Parliament and the Council recognise, however, that it is necessary to adopt Directives as soon as possible on the other physical agents referred to in the Commission's proposal.

REGULATION REFERENCES

Europe	ISO 2631-2, 1989, Evaluation of human exposure to whole-body vibration - part 2: continuous and shock-induced vibration in buildings (1 - to 80 hz)F.E.E.M. 4.1, 1990, Code of good practice: Ground and airborne vibration from the use of explosives.
Italy	UNI 9614, 1990 Measuring vibrations in buildings and criteria for evaluating annoyance 9916, 2004 Measurement and criteria evaluation of the effects of vibrations on buildings
United Kingdom	BS 7385 part. 2; 1993 BS 6472
Federal Republic of Germany	DIN 4150-1, 2001, Erschütterungen im Bauwesen - Teil 1: Vorermittlung von Schwingungsgrößen. DIN 4150-2, 1992, Erschütterungen im Bauwesen - Teil 2: Einwirkungen auf Menschen in Gebäuden. DIN 4150-3, 1999, Erschütterungen im Bauwesen - teil 3: Einwirkungen im bauliche anlagen (Le vibrazioni nelle costruzioni - parte 3: effetti sui manufatti). KTA 2201.2 (JUNE 1990): AUSLEGUNG VON KERNKRAFTWERKEN GEGEN SEISMISCHE EINWIRKUNGEN; TEIL 2: BAUGRUND) - DESIGN OF NUCLEAR POWER PLANTS AGAINST SEISMIC EVENTS, PART 2: SUBSURFACE MATERIALS (SOIL AND ROCK)
USA	USBM RI 8506 USBM RI 8508 USBM RI 8969 ANSI S2.47-1990, R1997 ANSI s12.18-1994 ANSI S12.9-1992/Part2

UNI 96\4, 1990. Vibration measurement in buildings and annoyance evaluation

EXTRACT

VIBRATIONS | Vibration measurement in buildings and annoyance evaluation | UNI 9614

Vibration measurement in buildings and annoyance evaluation

The present regulation agrees partially with ISO 2031/2 (see clarifications)

Premise

0.

Other than natural causes (seismic, wind etc.) vibrations in buildings can be linked to human activity, such as vehicle traffic on tire and rail, the functioning of machinery, (hammers, presses, etc.) road works and building (perforators, pile drivers, etc.) and the detonation of explosive charges, etc. These vibrations can be a strong source of annoyance to people exposed and curtail their well-being.

1. Purpose and field of application

The regulation defines the method of measuring constant level vibrations in buildings due to the work of external sources or internal to the buildings themselves.

The present regulation is not a guide for evaluating vibrations considered as the possible cause of structural or architectonic damage to the buildings.

In addition, this regulation is not a guide for evaluating vibrations that, aboard vehicles, ships, airplanes and in industrial installations, can jeopardize the comfort, the working efficiency, and the health-safety of the subjects exposed. These vibrations, whose limits are strictly dependent upon the duration of the vibrations, are also subject to specific regulations.

2. References

UNI 9670	Response of individuals to vibrations – Measurement apparatus
UNI ISO 5805	Mechanical vibrations and knocks concerning man – Dictionary
ISOI 1683	Acoustics – Normal dimensions of references for acoustic levels
ISO 2631/1	Evaluation of the exposure of individuals to global vibrations of the body – 1st Part: General instructions
ISO 5347	Method for calibrating the recorders of vibrations and knocks
ISO 5348	Mechanical vibrations and knocks – Mechanical montage of accelerometers (seismic recorders)
IEC 184	Method for specifying the characteristics of electro-mechanical seismographs for measuring vibrations and knocks
IEC 222	Method for specifying the characteristics of the auxiliary apparatus for measuring vibrations and knocks
IEC 225 (CEI 29-4)	Filters in bands of octave, ½ octave, 1/3 octave, used in the analysis of sounds and vibrations

3, Definitions

3.1. Type of vibration

Vibrations in a building can be defined:

- as a constant level, when overall weighted acceleration in frequency (see 4) detected with “slow” time constant (1 **s**) varies in time in an interval of amplitude less than 6 dB.
- as a non constant level, when the under-mentioned level varies in time in an interval of amplitude above 6 dB
- as impulsive when they originate from events of brief duration consisting of a rapid rise in acceleration up to a maximum value followed by a fall that could lead, or not, depending on the absorption of the structure, to a series of oscillations that tend to die out over time.

(cont.)

Italian regulations November 1991

VIBRATIONS

Criteria for the measurement of vibrations and the assessment of their effects on buildings

UNI 9616

Criteria for the measurement of vibration and the assessment of their effects on Buildings

The present regulation is in substantial agreement with the technical contents of ISO regulation 4866

0. Introduction

The problem of vibrations in buildings has taken on increasingly greater importance in recent years both in relation to the different structural types of modern constructions linked to a more rational use of materials with better characteristics of mechanical resistance and in relation to the multiplication of the sources of vibrations, especially those generated by human activities.

Vibrations can be the cause, other than annoyance to the occupants of buildings and a reduction in the operative efficiency and malfunctioning of or damage to equipment used, also a danger to the structural and architectonic integrity of the buildings as well as the safety of the occupants. Another particularly felt problem regards the preservation of historical monuments. .

It can be analyzed in different aims:

a) recognition of the problem: when evaluation needs to be made about whether the size of the vibrations might concern the integrity of the structure of the buildings or jeopardize the safety of the occupants and it therefore becomes necessary to make an in-depth study;
b) check or control, when you want to bring the level of vibration to within the limits of the specific regulations or you want to check the project aims;
c) prediction, when you want to evaluate the ability of the building to support accidental dynamic charges such as, for example, earthquakes, or you want to study measures for reducing vibratory phenomena.

These different aims require different methods of approach as far as regards both the measurement of the values and the treatment and evaluation of the data detected.

1. Purpose and field of application

The present regulation provides a guide for choosing the appropriate method of measuring and treating the data of vibratory phenomena with the aim of also allowing the evaluation of the effects of vibrations on buildings with reference to their structural response and architectonic integrity.

Another purpose of the regulation is to obtain comparable data on the characteristics of the vibrations detected at different times on the same building or different buildings with the same source of stress as well as providing evaluation criteria of the effects of the vibrations themselves.

Appendix B, which is not an integrative part of the regulation, shows only indicatively, the numerical values of acceptability of the vibratory levels measured on the buildings.

For simplicity, the present regulation considers variable ranges of frequency from 0.1 to 160 Hz. These intervals interest a large number of buildings and structural elements of buildings subject to natural stress (wind, earthquakes etc.) as well as stress caused by man (traffic, construction activity etc.). In some cases the intervals of frequency of the vibrations can be wider (e.g. vibrations induced by machinery inside buildings): nevertheless, stress with content higher than 150 Hz are not such as to influence significantly the response of the building.

Knocks directly applied to the structure with industrial machines, knocks produced by explosions, the beating of blades and other sources immediately at the limit of the restricted limits of the structure are not included in the range of frequencies indicated but their effects on the structure are.

DIN 4150-3, 1999, (in tedesco)

Page 1
NIN 4150-3, 1999-02

GERMAN REGULATION February 1999

VIBRATIONS IN CONSTRUTIONS DIN
Part 3 Effects on buildings 4150-3

ICS 91.120.25 Substitutes the 1986-05 revision

Description: Constructions, Buildings, Vibrations, and Actions

Contents

Continue on pages 2 to 12

Page 2
NIN 4150-3, 1999-02

Premise

The edition of the regulations shown here has been edited by the “Committee for the regulations on constructions within the Working Committee 00.05.00 for the study of effects of vibrations on structures. As integration to the DIN 4105-03: 1986 – 05 edition “Vibrations in Constructions”, it was decided unanimously to acquire knowledge and experience judged necessary and sufficient in practical application.

DIN 4150: 1986 – 05 “Vibrations in Constructions” consists of:

Part 1 – Preliminary detection of the characteristic size of oscillations
Part 2 – Effects on man in buildings
Part 3 – Effects on structures

Modifications;
with respect to the edition of May 1986 the following modifications have been made, among others:
a) Points 5.3 and 6.3 have been inserted regarding vibrations on pipes laid on the ground.
b) The reference values for the evaluation of the effects for continuous vibrations on buildings have been re-elaborated (see 6.1).

Previous editions
DIN 4150-3: 1975 – 06, 1985 – 05.

1 area of application

The present regulation establishes a procedure for the determination and the evaluation of the effects induced by vibrations on structures whose size provides resistance mainly to static stresses. The regulation applies to structures not designed to resist dynamic effects according to specific regulations and directives.
The regulation indicates values to which to refer to avoid damage occurring to the structure, damage understood as a reduction in the use value. Reference values are provided for some effects of the vibrations for a simplified evaluation.

2. Regulation references

The present regulation refers to other publications with and without data. These regulatory references, listed below, are cited in the text at various points. In the case of references with data, possible modifications and successive versions are part of the regulation only if cited in the next versions or re-elaborations. In the case of references without data the latest edition of the publication cited is valid.

DIN 1311
Theory of oscillations.
DIN V 4150-1
Vibration in constructions – Foundations, preliminary detection and measurement of the characteristic sizes of oscillations.
E DIN 4150-1
Vibrations in constructions – Part 1: preliminary detection of the characteristic sizes of oscillations.

DIN 4150-2
Vibrations in constructions – Part 2: Effects on man in buildings.

DIN 45669-1
Measuring induced oscillations – Part 1: Oscillation measurers – Requisites, Testing.

DIN 45669-2

Measuring induced oscillations – Part 2: Measurement procedure.

3 Definitions

The definitions in DIN 1311 and following are valid for the application of the present regulation.

3.1

Vibrations

Mechanical oscillations of solid bodies with potentially damaging or troublesome effects.

3.2

Damage

Permanent consequences of an action, leading to a diminution in the use value of the structure or its parts, with reference to its use.

3.3

Reference value

A reference that established on the basis of un-contradicted experience, guarantees damage will not occur.

3.4

Transient vibrations

Vibrations that take place with a recurrence insufficient to provoke effects of fatigue on materials and whose temporal succession does not provoke resonance in the specific structure.

3.5

Prolonged vibrations

All the vibrations not included in the definition of transient vibrations.

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4 Fundamental criteria for detecting and evaluating vibrations in structures.

4.1. Procedure

The method of instrumental detection and evaluation of the characteristic size of vibrations are described at points 5 and 6.

If these methods are not adopted for the evaluation of the effects of vibrations, the acting dynamic stresses must be checked (measured or calculated) with those admissible, taking account of the recurrences with which they take place. This method, however, is not suitable for the evaluation of slight damage (see also 4.5).

In single cases vibrations may take place that cannot be ascribed to only one of categories 3.4 or 3.5. In these cases a distinct evaluation must be carried out for each category.

In particular cases attention must also be paid to the indirect consequences of the vibrations or rather to the movement of the foundations (see also app. C).

4.2. Determining stress through measurement

The stresses in play can be directly deduced by measuring the deformations of part of the oscillating structure, with the modules of elasticity of the respective materials.

Amplitude and frequency of these characteristic sizes of the oscillations that are the basis of the calculation can be determined by measuring the movement, the speed and the acceleration.
Stresses on beams or plates subject to oscillation near the resonance can be calculated by approximation of the speed of the oscillations if the measurement is carried out at the point where amplitude is at maximum. Knowing the surroundings conditions and the rigidity is not necessary in this case for estimating the stresses (see chapter 6).

4.3. Determining stresses by calculation
Determining stresses is carried out according to the rules of the technique. The start data can be determined according to the procedure of prediction in conformity respectively with DIN V 4150-1 or E-DIN 4150-1.

4.4. Admissible stresses
To check the static resistance, everything must be referred to the coefficients of safety for additional dynamic stresses, as established by the specific regulations and recommendations, in function of the type and duration of the dynamic charges, the type of measurement, the characteristics of the materials and the type of construction. Safety conditions must be checked, where necessary, even regarding collapse through fatigue. We can deduce from resistance diagrams, if available, the limited admissible stresses, the amplitude of oscillation, the limits of deformation, etc., for the materials adopted, for the constitutive elements and for the connecting elements in relation to the number of alternate stresses predictable.
It will be possible to avoid the exact check of the structural fatigue collapse with a dynamic charge multiplied by a coefficient of fatigue equal to 3.
The safety check with respect to collapse by fatigue is not necessary if the value is part of a dynamic charge and less than 10% of the value of the admissible static stress.

4.5 Evaluation criteria
A diminution in the use value of building or parts of them from the effect of vibrations in terms of the present regulations can be, for example, the following types:

- jeopardy of the static safety of the buildings or parts of them and
- diminution in the capacity of the floors:

For buildings indicated in table 1, lines 2 and 3, there is a diminution in the use value also, for example, in the present of

- lesions in the plaster of the walls;
- increase in lesions already existing in the building;
- lesions between partitions, or partition walls or bearing walls or floors;

This type of damage is defined as slight damage.

4.6 Effect of vibrations on the ground
Strong vibrations can induce settlement of the ground and, therefore, collapse of the foundations, above all in loose ground of low and average consistency (sand, pebble). This is, above all, valid for recurrent vibrations, uniform sand and ground below the waterbed. For detailed information see appendix C.

5 Transient vibrations
From a large number of measurements of the speed of oscillations carried out on the foundations of buildings experimental values have been detected used as referenced for the evaluation of the effects of transient vibrations on constructions.
To evaluate, take the highest value (maximum value) into consideration (symbols) among the three components (symbols) of the speed of oscillation (symbols) on the foundation, indicated below more simply as (symbol) (see 5 *A*).
In addition, important indications are provided for evaluation by the higher oscillations of the floors pressed against the perimeter walls. The higher value of each of the two horizontal components should be considered as the basis of the evaluation.
Measuring the oscillations at this point (see 3,4) determines the horizontal response of the building to the stresses of the foundations. In table 1, figure 1, the reference values for (symbol) on the foundations and upper floor, for different types of construction, are shown.

Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 2201.2 (June 1990)

Design of Nuclear Power Plants Against Seismic Events
Part 2: Subsurface Materials (Soil and Rock)

(Auslegung von Kernkraftwerken gegen seismische Einwirkungen;
Teil 2: Baugrund)

A previous version of this Safety Standard was issued 11/82

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

Editor:

KTA-Geschaeftsstelle c/o Bundesamt fuer Strahlenschutz (BfS)
Willy-Brandt-Strasse 5 • 38226 Salzgitter • Germany
Telephone +49-1888/333-(0) 1621 • Telefax +49-1888/333-1625

KTA SAFETY STANDARD

June 1990	Design of Nuclear Power Plants Against Seismic Events Part 2: Subsurface Materials (Soil and Rock)	KTA 2201.2

CONTENTS

PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 50-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in Bundesanzeiger No. 194a on October 14, 2000. Copies may be ordered through the Carl Heymanns Verlag KG, Luxemburger Str. 449, 50939 Koeln (Telefax +49-221-94373-603).

All questions regarding this English translation should please be directed to:

KTA-Geschaeftsstelle c/o BfS, Willy-Brandt-Strasse 5, 38226 Salzgitter, Germany

Comments by the editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, the exceptions used, shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against the damage arising from the construction and operation of the facility (Sec. 7 para. 2 no. 3 Atomic Energy Act), in order to attain the protective goals specified in the Atomic Energy Act and the Radiological Protection Ordinance and further detailed in the "Safety Criteria for Nuclear Power Plants" and the "Guidelines for the Assessment of the Design of Nuclear Power Plants with Pressurized Water Reactor against Incidents pursuant to Sec. 28 para. 3 of the Radiological Protection Ordinance (Incident Guidelines)".

(2) In order to attain these protective goals, Safety Standard KTA 2201.2 - as part of KTA 2201 entitled "Design of Nuclear Power Plants against Seismic Events" - deals with the determination and application of characteristics of the subsurface materials which have to be taken as a basis when designing a nuclear power plaint against seismic events. KTA 2201 also contains the following parts:

Part 1: Principles

Part 3: Design of Building Structures

Part 4: Requirements to be Met by Methods for the Demonstration of the Aseismic Safety of Mechanical and Electrical Components

Part 5: Seismic Instrumentation

Part 6: Post-Seismic Measures

1 Scope

This safety standard applies to nuclear power plants.

2 Definitions

(1) Damping of Subsurface Materials

The damping of subsurface materials is equal to the energy which the soil withdraws from the oscillating system consisting of subsurface, materials and structure. It is made up of radiation damping and material damping.

(2) Soil liquefaction

Soil liquefaction is the reduction of the shear strength of a soil because of an increase in pore pressure as a result of a compression of the grain structure under dynamic loads.

3 Investigation of the Subsurface Materials

(1) The documents used to evaluate the conditions of the subsurface materials at the site shall Include in particular expert analyses concerning geology, seismology and subsurface materials.

(2) The results of the investigations of subsurface materials and the expert analyses shall be laid down in a generalized soil profile which should include not only the characteristics of the layers but also data concerning the groundwater level.

(3) The following characteristics of the respective soil layers should be quoted:

a) depth and thickness (m)

b) geological designation

c) soil classification

d) weight density of the moist soil (kN/m³)

e) coefficient of stiffness (kN/m²)

f) angle of internal friction (degree)

g) cohesion (kN/m²)

4 Dynamic Characteristics of the Subsurface Materials

(1) For the design of nuclear power plants against seismic impacts, Poisson's ratio, shear modulus and material damping shall be determined as dynamic characteristics of the subsurface materials. For this purpose, upper and lower limits shall be quoted as a function of the depth and of the stress condition of the soil when subjected to the structural load.

(2) The methods for the determination of the dynamic characteristics of the subsurface materials shall be selected as a function of the conditions of the subsurface materials.

In principle, both in-situ and laboratory tests shall be carried out. As an exception to this rule, the procedures referred to in paras. (3) and (4) may be used.

Note:
Methods for the determination of dynamic characteristics of subsurface materials are contained as examples in Section A 1 of Appendix A.

(3) If the subsurface materials and the geological boundary conditions of two sites are comparable, the dynamic characteristics of the subsurface materials of the one site may be assumed to apply to the other as well.

(4) The dynamic characteristics of the subsurface materials may be estimated for nuclear power plants at sites for which the maximum accelerations of the design basis earthquake were determined to be below 1.0 m/s².

(5) The shear modulus and the material damping should be determined as a function of the shear deformation and the stress condition in the soil.

Note:
A method for the determination of shear modulus and material dampings, either on the basis of in-situ investigations or by means of auxiliary calculations, is contained as an example in Section A 2 of Appendix A.

5 Changes of the Subsurface Materials

(1) Possible changes of the subsurface materials such as they may occur as a result of earthquakes shall be determined. These include in particular:

a) permanent deformations as a result of compaction or other changes of the grain structure,

b) reduction of shear strength, either as a result of soil liquefaction or as a result of other changes of the grain structure.

Note:
Basic principles for the evaluation of soil liquefaction are contained as examples in Section A 3 of Appendix A.

(2) For nuclear power plants at sites for which the maximum accelerations of the reference earthquake were determined to be below 1.0 m/s², or where the subsurface materials consists of stiff and geologically preloaded clays or equivalent cohesive soils, no demonstration with respect to soil liquefaction is required.

6 Models for the Subsurface Materials

(1) Within the system consisting of structure and subsurface materials, the representation of the subsurface materials may be effected as a spring-mass, fine-element, finite-difference or boundary-element model or any combination of these models.

(2) If the generalized soil profile can be represented by a single layer (uniform subsurface material), a damped spring-mass model may be used. The parameters of this model may be determined on the basis of the theory of the elastic half-space. In a simplified approach, they may be assumed to be Independent of frequency, provided an adequate parameter variation is effected.

Note:

The representation of the subsurface materials is dealt with in further detail in KTA 2201.3 (being prepared).

7 Interaction between Subsurface Materials and Structure

(1) The influences of dynamic characteristics of subsurface materials, in particular those of shear modulus and material damping, on the oscillatory response of the structure shall be included in the calculations by the assumption of a variation range of these characteristics.

(2) The variation range of the characteristics of the oscillatory system consisting of subsurface material and structure shall be covered when calculating the plant components.

Appendix A

Application Methods

Contents:

A 1 Investigation methods for the determination of dynamic characteristics of subsurface materials

Method	Measuring Method	a) Measured Quantity b) Derived Quantities	[1] Shear Deformation Range
In-situ methods			
Uphole method	Excitation in the borehole, measurement at the surface	a) Travel times (P and S wave velocities) b) Shear modulus, Poisson's ratio	approx. 10^{-7} to 10^{-5}
Downhole method	Excitation at the surface, measurements in the borehole		
Through transmission method	Excitation in a borehole, measurement in one or more adjacent boreholes		
Vibroseis method	Continuous excitation and measurement at the surface	a) Travel times (surface wave velocities) b) Shear modulus	approx. 10^{-7} to 10^{-3}
Laboratory methods			
Resonance test	Determination of the velocities with variable frequencies and variable amplitudes	a) Frequency, wave length (P and S wave velocities) b) Shear modulus, Poisson's ratio, material damping	approx. 10^{-6} to 10^{-4}
Triaxial dynamic test	Measurement under vertical and tangential loads with variable stress conditions	a) Movements, stresses (stress-shear deformation characteristic) b) Shear modulus, material damping, Poisson's ratio	approx. 10^{-4} to 5×10^{-2}
Simple dynamic shear test	Measurement with simple shear under uni-axial load and impeded lateral expansion		
Dynamic torsion test	Measurement under tangential load and uni-axial		10^{-5} to 5×10^{-2}
[1] In the case of earthquakes in the Federal Republic of experience so far shows that shear deformations are in the shear deformation range from 10^{-5} to 10^{-3}			

A 2 Determination of shear modulus and material damping on the basis of in-situ investigations or auxiliary calculation's

The determination of shear modulus (G) and material damping (D) may be effected along the lines of [1] in accordance with equation A 1 and equation A 2 as shown in **Fig. A 1**.

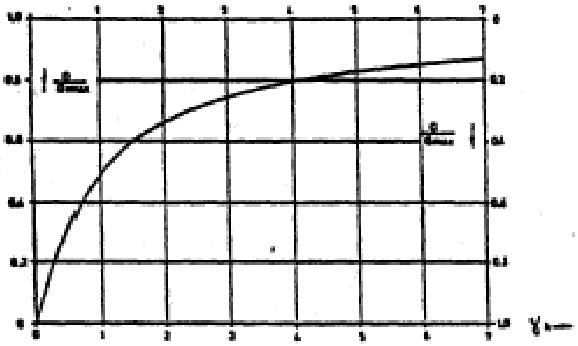


Fig. A 1: Relationship between shear modulus, material damping and hyperbolic shear deformation

$$G_{max} = \frac{1}{1+\gamma_h} G_{max} \qquad \text{(A 1)}$$

$$D_{max} = \frac{\gamma_h}{1+\gamma_h} D_{max} \qquad \text{(A 2)}$$

$$\gamma_h = \frac{\gamma}{\gamma_r}\left[1 + a \cdot \exp\left(-b\frac{\gamma}{\gamma_r}\right)\right] \qquad \text{(A 3)}$$

$$\gamma_r = \frac{\max \tau}{G_{max}} \qquad \text{(A 4)}$$

γ_h = hyperbolic shear deformation

G_{max} = shear modulus for smallest shear deformations

D_{max} = material damping for largest shear deformations

γ = shear deformation

γ_r = reference shear deformation

$\max \tau$ = maximum shear stress

The maximum material damping D_{max} and the quantities a and b can be determined for different types of soil with the aid of the reference equations quoted in [1]. The major influencing quantities include number and frequency of the stress cycles as well as the stress condition prevailing in the soil.

In general, G_{max} shall be determined by in-situ measurements. For estimation purposes, empirically derived approximate equations may be used such as they are found in literature, for example [1], and take the following form:

$$G_{max} = \alpha \cdot \frac{(\beta - e)^2}{1+e} \cdot \sigma'^{\delta}_m \cdot (OCR)^K \qquad \text{(A 5)}$$

e = pore ratio of the soil

σ'_m = mean effective principal stress in the soil

δ = exponent, as a rule 0.5

α, β = quantities depending on grain shape, grain size distribution and degree of saturation

OCR = degree of over-consolidation

K = exponent depending on the plasticity index of the soil

A 3 Basic principles for the evaluation of soil liquefaction

A 3.1 Liquefaction potential

Basically, uniform and fine sands exhibit a greater tendency towards soil liquefaction than non-uniform and coarse sands. The decisive influence is excercised by the compactness of the material. The tendency towards liquefaction increases with the degree of looseness. With all other conditions being identical, the tendency towards liquefaction will decrease with an increase in effective stresses in the soil.

In the case of high-lying groundwater levels, the danger of liquefaction is greater than in the case of deep-lying groundwater levels. The danger of liquefaction increases with the intensity and duration of an earthquake.

In this context, the permeability of the sand and the drainage conditions shall also be taken into consideration. The thinner the endangered layers and the faster they can drain into permeable adjacent layers, the shorter is the time during which the sand remains in the liquid state and the less persistent are the consequences.

Geologically preloaded, stiff clays and similar cohesive soils are insensitive to vibrations. They do not exhibit any tendency towards liquefaction.

Soils whose grain size ranges between middle silt and coarse sand are susceptible to liquefaction. This applies in particular to fine sands. As far as gravels are concerned, liquefaction is, in general, only a very short-term phenomenon so that no damaging shear deformations can occur. The duration of liquefaction depends on the conditions of drainage.

In stratified soils the liquefaction process, starting out from an easily liquefiable layer, may spread to soil areas which would not be endangered in normal conditions. Therefore, the danger of liquefaction shall be evaluated on the basis of the most unfavorable layer.

The following shall be effected for the evaluation of the danger of soil liquefaction:

(a) boreholes under and beside the planned structure down to a depth of 25 m below the surface of the terrain,

(b) drop penetration tests or pressure determination by ultrasonic means,

(c) determination of the highest ground water level,

(d) dynamic shear tests, if necessary.

A 3.2 Methods for the estimation of the possibility of soil liquefaction (along the lines of [2])

Step 1:

A grain size distribution curve of the soil to be investigated shall be plotted in a diagram in accordance with **Fig. A 2**.

If the grain size distribution curve is outside Zones 1 and 2, liquefaction need not be assumed.

If the principal portion of the grain size distribution curve is within Zone 1, limit line Z_1 in **Fig. A 3** is decisive for the further examination.

If the principal portion of the grain size distribution curve is within Zone 2, limit line Z_2 in **Fig. A 3** is decisive for the further examination.

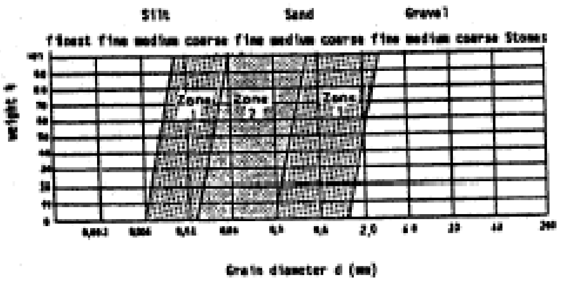


Fig. A 2: Grain size distribution areas susceptible to liquefaction

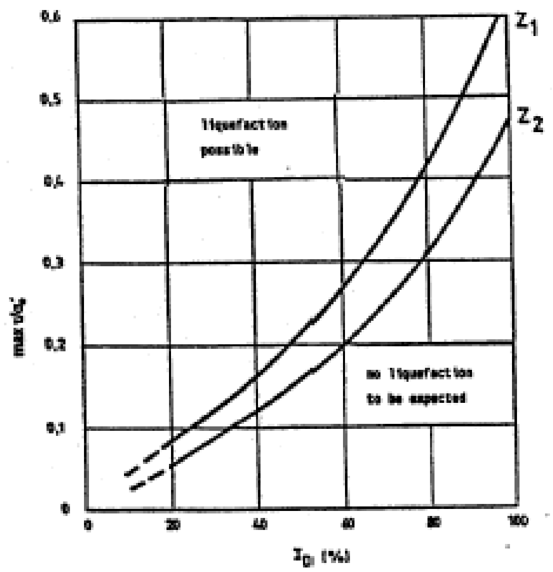


Fig. A 3: Diagram for estimating the possibility of soil liquefaction

Step 2:

The dynamic shear stress ratio τ/σ'_o shall be calculated from σ_o' and the relation

$$\max \tau = \sigma_o \frac{\max a}{g} r_d$$

where max a is the maximum acceleration, g the acceleration due to gravity and

σ'_o the effective vertical stress in the soil at depth t (stress resulting from structural load and weight of the soil after deduction of lift at the highest groundwater level)

σ_o the total vertical stress in the soil at depth t (stress resulting from structural load and weight of the water-saturated soil at the highest groundwater level)

r_d the reduction factor as a function of depth in accordance with **Fig. A 4**.

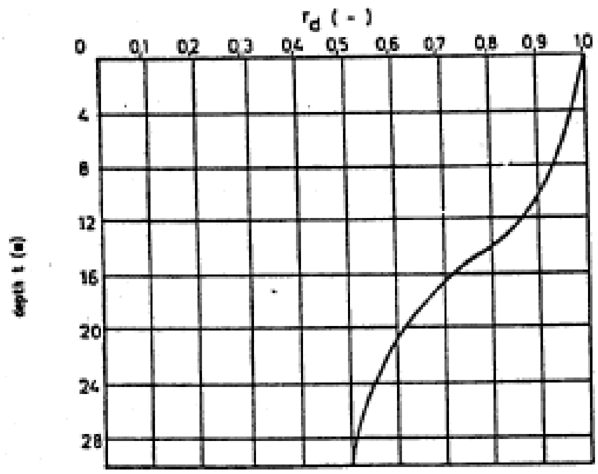


Fig. A 4: Reduction factor r_d as a function of depth t

Step 3:

If the intersection of the shear stress ratio max τ/σ_o' and the relative compactness I_D of the soil is below the relevant limit lines Z_1 and Z_2 plotted in **Fig. A 3**, there is no danger of soil liquefaction.

If the intersection is above the limit line, soil liquefaction cannot be ruled out. In such a case, more detailed investigations are needed.

A 4 References

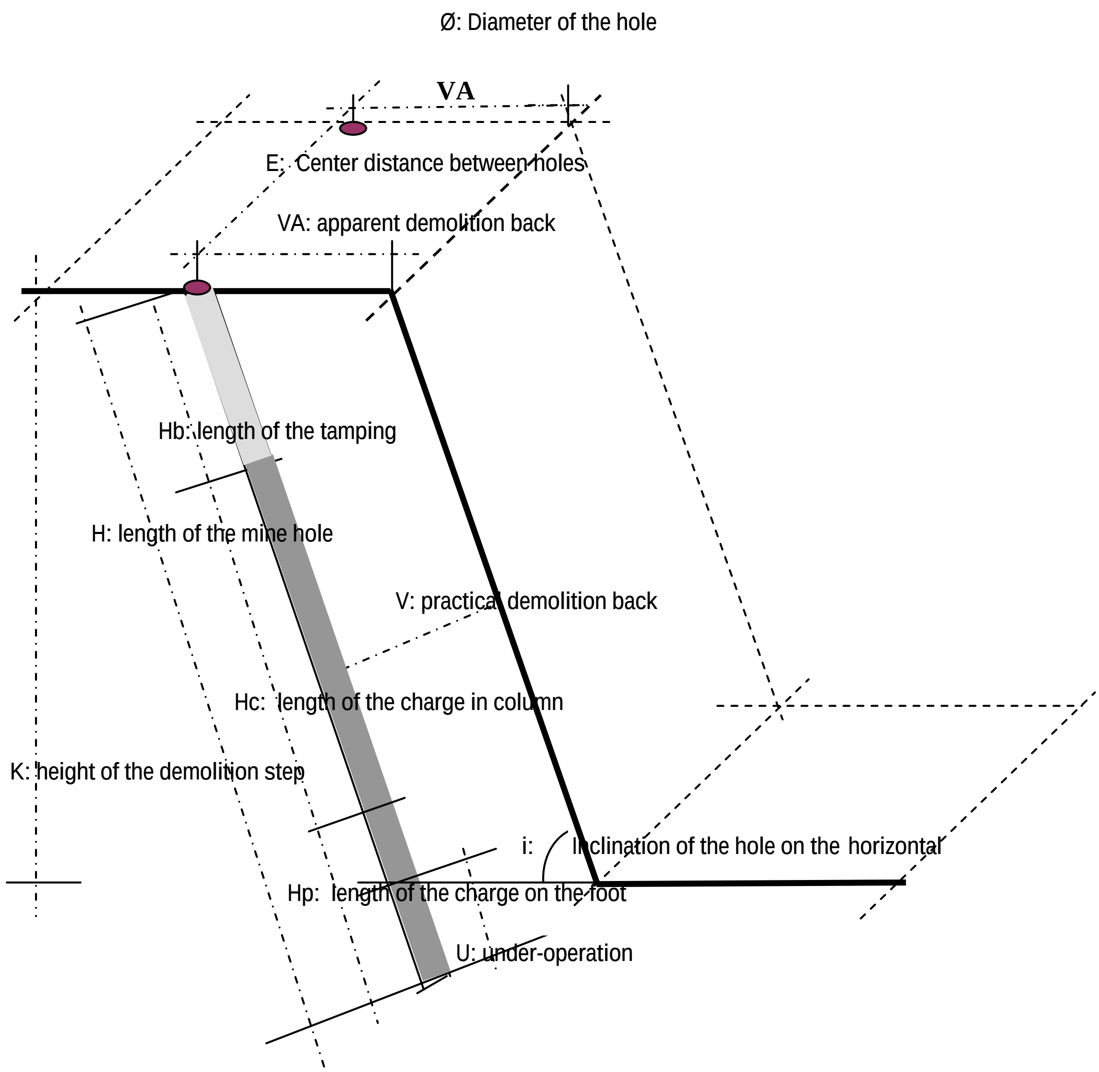
[1] HARDIN, B.O. and DRNEVICH, V.P.: Shearmodulus and Damping in Soils: Design Equations and Curves. J. Soil Mech. and Found. Div. ASCE, 1972, Vol. 98, SM 7, p. 667-692.

[2] SEED, H.B. and IDRISS, I.M.: Simplified Procedure for Evaluating Soil Liquefaction Potential. J. Soil Mech. and Found. Div. ASCE, 1971, Vol. 97, SM 9, p. 1249-1273.

DIAGRAM OF EXPLODING THE BLAST

Demolition step blast

GEOMETRICS OF THE STEP AND PERFORATION DIAGRAM



Step demolition blast

TABLE OF CHARGES OF THE HOLE – mod, NTX

k	height of step (vertical)	15.00	m
I	inclination of the hole on the horizontal	72	* (x/y = 1/3)
ø	diameter of the mine hole	80	mm
H	length of the mine hole	16.6	m
V	practical demolition back	2.6	m
VA	apparent demolition back	2.7	m
EN	relation center distance/demolition back	1.3	
E	center distance between holes	3.3	m
U	under-operation	0.8	m
	volume of influence of the hole	134	M3
E-c	wrapped explosive in column AN-FO		
	average length of cartridge L	500	mm
	average diameter of cartridge	70	mm
	average weight of cartridge	1.36	Kg/n
	cartridge/carton	16	n
	specific energy of explosion	3.1	MJ/k
	uncoupling cartridge-hole	0.40	
E-p	explosive at foot SLURRY wrapped		
	average length of cartridge L	500	mm
	average diameter of cartridge	70	mm
	average weight of cartridge	2.3	kg/n
	cartridge/carton	11	
	specific energy of explosion	3.3	MJ/kg
	uncoupling cartridge-hole	0.40	
E:nc	number of cartridges in column	20.0	
E:np	number of cartridges at foot	4.0	
H:b	length of tamper	5.1	m
	average shortening of cartridge in hole	5%	
H:c	length of charge in columns AN:FO	9.5	kg
H:p	length of charge at foot SLURRY	2.0	m
QE-c	quantity of explosive in column AN:FO	33.3	kg
QE-p	quantity of explosive at foot SLURRY	9.1	kg
QE	quantity of explosive in hole and AN:FO	40.3	kg
		126.9	MJ
QPap	specific perforation	0.12	M/m3 in bench
QEsp	specific consumption explosive	0.30	Kg/m3 in bench
		0.95	MJm3 in bench
QDsp	Specific consumption detonators	0.02	N/m3 in bench
c	coefficient of shattering of the rock	0.66	MJ/m3
S80	Index of marine pieces	0.5	

Bored hole demolition blast - mod. NTX

SYNTHESIS DATA ON SAFETY BLAST
(designed to contain the vibrations induced in nearby structures to protect within limits of pre-established seismic limits)

Purchaser:	
Site:	

Check seismic safety
Speed limit
Reduction curve
Scaled safety distance
Min distance structure

Max. charge for withdrawal

PROBABLE SPEED (50%): 4 mm/s

Edited by

Total charge
of which

7 crates
11 crates

Total number of holes

background Section

Volume demolished
Unitary density of charge

Attached:
Diagram of safety blast

Bored hole demolition blast

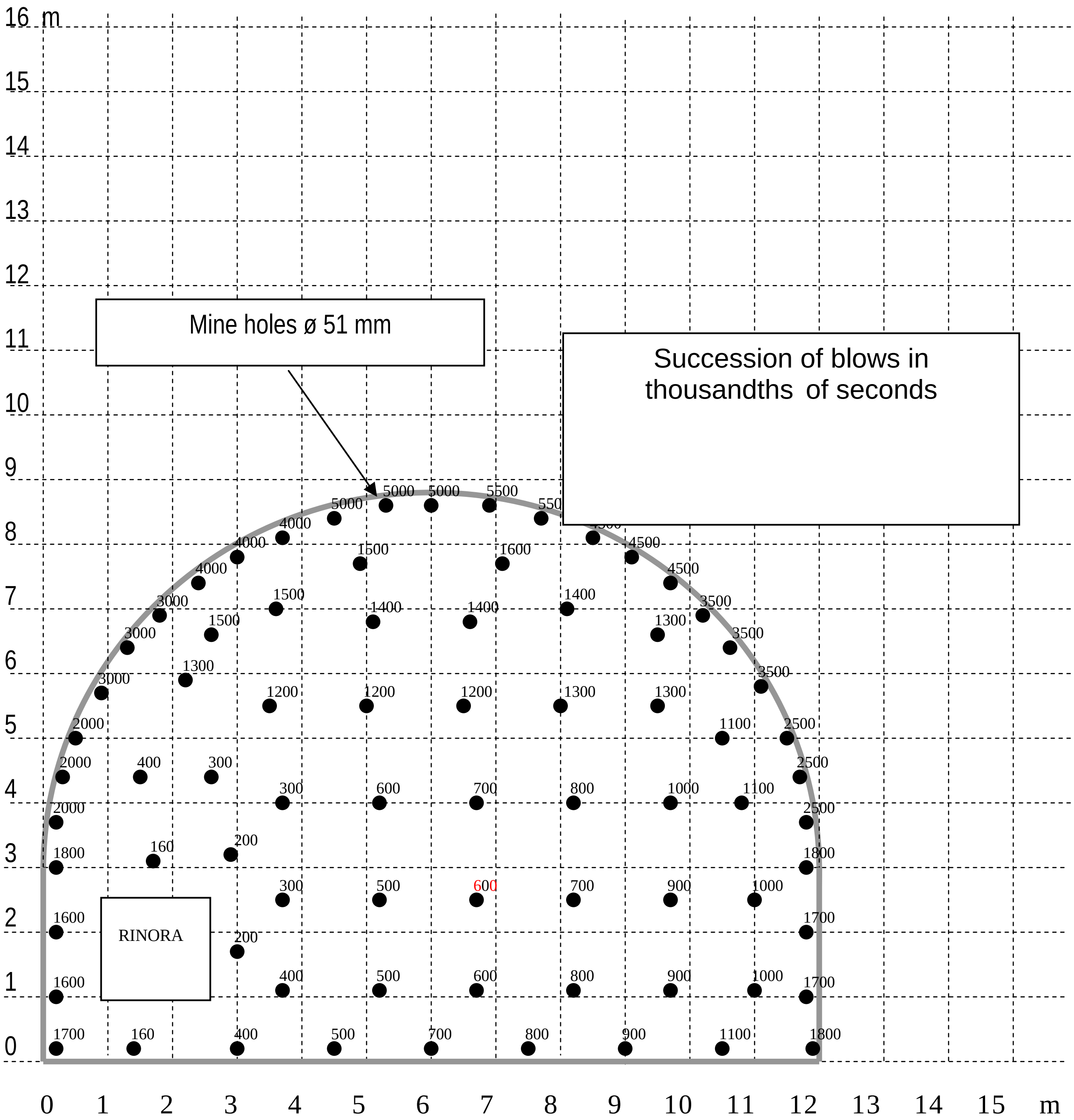
TABLE OF CHARGES FOR MINE HOLES - mod. NTX

					EXPLOSIVE								
	Cartridge length (m)			0,40	0,40	1							
	Cartridge weight (kg)			0,69	0,60	0,30			*total*			*coupling*	
	Energy of explosion (MJ/kg)			3,7	3,5	3,5			108	700	200	8%	
	Type of detonators	Nominal success trigger in seismic record	Hole length	Gel B6	Sigma 605	Sigma 6 19 mm profile	Charge for single hole		Num. holes	Charge for trigger time		Charge length	Tamper length / empty hole
		(s)	(m)	Cartucce per foro (n)			(MJ)	(kg)	(n)	(MJ)	(kg)	(m)	(m)
RINORA	fori diam. 109 mm		2,20	-	-	-	-	-	2	-	-	-	2,2
	MIZP 20 - t.1	1,020	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.2	1,040	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.3	1,060	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.4	1,080	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.5	1,100	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.6	1,120	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
SLARGO e SOTTOCORONA	MIZP 20 - t.7	1,140	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 20 - t.8	1,160	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 100 - t.2	1,200	2,20	-	4,0	-	8,40	2,4	2	16,80	4,8	1,5	0,7
	MIZP 100 - t.3	1,300	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.4	1,400	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.5	1,500	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.6	1,600	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.7	1,700	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.8	1,800	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.9	1,900	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.10	2,000	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.11	2,100	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.12	2,200	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.13	2,300	2,20	-	4,0	-	8,40	2,4	3	25,20	7,2	1,5	0,7
	MIZP 100 - t.14	2,400	2,20	-	3,0	-	6,30	1,8	3	18,90	5,4	1,1	0,7*
	MIZP 100 - t.15	2,500	2,20	-	3,0	-	6,30	1,8	3	18,90	5,4	1,1	0,7*
	MIZP 100 - t.16	2,600	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
	MIZP 100 - t.17	2,700	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
	MIZP 100 - t.18	2,800	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
	TZMSP - t.4	3,000	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
	TZMSP - t.5	3,500	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
	TZMSP - t.6	4,000	2,20	-	3,0	1,0	7,35	2,1	3	22,05	6,3	2,0	0,7*
PIEDRITTI e PROFILO	TZMSP - t.7	4,500	2,20	-	0,5	2,0	3,15	0,9	3	9,45	2,7	2,0	0,7*
	TZMSP - t.8	5,000	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.9	5,500	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.10	6,000	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.11	6,500	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.12	7,000	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.13	7,500	2,20	-	0,5	2,0	3,15	0,9	4	12,60	3,6	2,0	0,7*
	TZMSP - t.14	8,000	2,20	-	0,5	3,0	4,20	1,2	4	16,80	4,8	2,9	0,7*

- profile charges forced into holes up to 0.7 m from heading

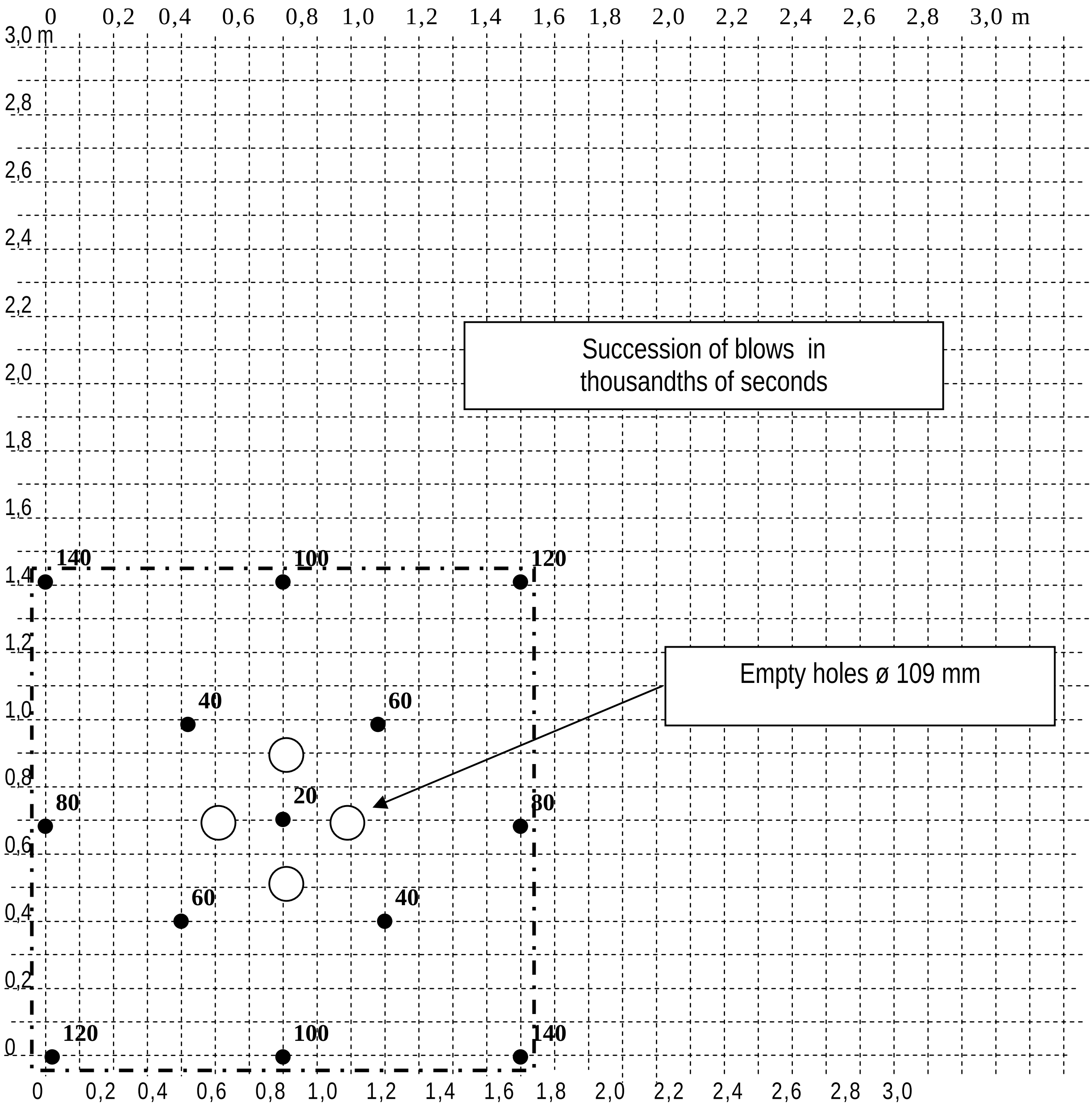
Bored hole demolition blast

DIAGRAM OF PERFORATIONS AND TRIGGER SUCCESSIONS OF THE CHARGES



Bored hole demolition blast

DETAIL OF THE RINORO ("CUT HOLE" TYPE)



PERFORMANCE AND SUCCESSION OF TRIGGERS FORM - mod. NTX

blast of . . . . hour . . . . at . . . .

TABLE OF EXPLOSIVE PRODUCTS - facsimile

Explosive emulsion

TABLE OF PRODUCTS

Emulgit LWC AL is the latest development of the LWC (Low Water Composition – low water content explosive emulsion) family. They do not contain dry particles of nitrate of Ammonia and are sensitized to gas bubbles, contributing to rendering their performance exceptional.
Emulgit LWC AL is employed optimally where high performance explosives are required in alternative to dynamite, such as charging feet in step demolitions in excavations and obliged sections (trenches, embankments) and in bored hole excavations (tunnels, wells, caves).
The cartridges are covered in a sheet of white polyethylene with two red stripes. The consistency of the explosive paste is very high.

Characteristics of the product

Weight per unit of volume:

Volume of gas 25C. 1 ATM:

Specific energy of explosion

Oxygen balance:

Detonation speed (Ø 30 mm confined):

Distance of blow (on sand bed):

Certificate type of EC conformity:

Identification code:

N.A.P.

Classification and membership TULPS

(Italian qualifications)

<u>Use</u>

*Extremely low sensitivity to knocks and attrition, cold and heat:
for optimal conditions of safety in transport, storage and use.
*High yield for minimum content of water and for optimum concentration of Aluminum with:
reduction of specific perforation and savings in both terms of costs and time (the complete oxidization of the Aluminum guarantees the non-emergence of "post-detonation combustion" or the combustion of the fractions of Aluminum not oxidized, characteristic of overloaded emulsions.
*Optimum sensitivity to triggering with both detonators and detonator fuses, even for the smallest diameters (it is unnecessary to load reinforcements-starters) for guaranteeing triggering all the charges in the blast.

*Absolute resistance to water:

for every condition of use.
*Special formats can be created on request.
*High consistency of the product.:
also for easy charging of horizontal or inclined holes even in hot climates.
*Minimum release of dangerous gas.

Details of use

Limitations

*Minimum diameter of the cartridge: 30 mm
*Not admitted in “gassy” environments.
*Performance guaranteed up to 6 months from manufacture.
*Climatic conditions recommended: from 0°C to 60°C.

Advice on use

*The high detonating energy of Emulgit LWC AL determines high performance in demolishing hard rock. The reaction of the Aluminum, slower than that of the matrix of nitrates in oil, prolongs the action of thrust of the explosive gas around the hole. Also in this way for bored hole demolition or for those with high back, i.e. when the rock requires more time to be opened up, a high fraction of the explosive energy is used in extending the shockwave in the structure of the product to maximize the efficacy of the demolition.
*Excellent results have also been had in demolishing bedrock tendentially plastic.
*In case the continuity of charge in the hole cannot be guaranteed, the use of detonator fuse is recommended of at least 20 g PETN/m; well coupled along the whole column of the cartridge.
*Storage up to -10°C does not alter the characteristics of the product.

Abacus of standard **formats**

Diameter

Length

Weight

Cartridge in carton

Net weight carton

Indications on the use in safety are shown on the relative SAFETY DATA CARD provided before the delivery of the product.

The data in the present notice are indicative. Medex reserves the right to modify format and characteristics without notice.

ACOUSTIC SIGNALS OF EXPLODING MINE – rec. NTX

To minimize the perception of unease connected to the unexpected and loud noise resulting from an explosive charge among neighboring residents it is appropriate to adopt acoustic signaling to minimize the surprise effect.

To carry our work near residential areas it is, therefore, appropriate to adopt acoustic signaling that furthers minimizing the surprise effect.
As a reference, a procedure to adopt to insert in the explosive/exploding mine service Order (ex. DPR 128/59 and/or D. Lgsl. 646/94) follows:

Explosive service order

(…)
point … The imminent explosion of the mine is pre-announced by the person in charge of the explosion with three long siren whistles-EARLY WARNING MINE EXPLOSION. A few seconds before the explosion and <u>until the explosion is completed</u> a second continuous siren whistle will follow – MINE EXPLOSION. Five brief whistles of the siren – DANGER OVER will communicate the regular completion of the explosion operations…

RESPONSE SPECTRUM: control in frequency of structural response

Structures respond much more to stress from movement of the ground when the dominant frequency of the train of the wave comes close to their characteristic frequencies. Walls and floors respond more to higher frequencies (15-20 Hz) while higher structures or the frames of the structure respond more to lower frequencies (5-10 Hz).

Differences in the response of various structural components can be calculated, starting from the movement of the ground, if their natural diminishing frequencies are known.

The curves suggested by USBM and USM are based upon the concept of the characteristic response of a structure. One or more response models characterize all structures. Each of these response models is distinguished by a characteristic (natural) response and a coefficient of diminution.
When the waves induced by the explosion of a blast have characteristic frequencies similar to the response frequencies of a structure, resonance phenomena can be triggered that could increase the probability of provoking damage. In this case the setting of more restrictive limits becomes necessary because of the maximum values of the vibrations induced.
Usually, a complex structure does not have only one natural frequency or only one factor of diminution. Single structural components have to be evaluated independently. For example, the *Report of Investigation Rl 8507, United States Bureau of Mines* has revealed that natural frequencies in partitions vary from around 11 to 25 Hertz and at the edges from 3 to 11 Hertz. Similarly, the diminution values vary approximately from 1 to 7 percent and for the partitions from 1 to 11 percent for the edges of the structure.
The response model at the passage of the seismic wave is taken with a model with a single degree of liberty (SGL). Even if it could be argued that this model is not always an applicable model, the information we obtain can in any case be useful in determining the response of the structure.
The equation of movement for the SGL model is the following:

$$u''+2\beta\omega_n u'+\omega_n^2 u = -y''$$

dove: u'', u', u Sono accelerazione, velocità e spostamento relativi

y'', y', y Sono accelerazione, velocità e spostamento assoluti del suolo

ω_n È la frequenza angolare naturale

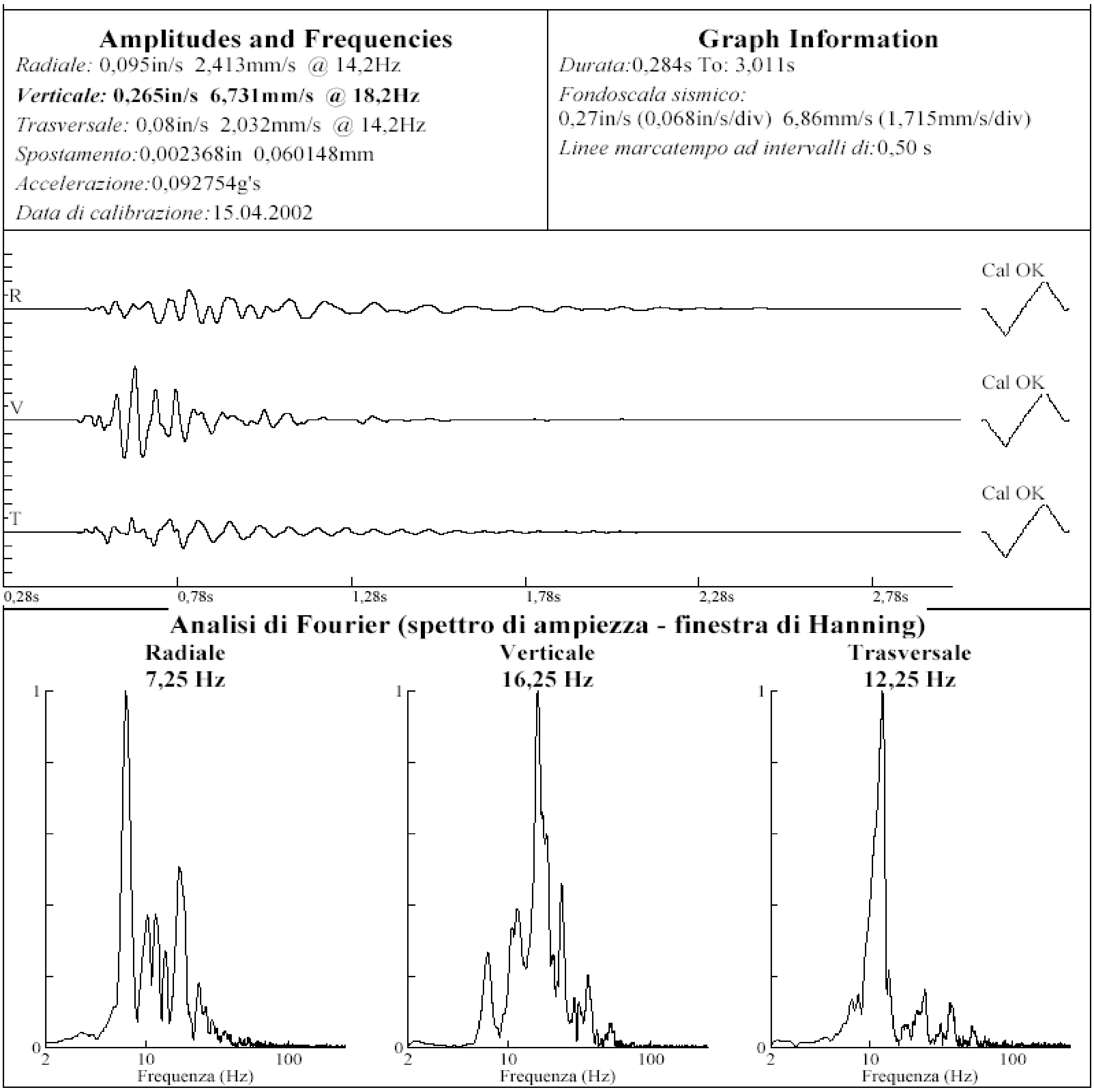
β È lo smorzamento

The solution of the previous equation for the relative movement at any moment can be obtained with Laplace's transformed equation.
The solution is

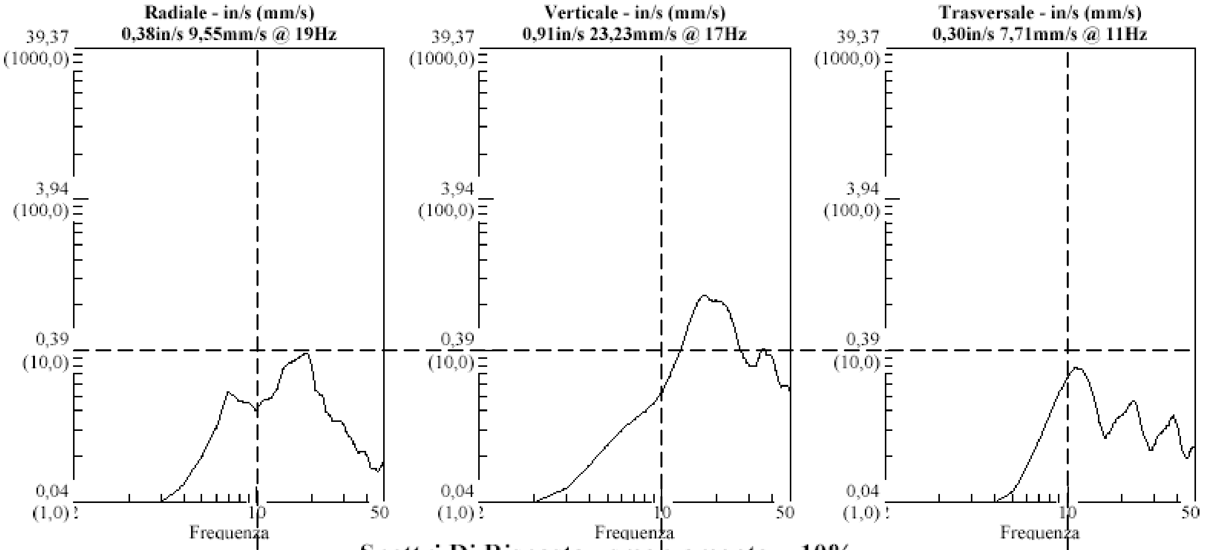
$$u(t) = \int_0^t y'(\tau) e^{-\beta\omega_n(t-\tau)} \left\{ \cos\left[\omega_n \sqrt{1-\beta^2}\,(t-\tau)\right] - \frac{\beta}{\sqrt{1-\beta^2}} \sin\left[\omega_n \sqrt{1-\beta^2}\,(t-\tau)\right] \right\} d\tau$$

The previous equation is checked for different values of natural angular frequency using a constant diminution.

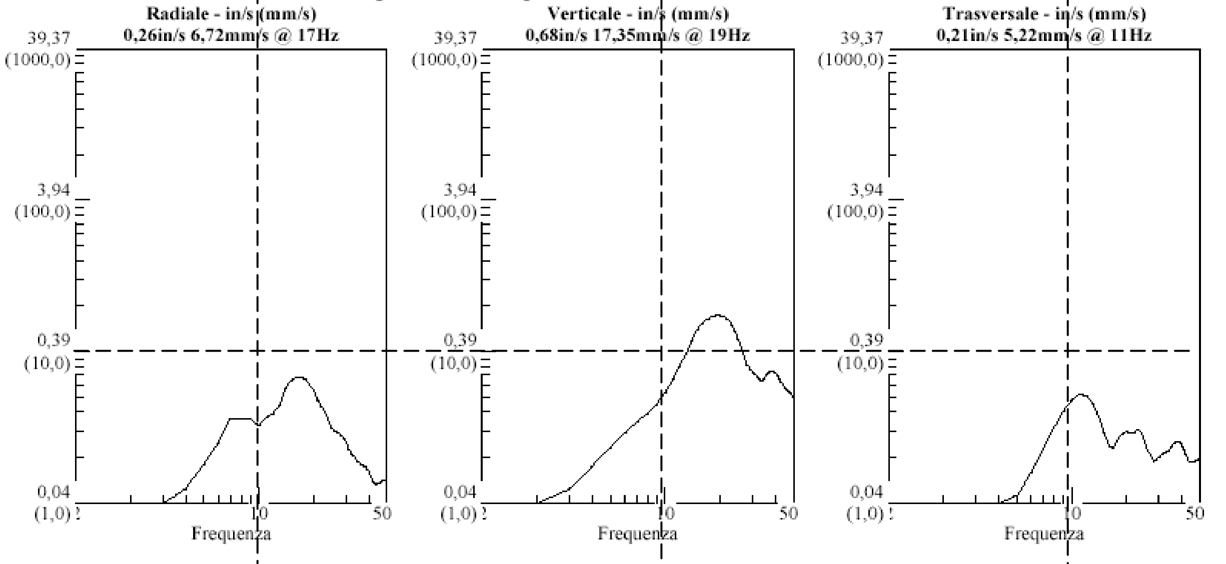
We obtain a maximum value for every frequency of u(t). When this maximum value is multiplied by the natural circular frequency, a pseudo-speed is obtained. This pseudo-speed is taken as a function of the angular frequency. This function is the response spectrum of the pseudo-speed.



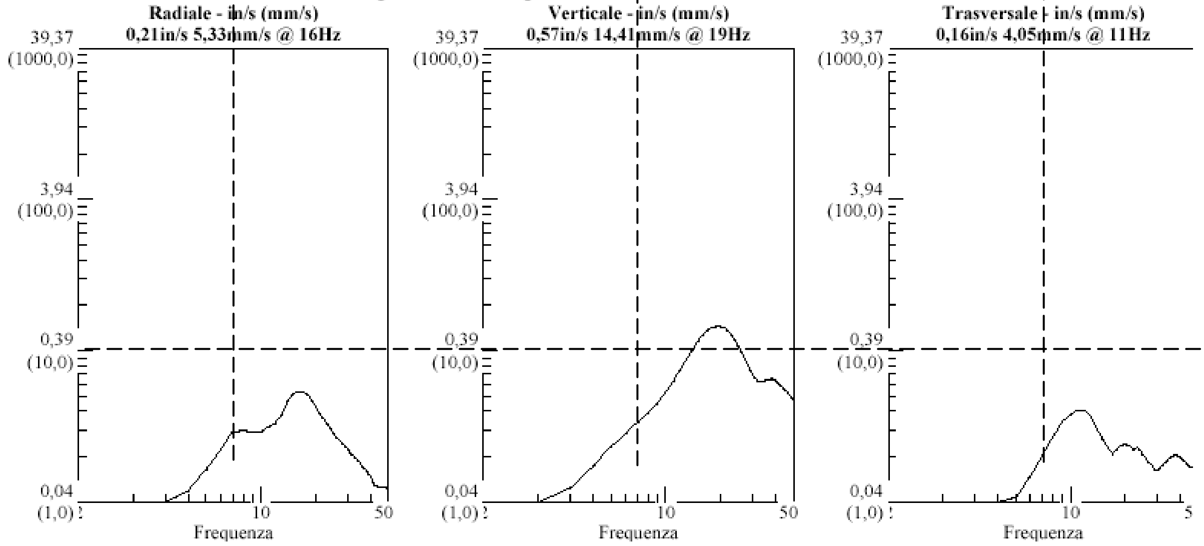
Spettri Di Risposta - smorzamento = 5%

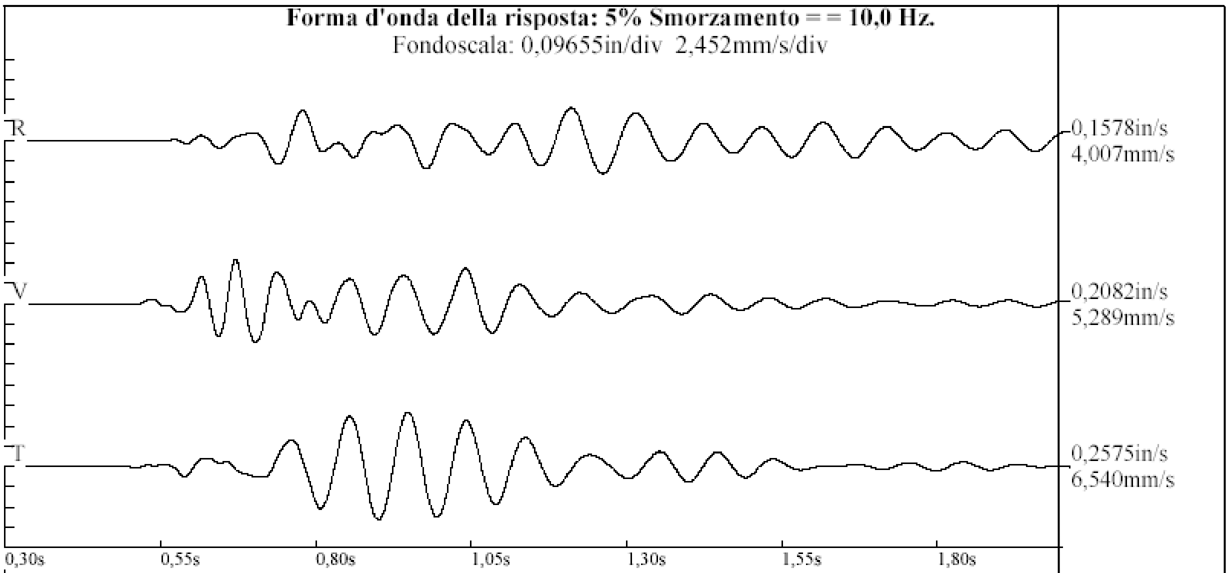


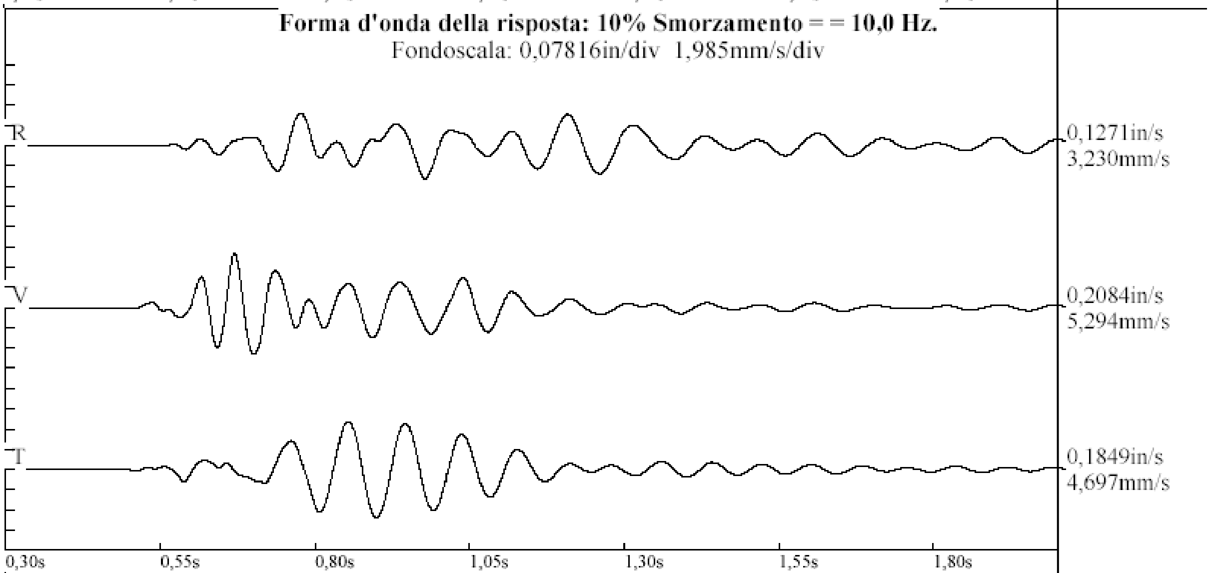
Spettri Di Risposta - smorzamento = 10%

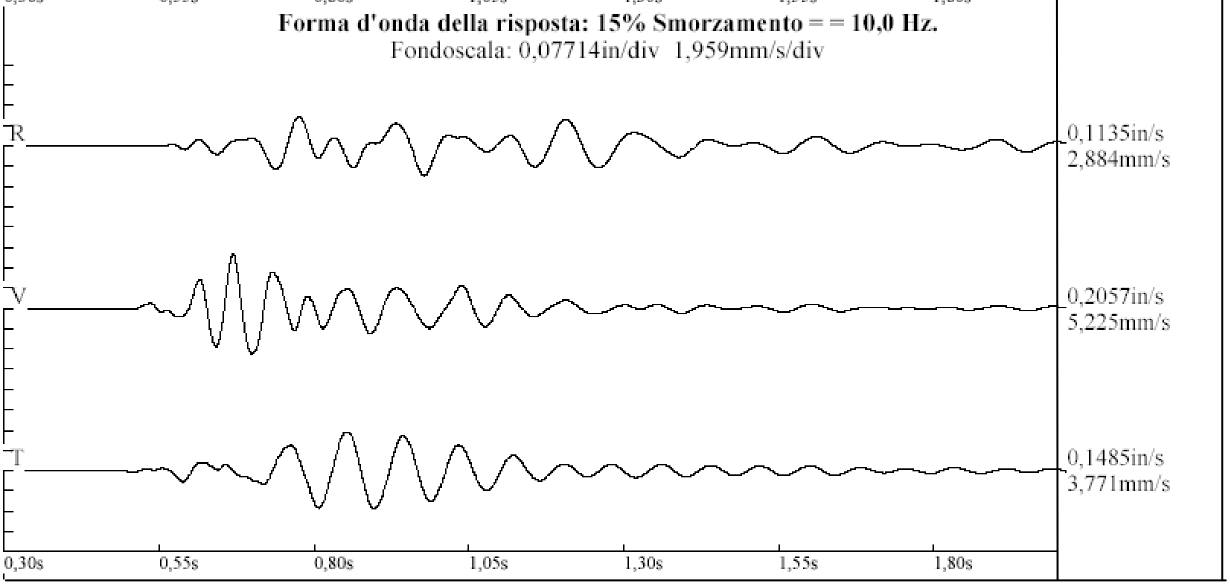


Spettri Di Risposta - smorzamento = 15%




Forma d'onda della risposta: 5% Smorzamento = = 10,0 Hz.
Fondoscala: 0,09655in/div 2,452mm/s/div
R
V
T
0,1578in/s
4,007mm/s
0,2082in/s
5,289mm/s
0,2575in/s
6,540mm/s
0,30s 0,55s 0,80s 1,05s 1,30s 1,55s 1,80s


Forma d'onda della risposta: 10% Smorzamento = = 10,0 Hz.
Fondoscala: 0,07816in/div 1,985mm/s/div
R
V
T
0,1271in/s
3,230mm/s
0,2084in/s
5,294mm/s
0,1849in/s
4,697mm/s
0,30s 0,55s 0,80s 1,05s 1,30s 1,55s 1,80s


Forma d'onda della risposta: 15% Smorzamento = = 10,0 Hz.
Fondoscala: 0,07714in/div 1,959mm/s/div
R
V
T
0,1135in/s
2,884mm/s
0,2057in/s
5,225mm/s
0,1485in/s
3,771mm/s
0,30s 0,55s 0,80s 1,05s 1,30s 1,55s 1,80s

CHARGE BLAST REPORT – mod. NTX

blast from………. hour…….. at………

k	height of step (vertical)				m
I	inclination of the hole on the horizontal				* (x/y = 1/3)
ø	diameter of the mine hole				Mm
H	length of the mine hole				m
V	practical demolition back				m
VA	apparent demolition back				m
EN	relation center-distance/demolition back				
E	center distance between holes				m
U	under-operation				m
	volume of influence of the hole				M3
E-c	type of explosive in column:				
	average length of cartridge L*				mm
	nominal diameter of cartridge ø				mm
	average weight of cartridge				Kg/n
	cartridge/carton				n
	specific energy of explosion				MJ/k
	uncoupling cartridge-hole				
E-p	type of explosive at foot				
	average length of cartridge L				mm
	nominal diameter of cartridge ø				Mm
	average weight of cartridge				kg/n
	cartridge/carton				
	specific energy of explosion				MJ/kg
	uncoupling cartridge-hole				
E:nc	number of cartridges in column				
E:np	number of cartridges at foot				
H:b	length stretch of tampering				m
	type of tampering				
Hbl	total length intermediate tamper				
H:c	total length of charge in column 8no int. tamper)				kg
H:p	length of charge at foot				m
	average shortening of explosive in column				
	average shortening of explosive at foot				
	average shortening of explosive cartridge in hole				
QE c	quantity of explosive in column				kg
QE-p	quantity of explosive at foot				kg
QE	total quantity of explosive in hole				kg
	type of trigger				
QPsp	specific perforation				m/m³ bench
QEsp	specific consumption explosive				m/m³ bench
QEm	specific consumption detonator fuse				m/m³ bench
QDsp	specific consumption detonators				m/m³ bench

Notes

Calculating the time trend of the MOVEMENT of the speed

The movement is calculated as integral to the speed. While the derivative allows finding the inclination of the upright tangent to a curve (ACCELERATION calculated from the speed), the integral allows calculating the area beneath. From a mathematical point of view the integral of a function can be written as follows:

$$\int_a^b f(x)dx = F(b) - F(a)$$

eq. 1

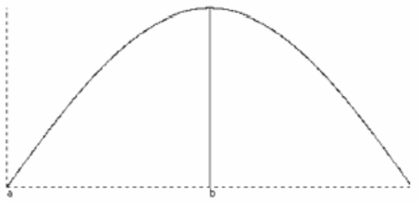
in which F is any function such as (eq. 1) for all those values of "x" contained included between "a" and "b".

The integral is the converse function of the derivative. Consequently a relation exists between the integral and the derivative as follows:

$$\int_a^b \sin(x)\,dx = -\cos(b) - \left(-\cos(a)\right) = -\cos(b) + \cos(a)$$

eq. 2

Since the derivative of -cos (x) = sine (x). (eq.2)



Considering half of the sinusoidal curve drawn above, the area beneath the curve has to be calculated from "a" to "b", considering that "a" = 0 and that "b" = 0.25, from equation 2 we obtain:

$$\int_0^{0,25} \sin(2\pi \cdot t)dt = -\frac{\cos(2\pi \cdot 0,25)}{2\pi} - \left(-\frac{\cos(2\pi \cdot 0)}{2\pi}\right) = 0,15915$$

eq. 3

The value 0. 15915 is the area beneath the curve. This value can be calculated directly through an known integral for simple sinusoidal functions.
Nevertheless, vibrations generated by explosions are not describable mathematically by known functions, therefore to calculate the integral numerically one of the following four methods must be adopted

Method 1 – rule of the rectangle

The technique of the rectangle to calculate the integral consists in calculating the area of the rectangle under the curve:

$$\int_a^b f(x)dx \approx (b-a)f(a)$$

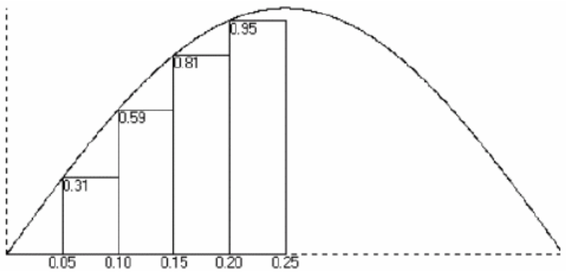
eq. 4

The area of f(x) from “a” to “b” is obtained multiplying the length from “a” to “b” by the value pf the function in “a”. Equation 3 is therefore used to calculate numerically the value of the area from “a” to “b”, considering the first half of a sinusoidal curve with “a” equal to zero and “b” equal to 0.25. The result of this operation is zero; obviously this value is wrong.

The problem is that “a” and “b” are too distant. What can be done is to subdivide this interval additionally into a group of smaller intervals, using five equal intervals from 0 to 0.05, from 0.05 to 0.10, from 0.15, from 0.15 to 0.20 and from 0.20 to 0.25. The following table shows the list of intervals, the value of the function at the start of the interval and the calculated value of the area.

	0,05 - 0,00	**0,10 - 0,05**	**0,15 - 0,10**	**0,20 - 0,15**	**0,25 - 0,20**
sin(2πa)	0	0,309017	0,587785252	0,809017	0,9510565
area	0	0,0154508	0,029389263	0,0404508	0,0475528

A graphic view of this method is shown below. Note that the total area given by the sum of the areas of the rectangles is less than the effective value of the area of the curve. This depends on the fact that the rectangles do not completely cover the area of the curve. The result can be, therefore, calculated summing up the areas of the single rectangles.



Even if the results obtained with this method can be improved increasing the number of intervals, the value of the total area from 0 to 0.25 always remains in defect by shortcoming.

Method 2 – the rule of the mean point

The rule of the mean point for calculating the integral is:

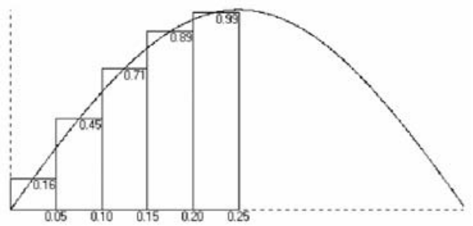
$$\int_a^b f(x)dx \approx (b-a)f\left(\frac{a+b}{2}\right)$$

eq. 5

As previously, equation 11 is used to calculate the area of the curve from “a” to “b”. Without subdividing the interval additionally, the result is 0.1768. This result is better than that obtained with method 1. What happens if we divide the interval as previously?

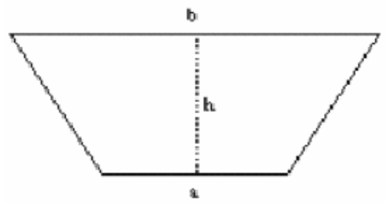
	0,05 - 0,00	0,10 - 0,05	0,15 - 0,10	0,20 - 0,15	0,25 - 0,20
sin(2π(a+b)/2)	0,1564345	0,4539905	0,70710678	0,8910065	0,9876883
area	0,0078217	0,0226995	0,03535533	0,0445503	0,0493844

The graphic view of this method is shown below. Note that the total area given by the sum of the areas of the rectangles is greater than the area of the curve. The result can be calculated summing up the areas of the single rectangles. The rule of the mean point offers a better result than the rule of the rectangle.



Method 3 – the rule of the trapezium

The area of the trapezium is given by the sum of the bases by the height divided by two.

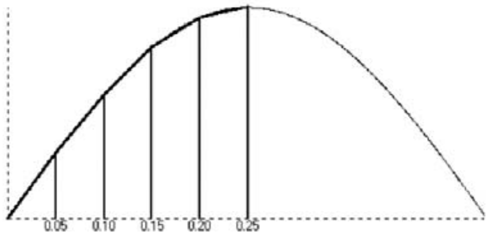


$$\int_a^b f(x)dx \approx [f(a)+f(b)] \cdot \frac{b-a}{2}$$ *eq.6*

As before, equation 5 is used for the area after having subdivided the interval. The following table summarizes the data:

	0,05 - 0,00	0,10 - 0,05	0,15 - 0,10	0,20 - 0,15	0,25 - 0,20
sin(2πa)	0	0,309017	0,587785252	0,809017	0,9510565
sin(2πb)	0,309017	0,5877853	0,809016994	0,9510565	1
area	0,0077254	0,0224201	0,034920056	0,0440018	0,0487764

summing the partial areas shown in the last line of the table we obtain an optimum result of 0.15785. The graphic view of the rule of the trapezium is shown below.



Area = 0,15785

Method 4 – Simpson's rule

Simpson's rule derives from the combination of the rule of the mean point and the trapezium. Simpson's rule for calculating the integral is as follows:

$$\int_a^b f(x)dx \approx \frac{b-a}{6} \cdot \left[f(a) + 4f\left(\frac{a+b}{2}\right) + f(b) \right]$$ *eq. 7*

(eq.7)

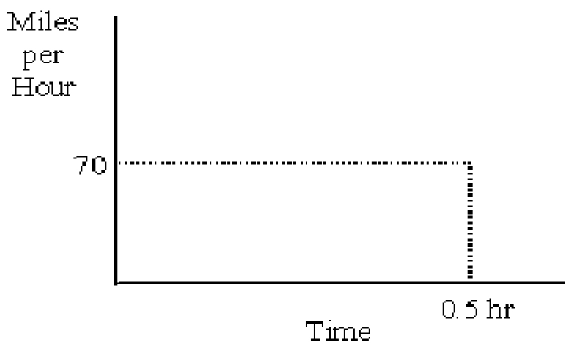
	0,05 - 0,00	0,10 - 0,05	0,15 - 0,10	0,20 - 0,15	0,25 - 0,20
sin(2πa)	0,00000	0,30902	0,58779	0,80902	0,95106
sin(2πb)	0,30902	0,58779	0,80902	0,95106	1,00000
sin(2π(a+b)/2)	0,15643	0,45399	0,70711	0,89101	0,98769
area	0,00779	0,02261	0,03521	0,04437	0,04918

The sum of these values gives the result of 0.15916.
Obviously Simpson's rule is the preferable method for the numerical calculation of the integral.

The calculation of the integral of the variable functions, such as those of seismic records, is more precise than the derivation. The presence of a slight background noise does not significantly alter the result of the calculation.

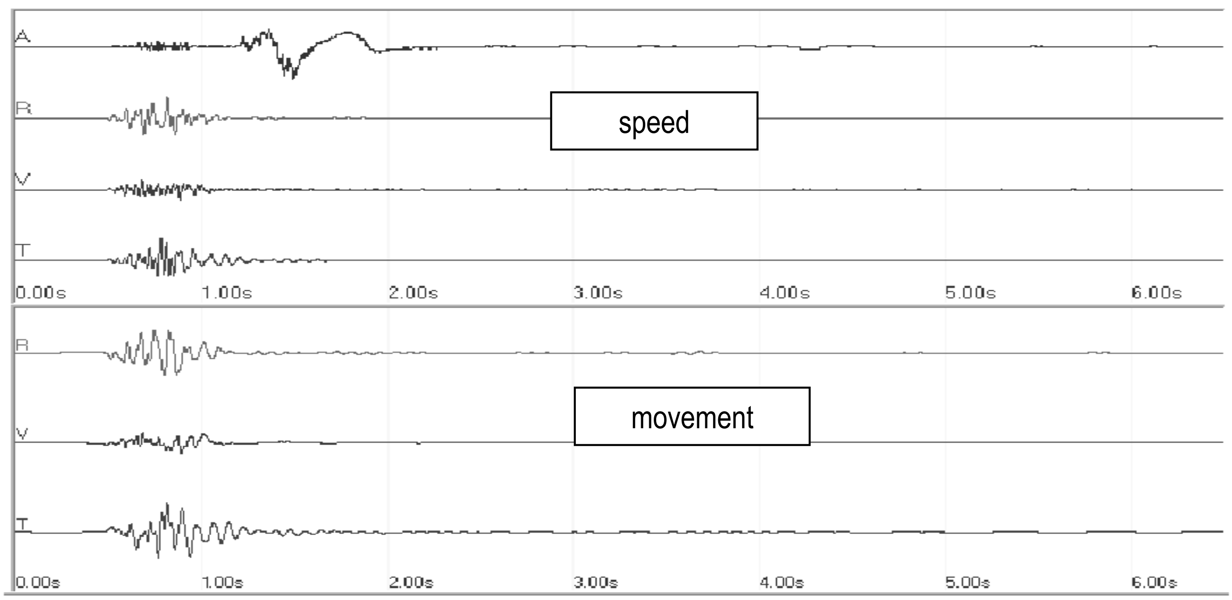
Converting speed into movement

The data of the speed can be converted into movement through integration. Remember that calculating the integral is the process for finding the area of a curve. Take the case of a vehicle being driven at a speed of 70 Kpm for 30 minutes. What distance will it cover? The answer is obvious, 35 km. What is the link with the integral?
Consider the following figure:



The curve is a rectangle. The area of the rectangle is found by multiplying the lengths of the two sides. One side of the rectangle is given by the constant speed of 70 Kmph for 30 minutes, the other side by the time of 0.5 hours. Multiplying the two sides we obtain the value of 35 Km.
The forms of waves of the speed of vibrations generated from an explosion are much more complex than a simple rectangle. In reality rectangles can also be used to calculate the area of a curve (Rule of the rectangle). In addition, it has also been specified that a more accurate method exists to do this called Simpson's rule.

The following figure shows recordings of the speed of a particle that has been converted into a recording of movement by an integral, calculated using Simpson's rule. Note that the integral tends to level out the higher frequencies. This situation is discounted consequent to the fact that for a given speed of the particle, the higher the frequencies, the less the movement.



After having calculated the integral of the waveform of vibration a significant problem can be verified. All the recordings contain background noise. This has no significant effect on the original recordings. Nevertheless, when the integral is calculated this background noise can cause a distortion and the movement of the zero line from the waveform of the integral. In most cases the problem can be solved filtering the integrated recording. The program performs this filtering automatically.

Sinusoidal estimate

Supposing that a recording of an event is equal to a sinusoidal curve, i.e. that the recording can be described by an equation.

$$v(t) = A \sin \omega t$$

eq.8

In which A is the maximum value assumed by the sinusoidal curve, t is the variable time, (symbols) in which f is the frequency and v(f) is the speed at moment t.

From the calculation of the integral we know that:

$$x(t) = \int A \sin \omega t dt = \frac{-A \cos \omega t}{\omega}$$

eq. 9

in which x(t) is the movement at moment t.

Considering only the maximum values and ignoring the negative signs of equation 8, we obtain:

$$v = A$$

eq. 10

$$x = \frac{A}{\omega}$$

eq. 11

quindi

$$x = \frac{A}{\omega} = \frac{v}{2\pi f}$$

eq. 12

This means that if the maximum speed of vibration and the frequencies associated to it are known, the maximum movement can be calculated with a certain margin of approximation (in the case in which the recording of the speed is the sinusoidal type).
For example, in this case the maximum speed is 0.57 in/s (14.48 mm/s) and the maximum frequency is 39.3 Hz. Consequently the estimated movement will be:

$$x = \frac{14{,}48 mm / s}{2\pi * 39{,}3 Hz} = 0{,}0586$$

eq. 13

SUMMARY TABLE OF THE DATA OF THE BLAST –rec. NTX

Table 1.1. Data from the analysis of the seismic measurements

Tabella 1.I. Dati dall'analisi delle misure sismiche.

			max	13,0	18.0	9,0	155	201	170	800	784,8	39,2	MJ/kg	MJ/kg	252
			min	0,1	0.2	0,2	6	5	5	25	90,2	2,1	3.1	4,1	22

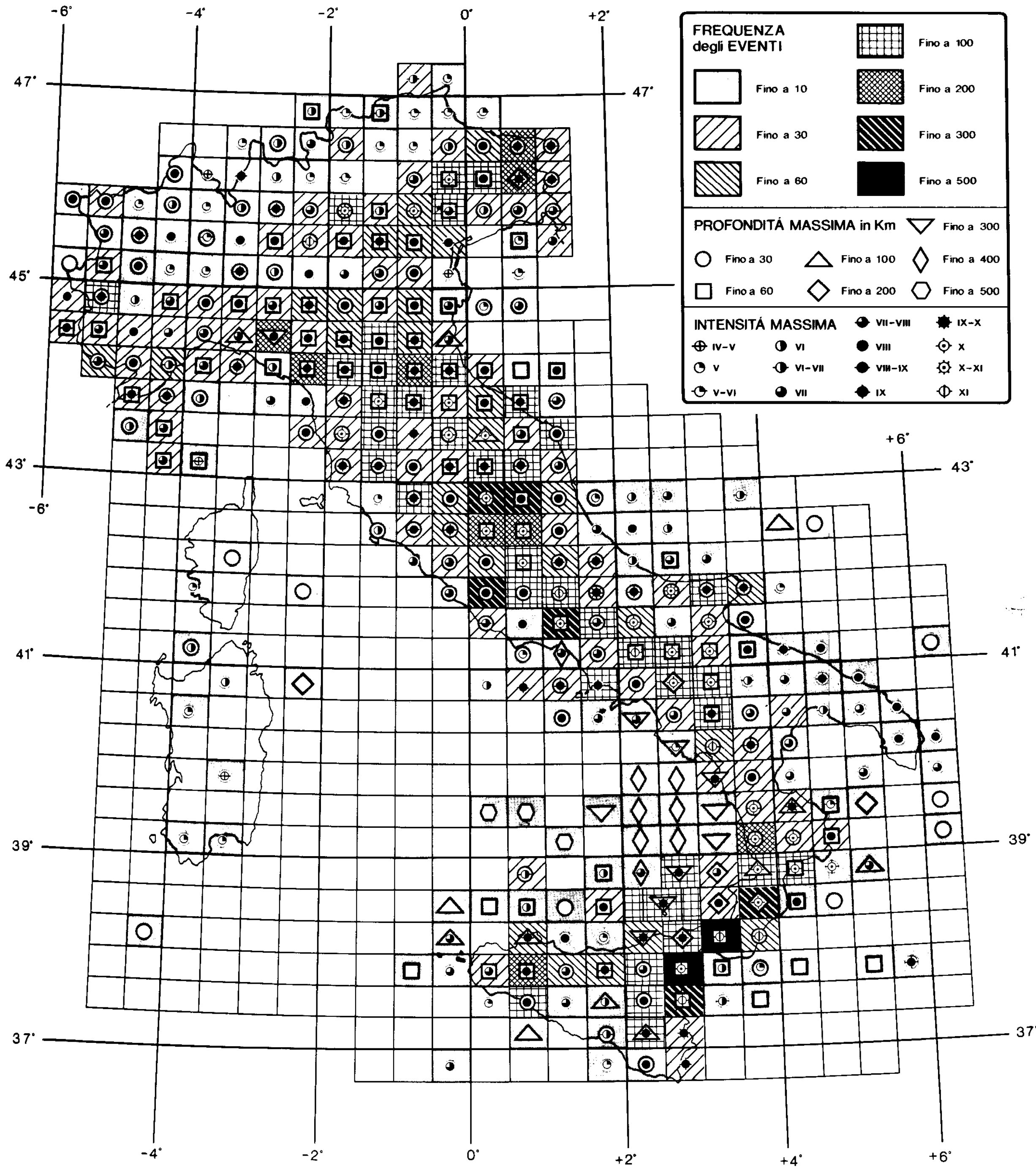
(...)

				componenti velocità			frequenza valore di picco			Distanza	Carica	Distanza scalata	AN.FO.	Slurry	
				Vr	Vv	Vt	fR	fV	fT	R	Q max	DS			
n.	data	ora	Note	mm/s	mm/s	mm/s	Hz	Hz	Hz	m	MJ	m/MJ$^{0.528}$	kg	kg	kg totali
17	28.2.02	12:00	Punto 1 galleria - Evento n.r. - Sismografo n. 1778 - Volata I (cielo aperto)	<1	<1	<1	n.r.	n.r.	n.r.	560	147,6	40,1		36	36
18	28.2.02	12:00	Pnt. 2 uffici - S. BC7688 - Ev. 6666YEH.OEG - Volata I	1,9	1,0	1,3	15	13	23	130	147,6	9,3		36	36
19	28.2.02	12:00	Pnt. 3 paese - Ev. n.r. S. 1089 - Volata I	<0,5	<0,5	<0,5	n.r.	n.r.	n.r.	600	147,6	43,0		36	36
20	28.2.02	12:00	Pnt. 4 imbocco - Ev. 217 - S. 1495 - Volata I	0,4	0,2	0,6	28	32	39	250	278,8	12,8		68	68
21	28.2.02	15:00	Pnt. 1 - Ev. 056 - S. 1778 - V. II (in sotterraneo)	5,5	3,4	5,6	64	170	128	100	195,3	6,2	63		63
22	28.2.02	15:00	Pnt. 2 - S. BC7688 - Ev. n.r. - V. II	<0,5	<0,5	<0,5	n.r.	n.r.	n.r.	590	195,3	36,4	63		63
23	28.2.02	15:00	Pnt. 3 - Ev. n.r. - S. 1089 - V. II	<0,3	<0,3	<0,3	n.r.	n.r.	n.r.	600	195,3	37,1	63		63
24	28.2.02	15:00	Pnt. 4 - Ev. n.r. - S. 1495 - V. II	<0,5	<0,5	<0,5	n.r.	n.r.	n.r.	350	195,3	21,6	63		63
25	28.2.02	17:00	Pnt. 1 - Ev. 057 - S. 1778 - V. III	12,0	11,0	6,1	34	170	64	100	775,0	3,0	250		250
26	28.2.02	17:00	Pnt. 2 - Ev. - V. III	<0,5	<0,5	<0,5	n.r.	n.r.	n.r.	590	775,0	17,6	250		250
27	28.2.02	17:00	Pnt. 3 - Ev. - V. III	<0,3	<0,3	<0,3	n.r.	n.r.	n.r.	600	775,0	17,9	250		250
28	28.2.02	17:00	Pnt. 4 - Ev. 220 - S. 1495 - V. III	0,8	0,6	1,3	20	35	44	480	775,0	14,3	250		250
29	1.3.02	17:00	Pnt. 1 - Ev. 058 - S. 1778 - V. IV	13,0	18,0	9,0	36	85	102	90	527,0	3,3	170		170
30	1.3.02	17:00	Pnt. 4 - Ev. - V. IV	0,8	0,8	0,8	43	73	73	350	527,0	12,8	170		170

(Cfr. relazione "Rapporto sulle misure del 28 Frbbraio e 1 Marzo 2002, ns. rif. 02-007, 27.03.02)

(...)

MAP OF EARTHQUAKES IN ITALY from the year 1000 to the year 1980



ELECTRICAL SEISMOGRAPHS

The electrical seismograph is a device able to transform a physical size into electric signals proportional to the physical size itself.

The knowledge of the proportionality between electric signals and physical sizes allows quantifying the amount of the given physical phenomenon and its time variations.

The different elements that constitute a seismograph and its “architecture” condition its characteristics and field of application.

The parameters of the seismograph that must be defined to check its suitability to reproduce the physical phenomenon faithfully are:

- sensitivity
- dynamics
- linearity
- band of functioning
- noise
- delay.

The following types of seismographs can be used for measuring elastic waves in solid objects:

- SPEED SEISMOGRAPHS or geophones or velocimeters
- ACCELERATION SEISMOGRAPHS or accelerometers
- DEFORMATION SEISMOGRAPHS or electrical resistance extensimeters (LVDT – long base)
- movement seismographs

For measuring elastic waves in liquids, the following seismographs can be used:

- PRESSURE SEISMOGRAPHS or HYDROPHONES.

Comparison between geophones and accelerometers

Geophones are seismographs able to detect instant by instant the speed of a material body while accelerometers are seismographs able to detect instant by instant the variation in the speed of a material body.
Even though these seismographs measure different physical sizes it is easy to see how the two sizes are correlated. An acceleration or deceleration corresponds to an increase or decrease in speed and vice versa.
Apart from its complexity, the movement of a material body in space can be reconstructed by knowing the components of acceleration and/or speed on the three axes of Cartesian space ("x", "y" and "z"), instant by instant.
The speed of a point at any instant, simplifying with the hypothesis of a straight line, can be calculated summing the acceleration with the initial speed for the time to which it is subjected.
For example, if a force f (f = 1Newton) is applied to an initially stationary (v= 0 meters/seconds) material body (m = 1 kilogram) an acceleration a = F/M results.

Time	*Acceleration*	*Speed*
0	1	0
1	1	2
2	1	3
3	-1	2
4	-1	1
5	-1	0

From a mathematical viewpoint it can be expressed as obtaining the trend of the speed of a material body by integrating its acceleration.

$$v = \int_0^t a\delta t$$

The behavior of the various frequencies of a geophone and an accelerometer can be analyzed with the help of a vibrating table. From the experiment we discover that:

- From the much lower oscillation frequencies of the vibrating table than the frequencies of the seismograph, we find a greater variation of signals at the extremes of the oscillations (the seismograph becomes sensitive to the variations of speed).
- From oscillation frequencies near that of the resonance we find a marked movement of the inertial mass, by effect of the resonance, in opposition of phase with the movement of the vibrating table[1];

[1] In this case the seismograph has a response depending on the various parameters: number of cycles of oscillation, "merit factor Q" (inverse to the dampening) etc. The seismograph accumulates mechanical energy, at the start of the oscillation and releases it the end of the oscillation. In permanent working conditions, the exit signal is amplified with respect to the distant response of the resonance and proportionally to the Q factor.

- From the osculation frequency of the vibrating table much greater than that of the resonance of the seismographs, we note the tendency of the inertial mass to stop and we, therefore, have the movement of only the structure of the seismograph with the consequent presence of signals directly correlated to the speed.

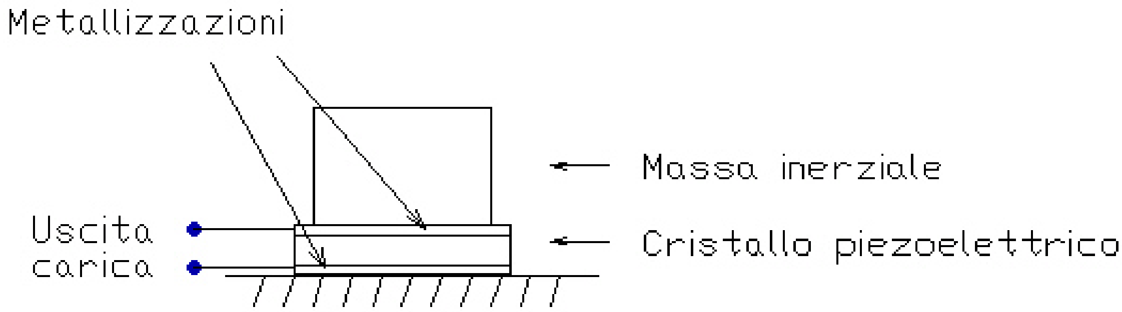
At this point we can see that at the conceptual level the distinction between accelerometer and geophone (velocimeter) does not exist but bands of functioning exist in which a seismograph behaviors like a geophone, an accelerometer or as a combined geophone-accelerometer.
It cam therefore generically be found that a movement seismograph;

- in the region of frequencies lower than those of resonance tend to behave as measurers of acceleration:
- in the region of frequencies higher than those of resonance tend to behave as measurers of speed.

For geophones in common use the frequency of resonance is in the order of several units of Hertz. To have a satisfactory response it is necessary that the geophone has a frequency of resonance lower than the frequency of the oscillating phenomenon whose speed over time must be measured.
With an increase in the factor of the Q merit of the mass-spring system of the geophone, the amplification increases, and, therefore,. behavior in the adjacent band pf frequencies near the frequency of resonance worsens: to deal with this inconvenience we reduce the mechanical oscillations by conditioning the response signal with resistances of suitable value (called *dumping* resistances). These are directly connected to parts of the bobbin of the geophone to generate a magnetic flow that contrasts the movement of the bobbin diminishing the phenomenon of accumulation of energy (lower Q = increase in the damping) with consequent increase in linearity of the seismograph in the face of the frequency.

Piezoelectric accelerometer

A Piezoelectric accelerometer is formed by an inertial mass and a piezoelectric crystal attached.



At the arrival of a seismic vibration the inertial mass tends to maintain its quiet position and the crystal interposes between the inertial mass and the base, becoming deformed and emitting a quantity of electric charge directly proportional to the deformation. The electric charge produced acts on the capacity of the crystal, generating electric tension proportional to the charge produced according to the following equation :

(EQUATION)

The seismograph is characterized by its own mechanical resonance that depends on the construction and due to the inertial mass and the elasticity of the crystal altering the result.

The frequency of the resonance of piezoelectric accelerometers range from the order of tens of Hertz to a few Hertz.

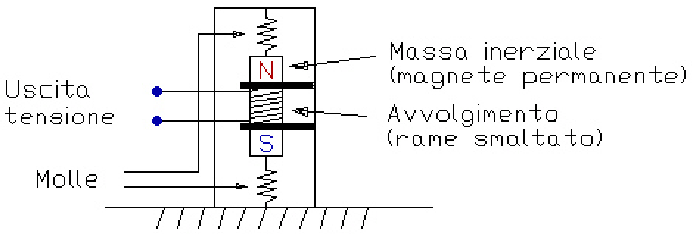
Capacitor with inertial mass recall bobbin (Servo-accelerometer)

A capacitor accelerometer is formed by an attached inertial mass with mobile armor of a condenser applied to a Weastone bridge with other three condensers of fixed capacity.
At the lower and upper ends the bridge is supplied with an alternate sinusoidal signal.
In conditions of rest the mobile armor is in such a position as the condenser whose capacity is equal to that of the adjacent condenser at rest and, therefore, the bridge is balanced, and, therefore, the right and left reading terminals are without tension.
As soon as the mobile armor is subjected to movement relative to the structure, a variation of the capacity takes place that unbalances the bridge that will see a signal leaving proportional to the unbalance. The signal suitably straightened and amplified is applied to a bobbin that recalls the inertial mass to its original position; the measurement of the current in the bobbin will be proportional to the force and, therefore, the acceleration to maintain the bridge in balance.

In this case to limit the frequency of use is the speed of response of the system and the capacity of the circuit that supplied the current for recalling the seismic mass.
Accelerometers of this type have functioning frequencies of static acceleration up to a few kHz

Inertial Mass Geophone

It consists of an inertial mass constituted with permanently magnetized material and suspended between one and two attached springs with a structure that allows the movement of the inertial mass on the axis of elasticity of the spring (it can be horizontal or transversal).
Coaxially to the axis of movement of the inertial mass a bobbin is present, composed of many turns of enameled copper wire.



The inertial mass tends to maintain its quiet position so that when the container that is attached to the support point moves, the relative movement of the container-inertial mass takes place.

The translation of the container, and therefore the bobbin, with respect to the magnetic inertial mass determines the variation in the magnetic field linked to the bobbin. The variation in flow, on the basis of Lenz's law, induces tension in the heads of the bobbin equal to :

E = B l v

where B is the magnetic field
l is the length of the electric wire immersed in magnetic field B
v is the magnetic field-electric wire speed.
The tension induced in the heads of the bobbin is, therefore, directly proportional to the speed with which the bobbin is moving with respect to the inertial mass.
Since the bobbin is attached to the container, in its turn connected to the material body whose speed is required, it follows that the tension measured instant by instant at the heads of the bobbin provides the measurement of speed instant by instant of the material body to which it is coupled.

An important element for knowing the precision of the measurement is determined by the mechanical response of the mass-spring system.
This constitutes a mechanical oscillation whose frequency of resonance

$$f_0 = \frac{1}{2\pi\sqrt{\frac{k}{m}}}$$

is given by :

The mechanical frequency of resonance of a geophone in common use is of the order of some units of Hertz.

(ILLUSTRATIONS)

Placing a geophone at the bottom of a hole near the demolition blast and preparing the measurement station for detecting the seism induced, needed for optimizing the blast.

Laser interferometer velocimeter

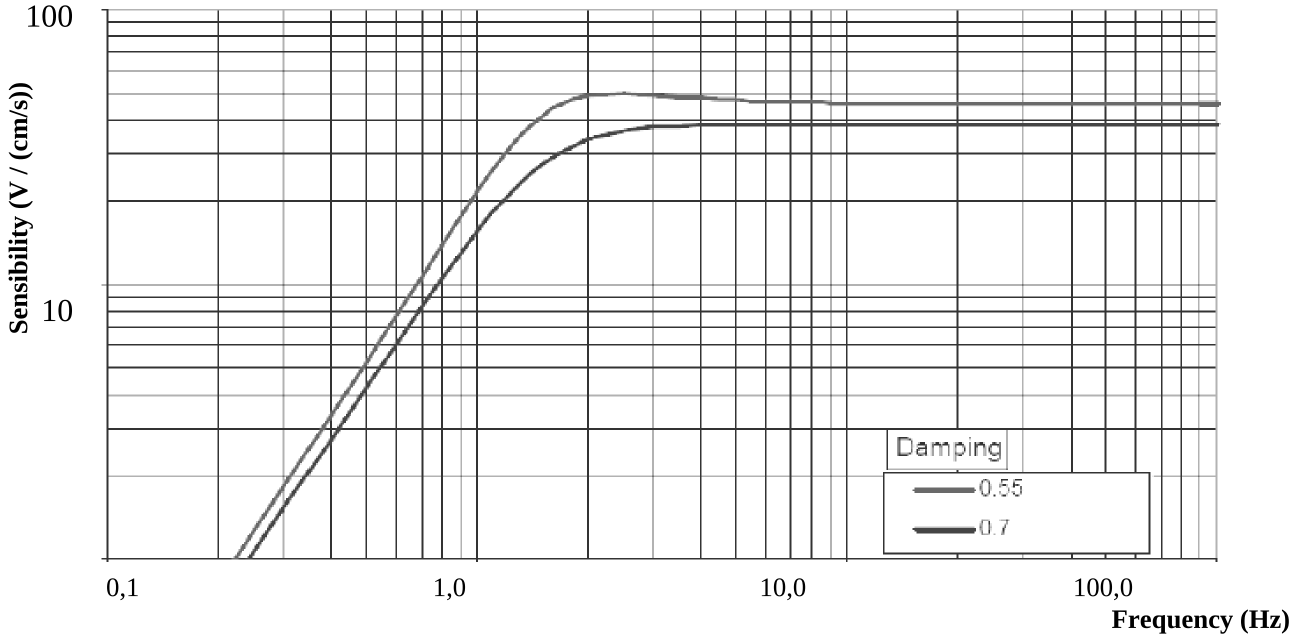
A laser interferometer velocimeter uses the Doppler effect obtained when an object emits an electromagnetic wave, e.g. light, and moves relatively with respect to one of reference.
If the object is approaching the point of reference, an increase in the frequency of the wave observed by the reference takes place, if the object is withdrawing a diminution takes place.
To measure the speed of a material body that does not emit electromagnetic waves it is necessary, therefore, that it reflects. In the case in which the electromagnetic wave consists of a ray of laser light, the reflection can be simply determined by a reflecting mirror-type surface.
The velocimeter laser, indeed, emits a ray of concentrated light, divided into two in the device by a semi-reflecting mirror. The first ray is sent toward the material body rendered reflection and returned to the device that can, therefore, with appropriate detectors, measure the difference in frequency of the two rays.
This difference (due to the Doppler effect) is proportional to the relative speed of the emitting laser and the reflecting object.

Frequency response of speed seismographs

The response in frequency is the range of frequencies within which the electric signal of the seismograph is linearly proportional to the amplitude of the event measured, or rather within which the seismic electric signal is constant for a constant movement.
The link between a seismic electric signal and amplitude of the event is normally expressed in decibels (dB). For example, a linear response within 3 dB between 3 and 200 Hz means that the seismograph is generating a constant voltage with a 30% variation between 3 and 200 Hz. From the spectrum of response of the seismograph it is possible to determine the specific frequency at which this difference is taking place. Many manufacturers of measurement systems for vibrations use electronically induced amplified explosions for the output of low frequencies to be able to use high frequency seismographs, which are smaller. The instruments with electronic amplification must be calibrated periodically.
The choice of the appropriate speed seismographs response in frequency is made in function of the measurement to be made. There are two choices: measuring the real phenomenon or the efficient measurement of the important characteristics. The entire range of frequencies needed for the description of the real phenomenon linked to the explosion is too vast for any seismograph. The delayed pressure impulses of the gas of explosion taking place with a frequency lower than 1 Hz and in proximity to the point of explosion have been measured with accelerations of over 1000 Hz. It follows that it is necessary to adopt a compromise solution and the definition of the real phenomenon is only possible when several kinds of seismographs are used. The optimum choice of the seismograph must, in any case, be made with reference to the particular characteristics of the movement to measure and the means with which the measurement is carried out.

Monitoring vibrations for checking cosmetic lesions in low structures is generally carried out by measuring the speed of the land or the particles of land in a range of frequencies from 3 to 200 Hz. This range ensures an appropriate recording of amplitude and frequency of stress, covering the fundamental range of frequencies of the structures and are associated to those peak values of speed that induce the greater movements. The response frequencies of the structures are generally included between 5 to 20 Hz for structures with one or two floors and between 10 and 40 for the walls and floors. Some mechanical equipment can have fundamental frequencies at 100 Hz but

these are usually anchored and placed under stress by floors and walls with very much lower characteristic frequencies.
The typical predominant frequencies of stress vary between 5 and 100 Hz as shown. For the instrumental control of movements with unusual frequencies or with extremely high frequencies it becomes necessary to use special seismographs with linear responses in the range of frequencies concerned.



Response curve of a speed seismograph for various damping.

ACOUSTIC SEISMIC MONITORING STATION – facsimile

NOMIS Mini-Graph® 7000
Portable monitoring station for acoustic seismic waves

PRODUCT DETAILS

Robust watertight aluminum container for operating in any weather conditions, possibility of storing up to 340 events in memory

Robust container for the recording unit, the vibrations and noise seismograph and for the accessories.

Instantaneous reading of the measurements with crystal display

Concession and technical assistance center for Italy:

Tri-axial velocimeter for measuring vibrations, microphone for measuring airblast waves, RS-232 portal for downloading data on PC or remote link via modem/GSM

Description

The Mini-Graph ® 7000 is a portable acoustic seismic monitoring station, compact, robust, economic and reliable. It is the latest generation of a family of instruments from the USA campaign, used throughout the world by specialist engineers and geologists of mechanical vibratory phenomena and for explosions. It is equipped with analysis software and Italian manual. Ideal for continuous monitoring of vibrations and noise generated by work, traffic, caving activities, etc., allows detecting conformity to the European and Italian regulations on admissible vibrations. It is simple to use. Arrangement for measuring can be made directly on the site. The data acquired can be read immediately on the liquid crystal display and then transferred to a PC via RS232 for elaboration and printing. The possibility of transferring data via modem or via GSM makes consultation easy from remote positions (e.g. office) saving time needed for sending personnel to the post.

Maintenance

The Mini-Graph ® 7000 is a robust instrument and does not require particular maintenance. Prolonged use in temperatures below zero might accelerate the process of wear of the batteries. The seismograph cables must be cleaned regularly.

Certifications

CE certificate of conformity to European regulations in the field of electric equipment.
Calibration certificate.

Function

Installation on the site is simple and rapid. The seismographs (geophone and microphone), after having been positioned, are connected to the acquired power plant by watertight aluminum spikes.
Connection automatically switches the instrument on that, in this way, begins measuring.
The recording of an event is carried out only when the values measured exceed a pre-established alarm threshold - trigger, conserving the measurement also for 0.5 s preceding the instant of triggering.
Completed the recording, the instrument checks the seismographs to verify the correct functioning and positioning, and then continues measuring, rearming itself for the next recording (rearming time 50ms).
In the case of measurement prolonged over 80 hours without exceeding the alarm threshold, the machine automatically carries out a check on the seismographs to verify correct functioning and positioning (self-calibration test).
The calibration tests are conserved in the memory, confirming that the measurements have taken place without exceeding the trigger threshold.
For various measurement needs, cable extensions or other seismographs (movement, accelerometers, …) are available and two levels of sensitivity (x 2 and x8, four times more sensitive).

The measurement can also be set at pre-established intervals, variable from … to … hours in the bar graph mode, with indication of the maximum value in a pre-established time interval.

<u>Technical characteristics</u>

General±

Number of channels: 4 pf which 1 acoustic and 3 seismic
Memory…………… solid state with summaries of all measurements, settings, recorded data
maintained and supplied while off. Lithium backup battery.
Timer mode………...for switching the instrument on and off during the day
Display……………..high contrast liquid crystal, two lines of 40 characters
Keyboard…………...6 keys for setting and command
Battery……………...6 volt internal for 7-10 days monitoring (possible connection to external
Battery and/or solar cell)
Operating temperature –15°C to +50°C (the duration of the battery is reduced in low temperatures)
Dimensions and weight: 20x10x6.6 cm for about 2 kg
Storage data ……….a maximum of 340 forms of waves complete with storage in the sold state
Memory (duration 4 seconds) with hour and date of the events, peak values and
frequencies, series number of the instrument, alphanumerical strings
Measurement unit….International or Imperial system
Duration of recording: from 1 to 20 seconds, in function of the sample frequency with pre-trigger
memory
Sample frequency…...standard 520 or 1024 cps per channel (on request up to 2048 cps per channel
with extension of memory
Serial portal RS232….for transferring data and settings direct from PC or remote via modem/GSM
Baud Rate……………1200 at 38.4 k bps

Seismic waves
seismographs…………velocimeters
response in frequency….. from 3 to 400 Hz ± 2% (on request with response ± up to 1 Hz)
sensitivity: model x 2 equal to 0.125 mm/s, model x 8 equal to 0.0315 mm/s
area of recording ….(can be selected by user) model x2 background scale 86 – 127 and 250 mm/s
alarm threshold – trigger ………….model x 2 0.25 mm/s
Model x 8 0.63 mm/s

Airblast
seismograph ………microphone with ceramic element – background scale 160 Db
Sample frequency…..from 32 to 1024 cps
Area of recording….(can be selected by the user) 100-142 Db, 108-148 Db
Alarm threshold……106 148 Db

The data in the present brochure are indicative. MEDEX reserves the right to modify format and characteristics without notice
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Calculating Fourier's Transform

The transmission of waves through natural means from the source to the point of measurement is often complicated by interposed geological formations, in whose network of joints the waves are reflected and also refracted, generating forms of complex waves and determining the gradual transformation of the energy from the high frequency harmonic components to those lower.
From a mathematical viewpoint the forms of waves of vibrations induced by a blast are characterized by an infinite number of same-phase harmonic sinusoidal components of different amplitudes and frequency. To be able to establish the amplitude of the harmonic component of each frequency Fourier's transform is calculated, or rather with a simplified method the FFT (Fast Fourier Transform).
The FFT is based on Fourier's theory according to which every periodic function, f(t), can be expressed as the sum of an infinite number of same-phase simple and different sinusoidal components multiplied by a coefficient.
A periodic function f (t) can be expressed as:

$$f(t) = f(t+T)$$

for all the ts the constant T is the period of the function f(t).
The function f(t) can be expressed through the Fourier series

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty}\left[a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)\right]$$

in which (formula) the term (letter) is called the radial frequency.
Starting from the Fourier series we can obtain Fourier's integral and consequently Fourier's transform.
Fourier's transform is defined as follows:

$$F(f) = \int f(t) e^{-j2\pi ft} dt$$ dove *f* è la frequenza in Hertz.

where f is the frequency in Hertz.

The function F8f) is complex and can be expressed as

$$F(f) = R(f) + jI(f)$$

where R/f is the real part of F(f) and |(f) is the imaginary part of F(f).
The amplitude spectrum, the analysis generated by this program is given by:

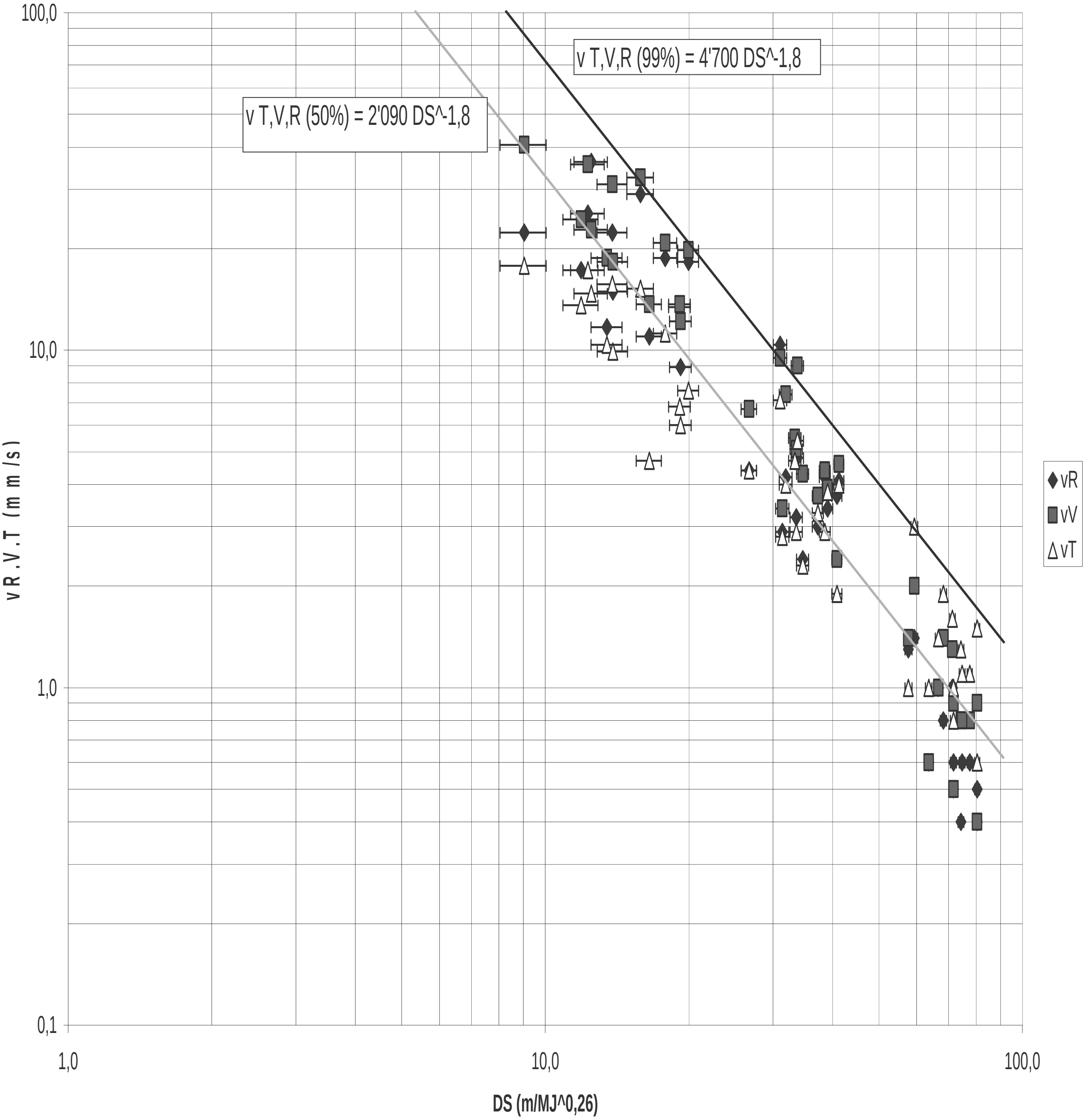
$$A(f) = \sqrt{R^2(f) + I^2(f)}\ .$$

For the analysis of the effects of the vibrations induced, the Fourier transform compares the vibrations induced with sine and cosine functions at various frequencies. The results of Fourier' transform indicate the predominance of the frequency of one of the harmonic components over the others. The maximum amplitude of the maximum harmonic component of Fourier's transform is not necessarily dependent upon the maximum amplitude of the recording.

Calculating the SPEED OF VIBRATION by extrapolation

Example:
Diminution curve calculated in cave XXX for STANDARD N.XXX blast with long seismograph aligned in direction 30° NORTH by regression of power of a sample of 117 measured data.

Speed of vibration of the earth at the passage of a transient seism:
Law of reduction of the site-limit of trust



Area of significance of the dinimution curve

	vR	vV	vT	R	Q max
	mm/s	mm/s	mm/s	m	MJ
max	36,1	40,6	17,8	300,0	595,5
min	0,4	0,4	0,6	47,0	164,8

Statistics

	m1 (di Q)	m2 (di R)	K
exponents of Q and R and values of 'b'	0,46	-1,796	7,65
standard error for the coefficients	0,099812	0,06	0,6479
coeff. of determination	0,89		
sy	0,43		
statistic F	453,77		
degree of freedom	114		

Example 1

Given the reduction curve expected shown above, calculate the maximum speed of vibration and the one that will certainly not be exceeded because of the explosion of a cooperating charge of 250 kg consisting of 50 kg of Premex 851 explosive emulsion and 200 kg of An.Fo. at a distance of 250 meters.

Response to example 1

Distance of the point of measurement from the point of explosion R = 250m

Specific energy of the explosion:

- foot charge and reinforcement in column: 50 kg of Premex 851, specific energy of explosion equal to 4.3 MJ/kg
- column charge: 200 kg of An.Fo. AN-FO 4, specific energy of explosion equal to 3.2 MJ/kg for 200 kg = 640 MJ for a total of 215 + 640 = 855 MJ

Scaled distance on the 0.26 elevated charge:

$DS = R/Q^{0,26} = 250\ m / (855\ MJ)^{0,26} = 43,2\ m/MJ^{0,26}$

Even though this scaled distance is included in the area of variation of the scaled distances of the reduction curve, just as from the distance from the point of explosion, the value of the energy of explosion, instead, is outside, and greater by over 40% (855 MJ > of 595.5 MJ, upper value limit of the various charges exploded in the measurement campaign for the definition of the reduction curve of the site).

The probable values and the maximum values of the speed of vibration at the scaled distance of $43.2\ m/MJ^{0.26}$ cannot, therefore, be considered as reliable.

Example 2

Given the diminution curve expected shown above, calculate the maximum speed of vibration and the one that will certainly not be exceeded because of the explosion of a cooperating charge of 150 kg consisting of 30 kg of Emulglt LWC AL explosive emulsion and 120 kg of An.Fo. Hanal 1U. at a distance of 70 meters.

Response to example 2

Distance of the point of measurement from the point of explosion R = 70
Specific energy of the explosion:

- foot charge and reinforcement in column: 50 kg of Emulglt LWC AL., specific energy of explosion equal to 4.4 MJ/kg for 30 kg = 132 MJ
- column charge: 120 kg of An.Fo. AN-FO 4, specific energy of explosion equal to 4.0 MJ/kg for 120 kg = 384 MJ for a total of 132 + 384 = 516 MJ

Scaled distance on the 0.26 elevated charge:

$DS = R/Q^{0,26} = 70\ m\ /\ (516\ MJ)^{0,26} = 13,8\ m/MJ^{0,26}$

The scaled distance is included in the area of variation of the scaled distances of the diminution curve, just as the distance and the charge.

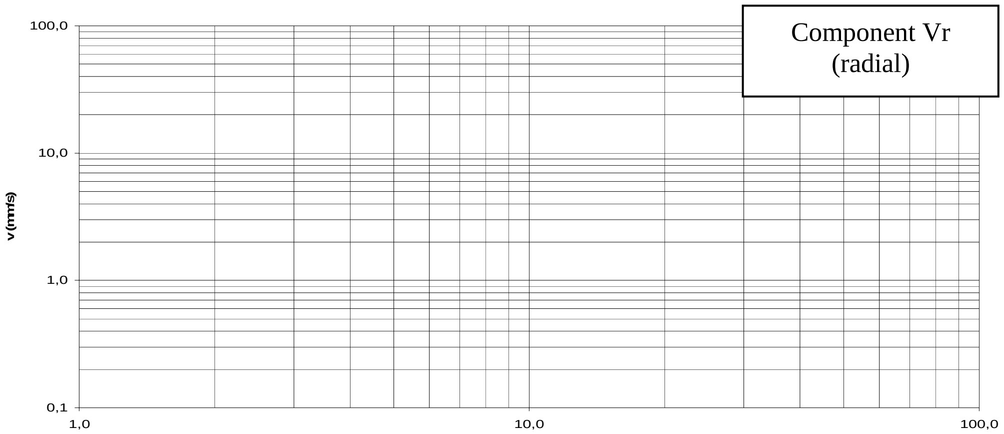
The probable values and the maximum values of the speed of vibration at the scaled distance of 43.2 $m/MJ^{0.26}$ cannot, therefore, be considered as reliable.

The probable values and the maximum values of the speed of vibration corresponding to the scaled distance of 49.4 $m/MJ^{0.26}$ can, therefore, be considered as reliable.

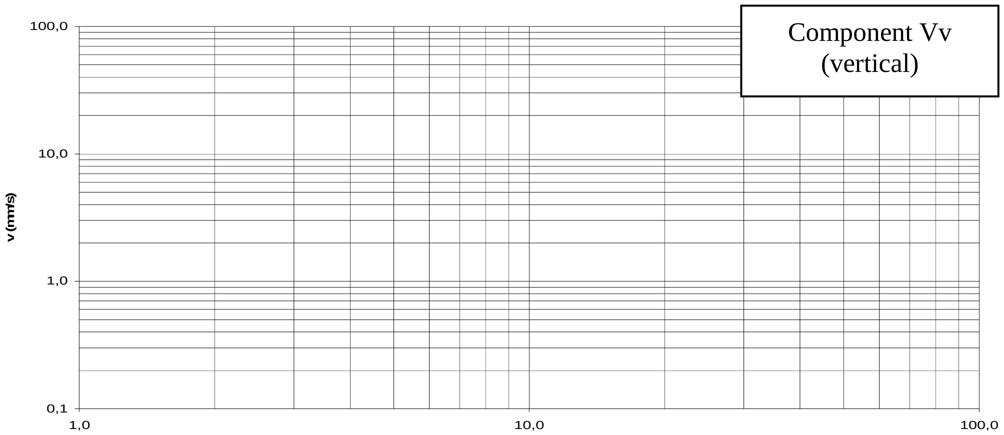
Probable speed (50%) = $2.090\ DS^{-1,8} = 2.090\ (70/513^{0,26})^{-1,8} = 19$ mm/s
Probable speed (99%) = $4.700\ DS^{-1,8} = 4.700\ (70/513^{0,26})^{-1,8} = 42$ mm/s

VIBRATION SPEED interpolation graph – mod. NTX

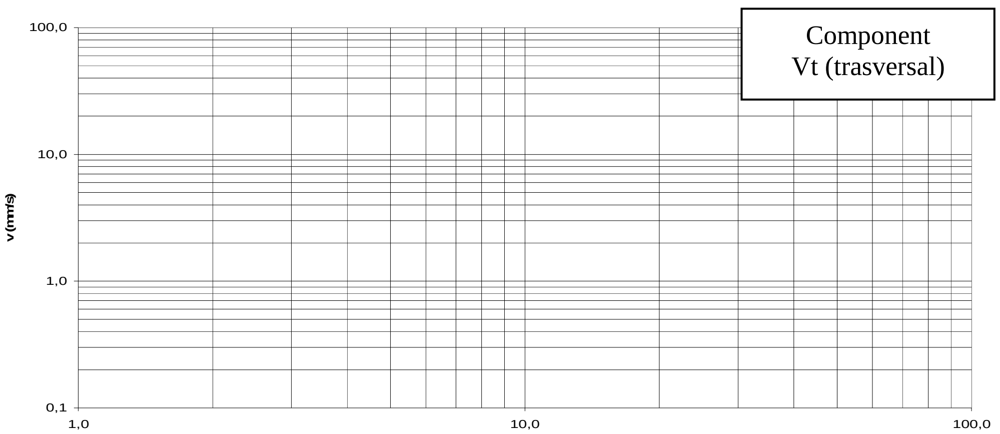
Measurement of the day…………200…. Hour………..
Calculation of the speed value induced at point C………………….. site at……… …..m from the blast
D……………….site at ………. m from the blast
Reference measurement…………..A - seismograph……………event………………R = …………..
B - seismograph……………event………………R = …………..



Inclined distance R (m)



Inclined distance R (m)



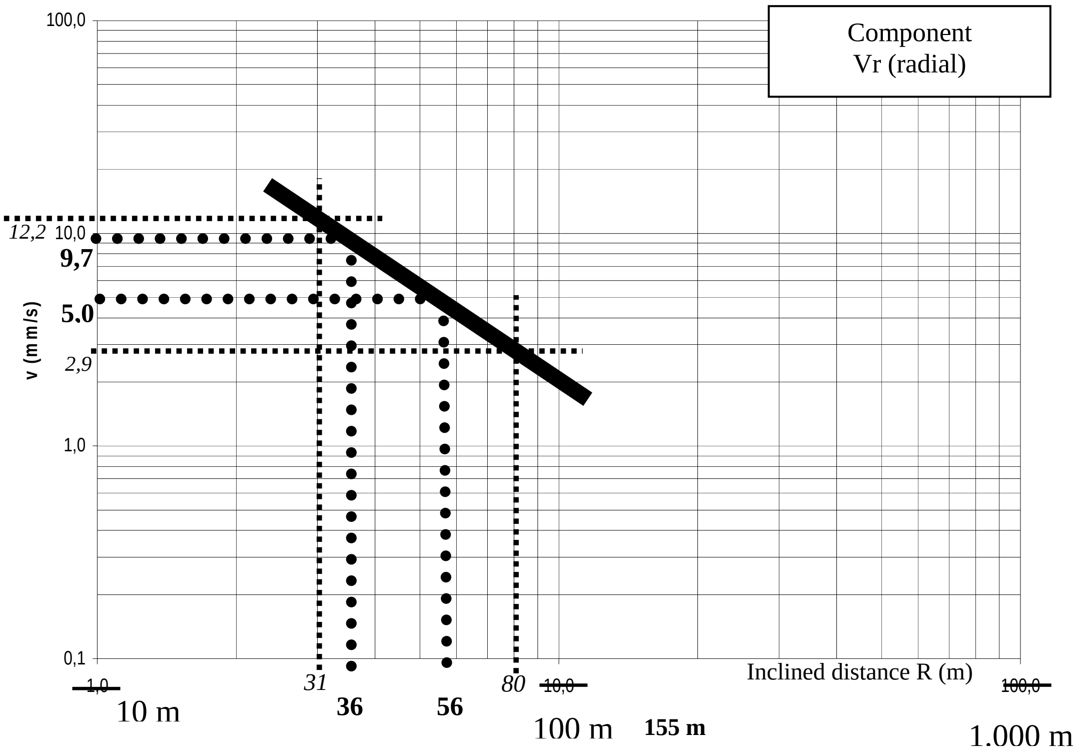
Inclined distance R (m)

Example:

Exploding a step blast.

A seismograph placed at 31 meters has measured 12.2 mm/s;
A second seismograph, placed at 80 m, has measured 2.9 mm/s.

In a point placed at 36 meters from the blast, aligned between the two seismographs, the probable speed of vibration is, therefore, detectable by interpolation as equal to 9.7 mm/s.
In another placed at 56 meters from the blast, still aligned between the two seismographs, the probable speed of vibration is, instead, detectable by interpolation as equal to 5.0 mm/s.



This interpolation also remains valid for the estimate of distance within an area of 20% beyond the limited measurement distances (e.g. also within 80 m + 20% of 80 = 96 meters and of 31 m – 20% of 31 = 25 m.

EARLY WARBIBG LEAFLET EXPLODING MINE – rec. NTX

GENERAL CONSTRUCTION COMPANY

Red Square 2

71538 Corteno Volsci

Palermo Building Yard –Valleybelow District

CONSTRUCTION OF THE NEW HYDRAULIC TUNNEL
NORTH SIDE ENTRANCE

NOTICE

Dear Madam,
Dear Sir,

On………………at about …………a.m. until ……..p.m. there will be an explosive blast for the excavation of a tunnel whose entrance is at…………..

The excavation with explosives has been designed by specialist engineers in order to minimize the disturbance to people living in the vicinity. With the use of explosives it is possible to reduce the duration of the work notably, in this way keeping the discomfort produced by the excavation activity to the minimum.
The explosion will be heard within a range of 150 m with a slight vibration and a weak rumble. The vibrations produced are guaranteed not to cause damage and will not exceed the disturbance threshold laid down by the regulations.

Early warning of the immanent explosion of the charge will be given by three long siren whistles
A second continuous siren whistle will precede the explosion by a few seconds.
Five brief siren whistles will signal the completion of the explosion activity.

For further information contact Mr. Mario Rossi at number ……………….

Please excuse any possible discomfort we may cause you and accept our best wishes.

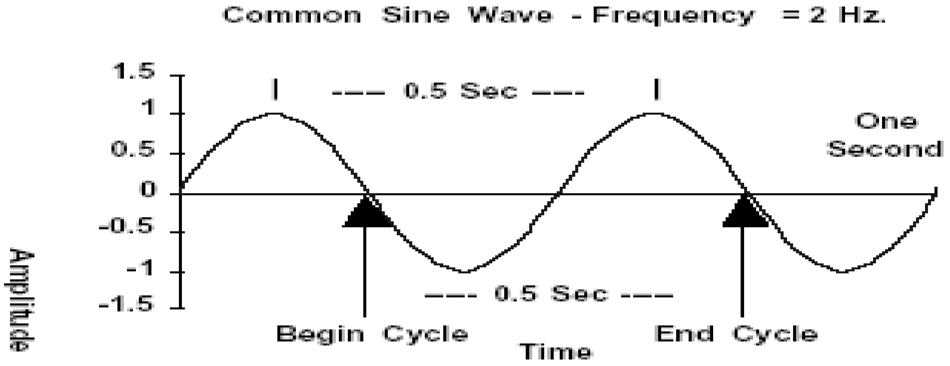
Place and date……….

GEBERAL CONSTRUCTION Company

Calculation of the frequency associated with the peak with the ZERO CROSSING method

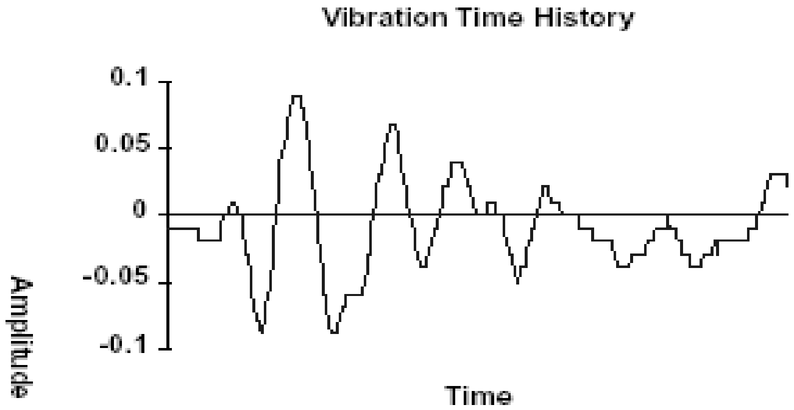
The method generally used to calculate rapidly the frequency associated with a peak of speed of vibration is called the “zero-crossing method”, or rather the crossing of the zero.
This method, even if not perfect, leads to acceptable results in most cases.

From a mathematical viewpoint the frequency of a vibration is the converse of the time that the elementary particle of the soil crossed by the seismic wave takes to make a complete cycle.



This calculation is immediate for a sinusoidal wave. For the sine function the time of a cycle can be defined as the time between the beginning and the end of a cycle or the time included between two successive maximums or two minimums. In the example of the figure shown above the period is 5 seconds.

The frequency is the converse period. Therefore the frequency is 1/05 = 2 Hz.



Seismic waves induced by exploding mines never have a regular form: the characteristic frequency of each peak of the form of wave measured needs to be calculated, supposing that two successive crossings of the zero line represent the half-wave of a sinusoidal wave.