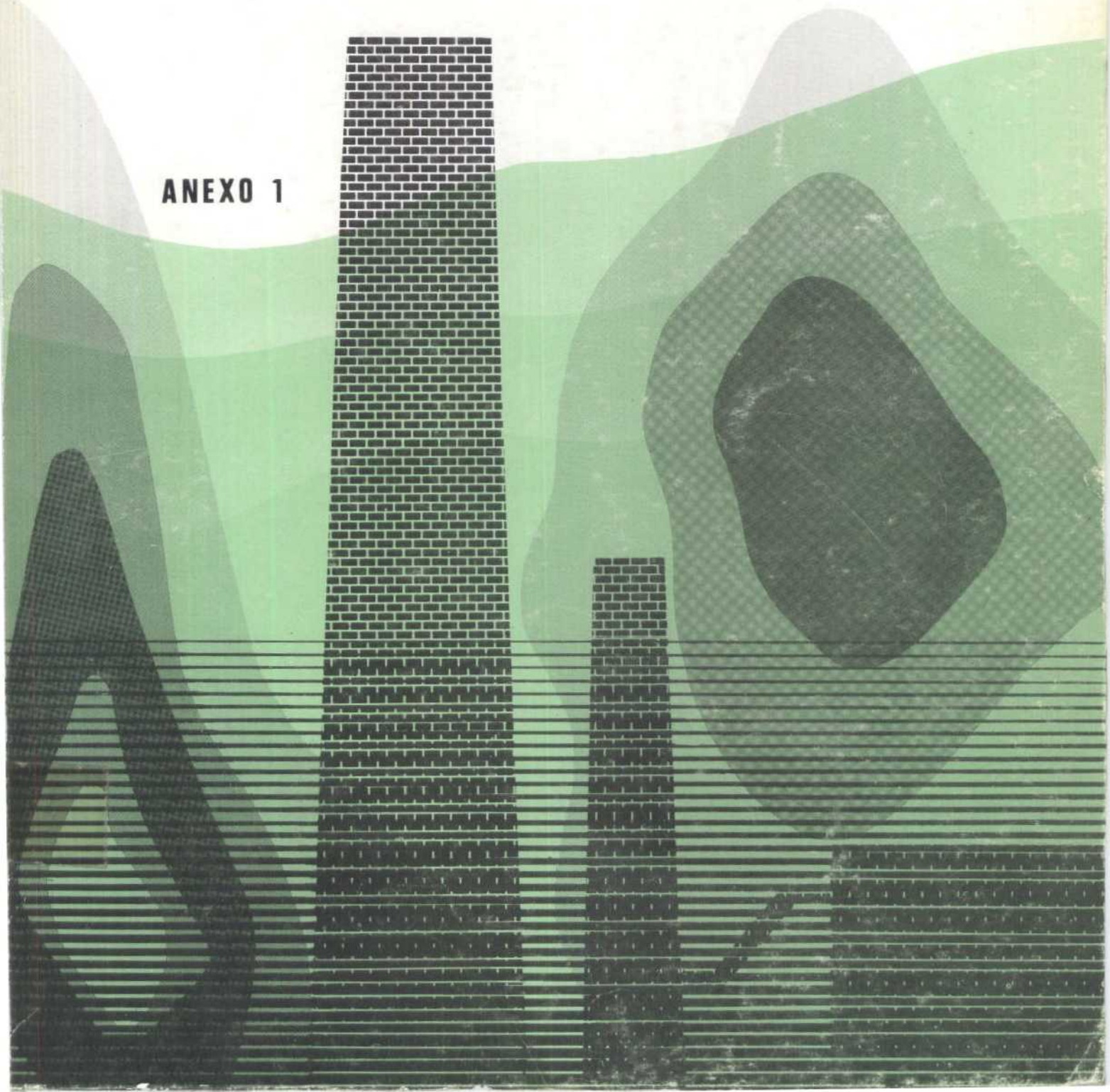
MINISTERIO DE INDUSTRIA
DIRECCION GENERAL DE MINAS
INSTITUTO GEOLOGICO Y MINERO DE ESPAÑA

PLAN NACIONAL DE LA MINERIA
PROGRAMA NACIONAL DE INVESTIGACION MINERA

DISPOSITIVOS DE MEDIDAS DE VIBRACIONES

ANEXO 1



ANEJO N° 1

00211

DISPOSITIVOS DE MEDIDA DE VIBRACIONES.

INDICE

1.- INTRODUCCION

En los últimos años se ha escrito en abundancia sobre sismógrafos especiales con vistas a registrar las vibraciones producidas por voladuras. En este sentido, los diferentes tipos han venido denominándose con nombres como los de registradores de la "aceleración", de la "velocidad" o del "desplazamiento" según el parámetro a medir. En cualquier caso, ningún sismógrafo debería caracterizarse de tal forma sino en un sentido relativo. Ello, debido a que cualquier sismógrafo con un factor de amortiguación de 0,6 da una respuesta proporcional al desplazamiento de la partícula para vibraciones del terreno mayores que las frecuencias de los miembros de inercia, en tanto que, el mismo miembro de enercia, responde proporcionalmente a la velocidad de la partícula para frecuencias del terreno iguales o menores que la mitad de su propia frecuencia, y, por el contrario, tiene una respuesta proporcional a la aceleración cuando las frecuencias del terreno son menores que la mitad de su frecuencia propia.

Así pues, la primera consideración que debe tenerse en cuenta bien al diseñar un sismógrafo o al elegirlo para una campaña vibrográfica, es decidir o conocer el intervalo de frecuencias que van a medirse. En efecto, las vibraciones producidas por voladuras en rocas producen frecuencias que oscilan entre 25 a superiores de 100 c.p.s., en tanto que, en sue

los, tal variación se encuentra generalmente entre 3 y 25 c. p.s.

De estos datos, podemos decir que para registrar las vibraciones originadas por voladuras, necesitamos un sismógrafo con respuesta plana, esto es, con un valor de la constante "Z" - factor de resonancia o amplitud relativa- de 3 a superior a 100, y, así, nos encontramos, que únicamente un sismógrafo en el que su frecuencia natural sea menor o próxima a la unidad cumplirá tal condición en el caso de vibraciones producidas por voladuras.

El sismógrafo portátil típico consiste de un transductor (transducer) sísmico, un medidor de tiempo y un sistema de registro. El último, puede ser eléctrico, fotográfico o mecánico. El medidor de tiempo es simplemente un generador de frecuencia,muy preciso, que imprime, sobre el registro sismográfico, líneas a intervalos regulares de tiempo. El transductor sísmico, por su parte, cumple la misión de convertir las vibraciones del terreno en un voltaje variable o en un movimiento similar de un emisor de luz, la cual se registra en un rollo móvil de papel sensible a la luz.

2.- ASPECTOS TEORICOS

Un transductor sísmico puede proyectarse para responder un modo lineal bien al desplazamiento de la partícula, a la velocidad o a la aceleración.

Dicho transductor puede representarse por un modelo discreto tal como el representado en la fig 1. La ecuación de movimiento de dicho sistema sometido a una oscilación forzada es:

$$m\ddot{x} + r\dot{x} + sx = F\cos wt \quad \ldots\ldots (1)$$

Fuerza de inercia.	fuerza elástica.	Fuerza de amortiguación	Fuerza oscilante

en donde

- F = amplitud de la fuerza
- w = frecuencia angular = 2 M f
- f = frecuencia de excitación
- m = masa de inercia
- x = amplitud instantánea de la onda de desplazamiento.
- r = factor de amortiguación
- k = constante del muelle

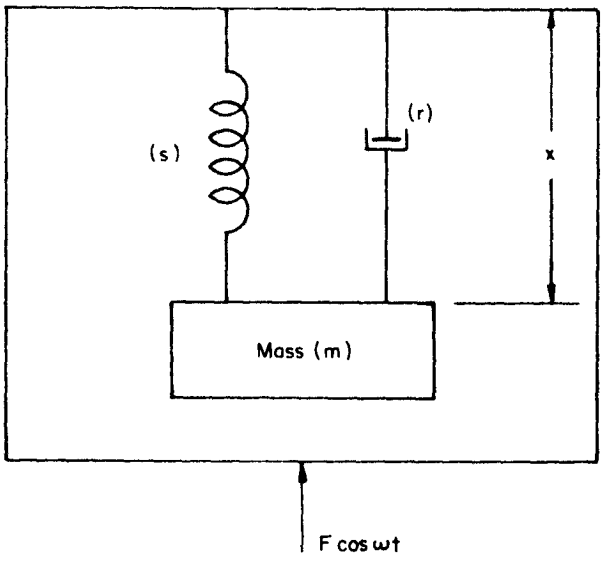


Fig. 1.- Modelo discreto de un transductor (transducer) sísmico.

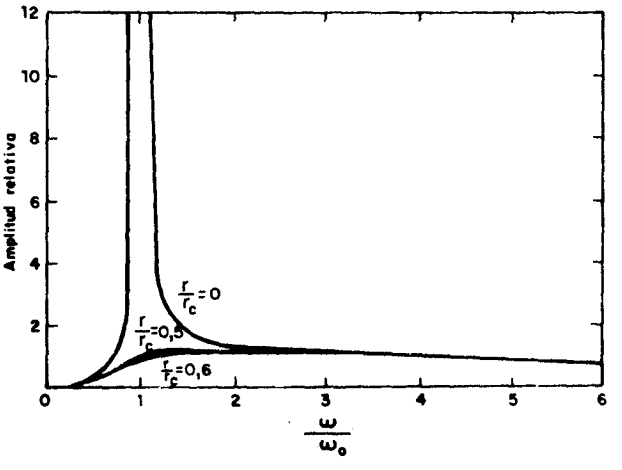


Fig. 2.- Curvas de respuesta teórica de un transductor (transducer) del desplazamiento o de la velocidad.

Una solución de la ecuación es,

$$x = \frac{F \cos (wt - \phi)}{\left[r^2 w^2 + (s - mw^2)^2\right]^{1/2}} \quad \ldots\ldots\ldots (2)$$

en donde el ángulo de fase o de decalage viene dado por:

$$\phi = \tan^{-1} \frac{r w}{s - m w^2} \quad \ldots\ldots\ldots (3)$$

La frecuencia de resonancia del sistema no amortiguado (r = o) es:

$$w_o = 2\pi f_o = \sqrt{s/m} \quad \ldots\ldots\ldots (4)$$

El factor de amortiguación crítico r_c viene dado por:

$$r_c = 2 m w_o \quad \ldots\ldots\ldots (5)$$

De las ecuaciones (4) y (5), las ecuaciones (2) y (3) pueden transformarse en:

$$x = \frac{F \cos (wt - \phi)}{m w^2 \left[4 \left(\frac{r}{r_c}\right)^2 \left(\frac{w_o}{w}\right)^2 + \left(\frac{w_o^2}{w^2} - 1\right)^2\right]^{1/2}} \quad \ldots (6)$$

y

$$\phi = \tan^{-1} \frac{2 \left(\frac{w}{w_o}\right) \left(\frac{r}{r_c}\right)}{1 - \left(\frac{w}{w_o}\right)^2} \quad \ldots\ldots\ldots (7)$$

Para un impulso sinusoidal la aceleración máxima o de pico, a, está expresada en función de la velocidad máxima o de pico, v, y del desplazamiento máximo o de pico, u, por,

$$a = w\,v = w^2\,u \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

y la fuerza necesaria para mover el sistema es:

$$F = m\,a \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (a)$$

Los transductores sísmicos pueden proyectarse, como ya hemos dicho, para medir el desplazamiento de la partícula, la velocidad o la aceleración del movimiento vibratorio. Por tanto, resultan de interés tres tipos básicos de transductores.

2.1.- MEDIDORES DE DESPLAZAMIENTO

Para un transductor de desplazamiento el movimiento vibratorio queda representado por el desplazamiento máximo, u, y la amplitud, A_u, del registro y proporcional al desplazamiento, x. Así,

$$Au = ku\,x \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

en donde ku es la constante de proporcionalidad. De las ecuaciones 6,8 y 9 la ecuación 10 se transforma en,

$$Au = \frac{ku\;\; u\cos(wt - \phi)}{\left[4\left(\frac{r}{r_c}\right)^2\left(\frac{wo}{w}\right)^2 + \left(\frac{w_o^2}{w^2} - 1\right)^2\right]^{1/2}} \quad \ldots\ldots\ldots \quad (11)$$

Resulta evidente, de esta ecuación, que cuando la frecuencia del movimiento disminuye de w_o a 0, la del registro sismográfico tiende hacía cero, y que, para frecuencias del movimiento elevadas comparadas con w_o, la del registro es proporcional al desplazamiento, transformándose la constante ku en el factor de aumento del transductor. Por tanto, un transductor ideal de desplazamiento debería tener una frecuencia de resonancia baja, lo que requiere una constante del muelle también baja y una gran masa inerte. El intervalo útil de frecuencias operantes está por encima de la frecuencia de resonancia.

Las curvas de respuesta teórica de un transductor de desplazamiento se muestran en la Fig. 2.

2.2.- MEDIDORES DE VELOCIDAD

En un transductor de velocidad el movimiento queda representado por la velocidad máxima, v, y la amplitud es proporcional a la velocidad, derivada del desplazamiento medido. Así,

$$Av = k_v \frac{d\,x}{d\,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

en donde k_v es la constante de proporcionalidad. De las ecuaciones 6, 8 y 9, la ecuación 12 se transforma en

$$Av = \frac{k_v\, v\, \text{sen}\,(wt - \phi)}{\left[4\left(\frac{r}{r_c}\right)^2 \left(\frac{w_o}{w}\right)^2 + \left(\frac{w_o^2}{w^2} - 1\right)^2\right]^{1/2}} \quad \ldots\ldots\ldots (13)$$

La ecuación 13 nos muestra que, cuando la frecuencia del movimiento desciende de w_o a 0, la del registro tiende hacia cero, y, cuando la frecuencia del movimiento es grande comparada con la frecuencia de resonancia, la amplitud del registro es proporcional a la velocidad de la vibración y la constante de proporcionalidad se transforma en la constante de aumento del transductor. Las curvas de respuesta teórica para un transductor de velocidad son idénticas a las del de desplazamiento (Fig. 2). Por tanto, un transductor ideal de velocidad debería tener una frecuencia de resonancia baja, lo que implica un valor bajo de la constante del muelle y una gran masa de inercia, y el rango útil de las frecuencias operantes está por encima de la frecuencia de resonancia del sistema.

2.3.- MEDIDORES DE ACELERACION

En un transductor de aceleración, el movimiento se representa por el valor máximo de la aceleración, a, y el registro es proporcional al desplazamiento medido. Así,

$$A_a = kax \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

en donde k_a es la constante de proporcionalidad. De la ecuaciones 4,6,8 y 9, la ecuación 14 se transforma en;

$$Aa = \frac{k_a a \frac{m}{s} \cos(wt-\phi)}{\left[4\left(\frac{r}{r_c}\right)^2 \left(\frac{w}{w_o}\right)^2 + \left(1 - \frac{w^2}{w_o^2}\right)^2\right]^{1/2}} \quad \ldots\ldots\ldots \quad (15)$$

La ecuación 15 nos muestra que cuando w se incrementa por encima de w_o, la taza de deflección desciende a cero y, cuando w desciende de w_o a o, la traza de deflección es proporcional a la aceleración del movimiento. El aumento del transductor es (Kam) /s. Las curvas de respuesta teórica de un transductor de aceleración vienen expresadas por la Fig 3. Por tanto, un transductor ideal de aceleración debería tener una frecuencia de resonancia elevada, lo que implica una constante del muelle asimismo elevadas y una masa pequeña, y el rango útil de frecuencias operantes se encuentra por debajo la frecuencia de resonancia del sistema.

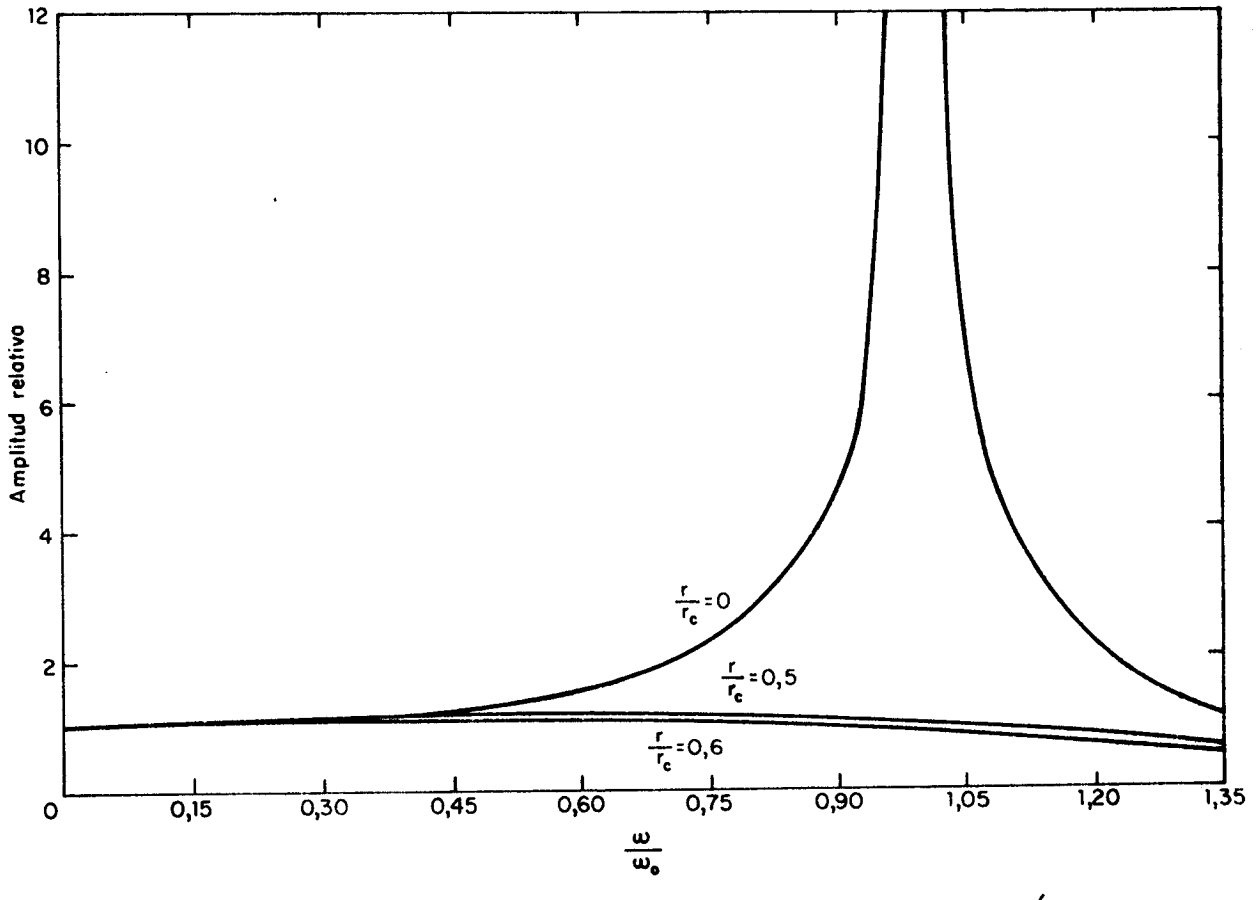


Fig. 3.- Curvas de respuesta teórica de un transductor (transducer) de la aceleración.

3.- DESCRIPCION DE UN SISMOGRAFO TIPICO

Un sismógrafo portátil típico esta formado por un estuche o caja rígida, motada sobre trípode con tornillos de nivelación, que contiene un mecanismo medidor de tiempo, otro de registro y tres péndulos con sus ejes perpendiculares entre - sí y orientados de forma tal que el movimiento de uno de ellos sea vertical y, el de los otros dos, horizontal. El movimiento de los péndulos queda representado por la reflexión de los rayos de luz sobre el rollo de papel fotográfico. Dichos rayos se reflejan en espejos adecuadamente unidos a los brazos de los péndulos. El desplazamiento real sufrido por el equipo se incrementa óptica y mecánicamente de forma tal que el movimiento registrado es generalmente de 25 a 150 veces superior al real. La frecuencia de resonancia suele ser baja - (1-4 c.p.s.) y el registro obtenido proporcional al desplazamiento. Por otro lado, el rango dinámico del aparato se define como la razón de la mayor deflección del registro a la mínima que puede medirse, estando limitado, dicho rango, por la estabilidad del instrumento y la anchura del registro sobre - el rollo de papel. Debido a que el coeficiente de aumento es fijo en este tipo de instrumentos, el rango dinámico queda limitado, aproximadamente, a un valor de 20.

Un sismógrafo típico para registrar la velocidad consiste de dos unidades. Tres medidores ortogonales entre sí alojados en el interior del elemento principal, y los amplificadores, las baterías, el emisor de luz, el control de tiempo,

los galvanómetros y la cámara registradora, alojados en estuche separado. El elemento principal se diseña de un modo tal que pueda queda firmemente anclado sobre el terreno, no teniendo la misma limitación del rango dinámico que la presentada en el caso de un registrador de desplazamiento. Los tres - elementos de registro miden la magnitud de los tres componentes ortogonales de la velocidad de partícula, vertical, radial y longitudinal. Cada elemento de registro puede quedar - representado por el modelo ya visto en la Figura 1. La frecuencia de resonancia de dichos elementos es baja, generalmente entre 2 y 5 c.p.s., la masa del sistema es grande y la cte. del muelle baja. Debido a que el coeficiente de aumento es variable y dependiente de los circuitos electrónicos, el rango dinámico es grande. Por medio del empleo de circuito electrónicos estables la señal de salida de los geófonos (elementos de medida) de la velocidad de partícula puede registrarse directamente, o integrase los registros de desplazamiento o derivar los registros de la aceleración.

La cámara registra las señales de luz de los galvanómetros en un rollo móvil de papel sensible a la luz y en el que el marcador de tiempo imprime el contaje. Estos sismógrafos tienen, aproximadamente, una respuesta lineal y de frecuencia entre 2-250 c.p.s.

Un sismógrafo portátil típico medidor de la aceleración emplea tres elementos de medida externos, geófonos, que pueden colocarse para medir los tres componentes ortogonales, la vertical y las dos horizontales, de la aceleración. Cada - elemento de medida puede asimismo representarse por el modelo discreto de la Fig. 1 y su señal de respuesta es proporcional

al desplazamiento sufrido por el mismo. La frecuencia de resonancia de tales elementos es elevada, generalmente 10 a 100 veces la frecuencia medida, la masa pequeña y la constante de muelle elevada.

Existen dos sistemas generales típico de registrar el movimiento: (i) por medio de circuitos electrónicos que producen una señal de salida proporcional a la gravedad, (ii) por medio de galvonómetros y emisor de luz que dan lugar a un movimiento que se registra en un rollo de papel sensible a la luz. El último sistema conserva la forma de la onda en tanto que, el primero, indica únicamente la aceleración máxima.

Debido a que los geófonos no están localizados en el elemento principal, puede someterse a un tipo de montaje que no está sujeto a las limitaciones del tipo tripode. El factor de aumento de esta clase de sismógrafos es variable, el rango dinámico es amplio aunque está limitado por la respuesta lineal de los circuitos electrónicos, indicadores, cables y demás componenetes. Estos sismógrafos tienen un intervalo útil de frecuencias operantes desde 2 a 250 c.p.s. aproximadamente.

Actualmente, el sistema descrito para los sismógrafos registradores de la aceleración, puede aplicarse asimismo para medir el desplazamiento o la velocidad. Así, el elemento de inercia (masa) del geófono al moverse dentro del campo magnético y proporcionar la señal de respuesta, si dicha señal alimenta un osciloscopio nos dará la velocidad en tanto que, en el caso de la aceleración, alimenta un galvanómetro.

4.- DISPOSITIVOS DE REGISTRO CONVENCIONALES

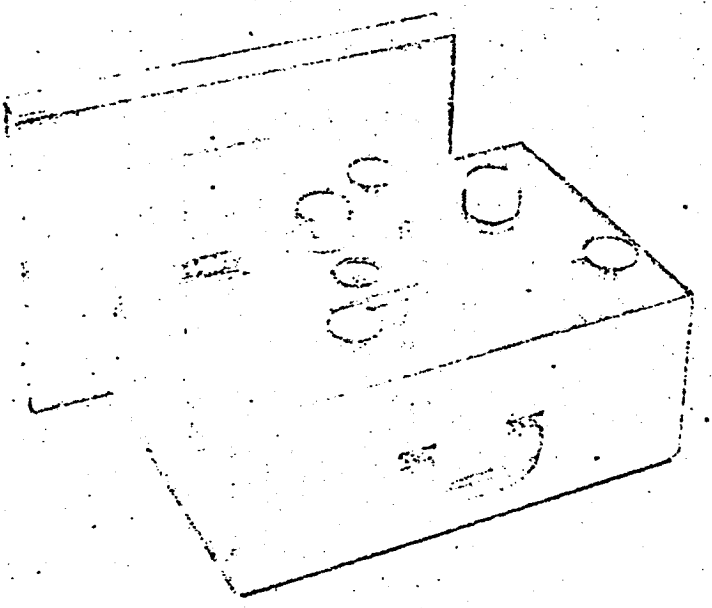
A este nivel resulta conveniente prestar una información entresacada de los contactos mantenidos con diferentes casas comerciales y que creemos servirán de ayuda en estudios posteriores. Las casas consultadas fueron las siguientes:

Vibration Mausurement Engineers Inc. (USA)
Sensor Italiana (Italia)
Vibra-Tech Engineer Inc. (USA)
Abem (Suecia). Representante en España Vegarada S.A.
Slope Indicator Company (SINCO) (USA)
Nitro Consult (Suecia)
W.F. Sprengnether Instrument. Co. Inc. (USA).

Exponemos a continuación las características y precio de los aparatos suministrados por dichas casas.

VIBRATION MEASUREMENT ENGINEERS Inc.

VME



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The Seismolog is a precision built, highly sensitive but durable and rugged unit. Full operating directions are inside cover. All controls are plainly labeled. Anyone can set it up and operate it.

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The Seismolog measures 9" x 13" x 19". It can be used in cramped quarters, an important feature for critical placement in buildings or when recording vibrations from machinery.

Seismolog is the registered trade name for an accurate, compact, rugged, completely self-contained portable seismograph. The Seismolog can be operated by your own employees for inexpensive, permanent camera recorded graphs of earth vibration. The Seismolog provides practical and efficient control of blasting and other operations that produce earth tremors.

Seismolog is the product of many years of research and hundreds of field tests. The experience gained in nearly a quarter of a century of seismic engineering practice and the recording of thousands of seismographic measurements has been engineered into its design.

The Seismolog measures vibration amplitudes as small as 1/10,000 of an inch, photographed and magnified 50 times by a mechanical optical system. Studies of the tape recording, calculated with data on distances, number of holes, amount of explosive charge, etc., enable VME to make authoritative analyses, reports and recommendations. Records are kept on file beyond statute of limitations periods as a protective measure.

It must also be emphasized that vibrational energy transmitted to outlying areas is wasted energy. Under proper seismic control much of the waste can be converted into useful work, better breakage, and increased production.

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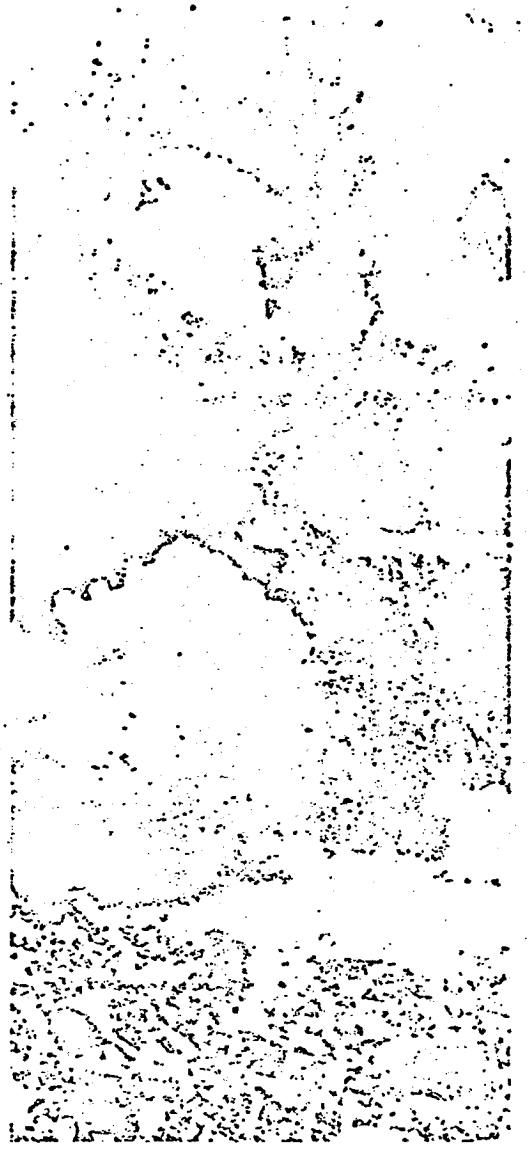

1. Seismologs are made available to you in conjunction with the Record Analysis Service. A supply of interchangeable, sealed cameras (with mailing cartons) comes with the Seismolog assigned to you.

2. You conduct the field tests with your regular employees. Any intelligent person can operate the Seismolog. Simple, clear-cut instructions in the cover of the carrying case detail the few steps to be followed. Color controls assure errorproof operation.

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5. VME analyzes the graph and supporting data, then sends routine reports by first class mail on the day the camera is received. Color code forms advise "SAFE," "CAUTION" or "DANGER" results. Findings indicating "DANGER" are reported to you immediately by phone. All records are indexed, certified by VME and filed for future reference.

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VME engineers provide emergency service and consultation with all users of commercial explosives; federal, state and municipal government officials, underwriters, adjusters and attorneys. The fact that all records of the seismographic service are under seal to be broken only by the independent, reputable and authoritative staff at VME provides a legal safeguard against the inference that the instruments, graphs and interpretations are a self-serving device of the client.

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Seismological Engineering

Prices are as follows:

1 new Seismolog including one camera	$2,995.00
1 rebuilt Seismolog including one camera	$2,145.00
1 kit of spare parts – 1 spare motor 5 spare batteries 2 spare bulbs wrenches - pliers - nuts - bolts, etc. 20 rolls of film	$200.00
spare camera	$25.00
in lots of 5	$20.00

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When you order one of these units, we request that you open in our favor an irrevocable letter of credit confirmed by a United States Bank.

Very truly yours,

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GROUND VIBR... MEASUREMENT
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Developments in rock blasting techniques, including the use of multiple-row blasting with short delay ignition have made it possible to excavate rocks close to or below buildings even in closely built-up areas.

Blasting operations must be carefully planned and carried out to avoid discomfort to persons or damage to property. This increase in the use of rock blasting in city areas alone has led to a number of problems due to ground vibrations, air shock waves, and the psychological effect of noise. While the latter seldom if ever causes damage, it does create irritation and often discomfort to persons living or working near the explosion sites. A result of this is a steady increase in the number of complaints in respect of damage to houses and other premises. Many such complaints are genuine and damage may undoubtedly be caused when incorrect blasting techniques are used. Inevitably most, if not all, blasting operations are used as a basis for complaints, even when the technique employed can cause neither damage nor discomfort.

The solution to these problems is two fold. Firstly to determine acceptable threshhold values for varying degrees of damage, and secondly to have a reliable, inexpensive instrument for measuring the ground vibrations that can cause damage.

What causes damage and discomfort

During the last ten years much experimental and practical work has been carried out on the character of these ground vibrations. This work revealed that persons react strongly and negatively to vibrations that have amplitudes well below, often 2-3 times, those needed to cause damage to property. This directly means that a large number of complaints are unwarranted. Amplitude, however, is only one of the factors to be considered; it is often the frequency of the ground vibration that is more significant as far as damage is concerned.

It has been shown that the damage factor (D) is in general directly proportional to the magnitude of the ground displacement amplitude (A) and to the frequency (f), and inversely proportional to the propagation velocity (c) of the compressional wave.

Expressed mathematically this gives $D = \text{Constant} \cdot \frac{A \cdot f}{c}$

In view of the difficulties of measurement of the propagation velocity (c), calculations of damage factor are normally based on the values of the greatest acceleration (a) and the greatest vibration velocity (v).

These are calculated from a knowledge of the displacement amplitude (A) and the frequency (f)

$$a = 4\pi^2 \cdot f^2 \cdot A \text{ (in m/sec}^2\text{)}$$

$$v = 2\pi A \cdot f \text{ (in mm/sec)}$$

Note that 2A is the peak to peak amplitude measured between maximum positive to maximum negative deflection.

The magnitudes of the four variables, frequency, amplitude, acceleration, and vibration velocity encounted in ground vibration measurements are:

f = 5-500 c/s; (loose formations, sand, clay, 5-20 c/s) (Looser rock 30-40 c/s) (hard rock 40-100 c/s)

A = 5-800 μ ; (1μ = 0,001 mm)

a = 0,01-10 g; (accelerations of up to 1 g are normally acceptable in built-up areas)

v = 0,5-2500 mm/sec

In general low frequency vibrations with large amplitudes give the highest vibration velocity. On site measurements confirm that vertical vibrations have larger amplitudes than horizontal ones, and for most normal purposes it is sufficient to measure only these vertical vibrations. Since acceleration (a) is proportional to the square of the frequency (f), a small ground displacement at a high frequency will cause a high acceleration. This can be misleading, but if the vibration velocity is calculated at the same time it will be found that the velocity is small and that the vibration is therefore not as critical as the initial acceleration assessment indicated. This is shown by the following example:

A = 0,17 μ , f = 300 c/s
gives
a = 0,061 g
v = 0,32 mm/sec

while
A = 100 μ , f = 13 c/s
gives
a = 0,068 g
v = 8.16 mm/sec

While acceleration is almost the same, vibration velocity is more than 20 times higher. This once again emphasizes the need for measurements of both amplitude and frequency.

From the numerous studies made of ground vibration it is possible to compile tables of amplitude and velocity threshhold values for damage assessment.

DISPLACEMENT AMPLITUDES

Type of building	Maximum allowable Amplitude
1. Buildings owned or occupied by persons directly interested in the blasting; Bridges, Quays, etc.	380 μ 15×10^{-3} inch.
2. Detached houses in good condition, workshops, office blocks	190 μ $7,5 \times 10^{-3}$ inch.

5. Mine shafts and galleries; houses in poor condition, old age pensioners' dwellings, museums	95 μ	3.5×10^{-3} inch

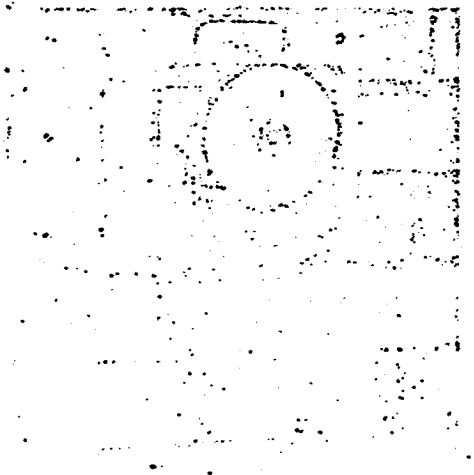
FREQUENCY

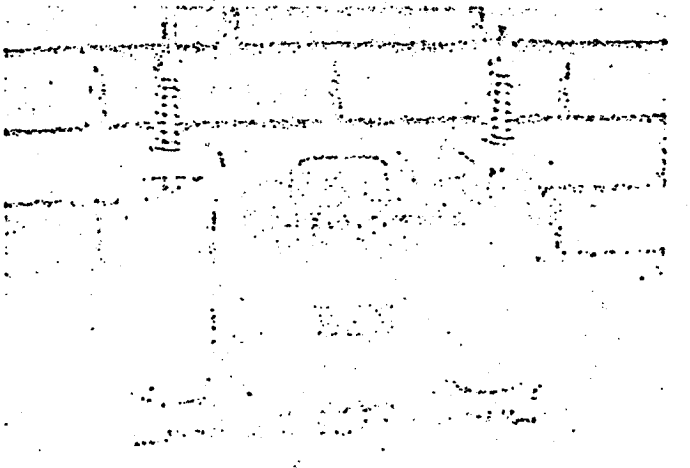
Type of damage	Vibration Velocity	
No noticeable cracks	70-75 mm/sec	3 inch/sec
Insignificant cracking & fall of plaster	100-110 "	4.5 "
Cracks	150-160 "	6 "
Serious cracks	225-230 "	9 "

GROUND VIBRATION MEASUREMENTS ARE SIMPLE TO CARRY OUT

Simplicity and reliability are the two major requirements for a ground vibration instrument. In addition price should be such that it encourages the use of the instrument for all blasting operations where there may be risk of complaints or damage to property. These requirements are met by the Kongsberg Tellus, developed in conjunction with the Norwegian Rock Blasting Institute and now made available through Craelius, an Atlas Copco Company.

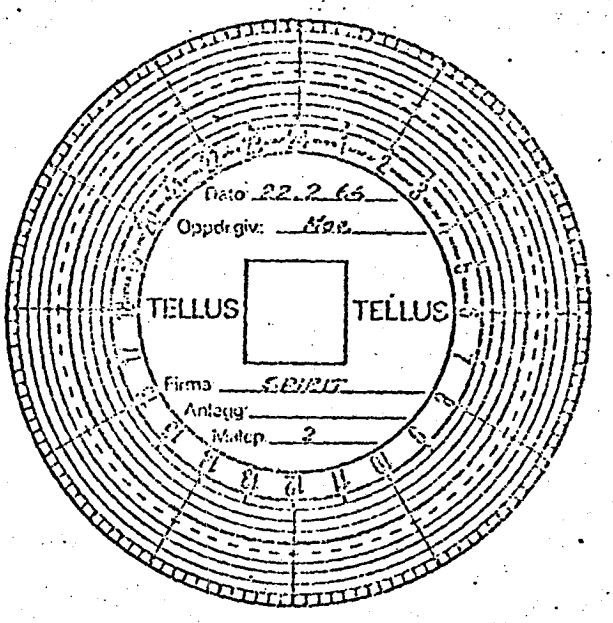
The Kongsberg Tellus consists basically of a weight system with a pen arm that records on a wax coated circular chart. The entire unit is fitted in a robust waterproof casing and weighs only 4,5 kg (10 lb). The Kongsberg Tellus measures the amplitude and frequency of vertical ground vibrations in the range 10-500 μ and 15-170 c/s at a maximum load of 7 g. This measuring range covers the vibrations encountered in most, if not all, rock blasting techniques that are used in civil engineering today. The Kongsberg Tellus is easy to set up at ground level or on the foundations of a building. It is placed in a special silumin bracket that is bolted on the rock close to, or inside a building, so that best possible rock contact is obtained. The bracket may be fixed to any vertical surface of concrete, bricks, stone, or rock. An alternative method is to place the Tellus on a stand that has spring-suspended heavy weights. This ensures contact with the rock even with high downward accelerations and is most convenient to use when difficulties occur in fixing the bracket in a suitable position. A similar effect to the loading arrangement can be achieved by pressing the Tellus by hand down against the rock surface.





Choose from two Tellus models

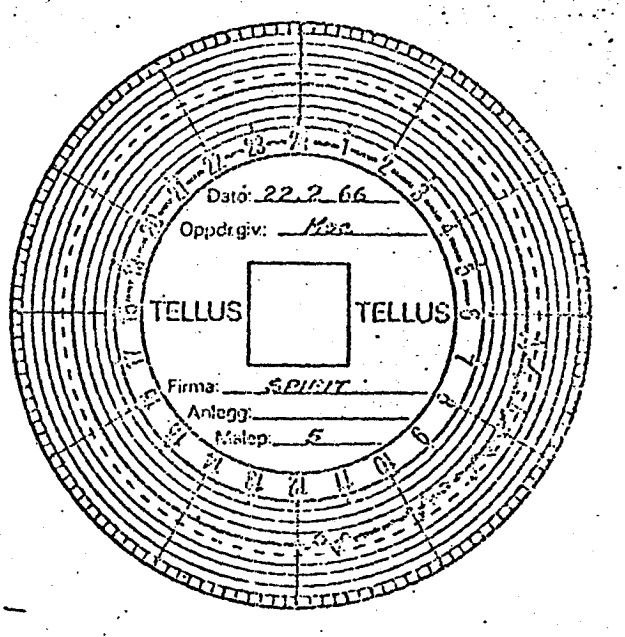
Tellus M (mechanical) has a clockwork drive and registers amplitudes only continuously over 7 days after each winding. The reading is recorded on a waxcovered helical-formed paper disc. No attention is required during the 7-day period. The recording chart is provided with a time reference enabling the operator to record vibrations with an accuracy of ±5 minutes.



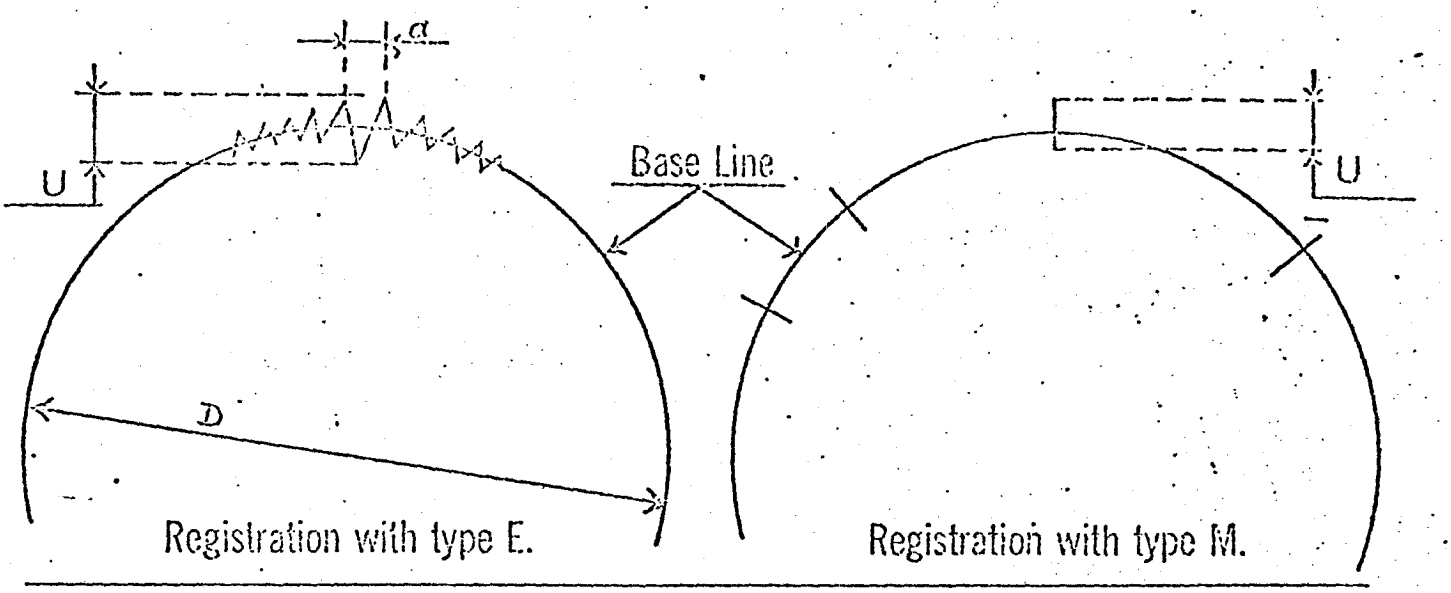
Recording chart for KONGSBERGS TELLUS type M (Actual chart diameter is 11 cm (4 5/16"))

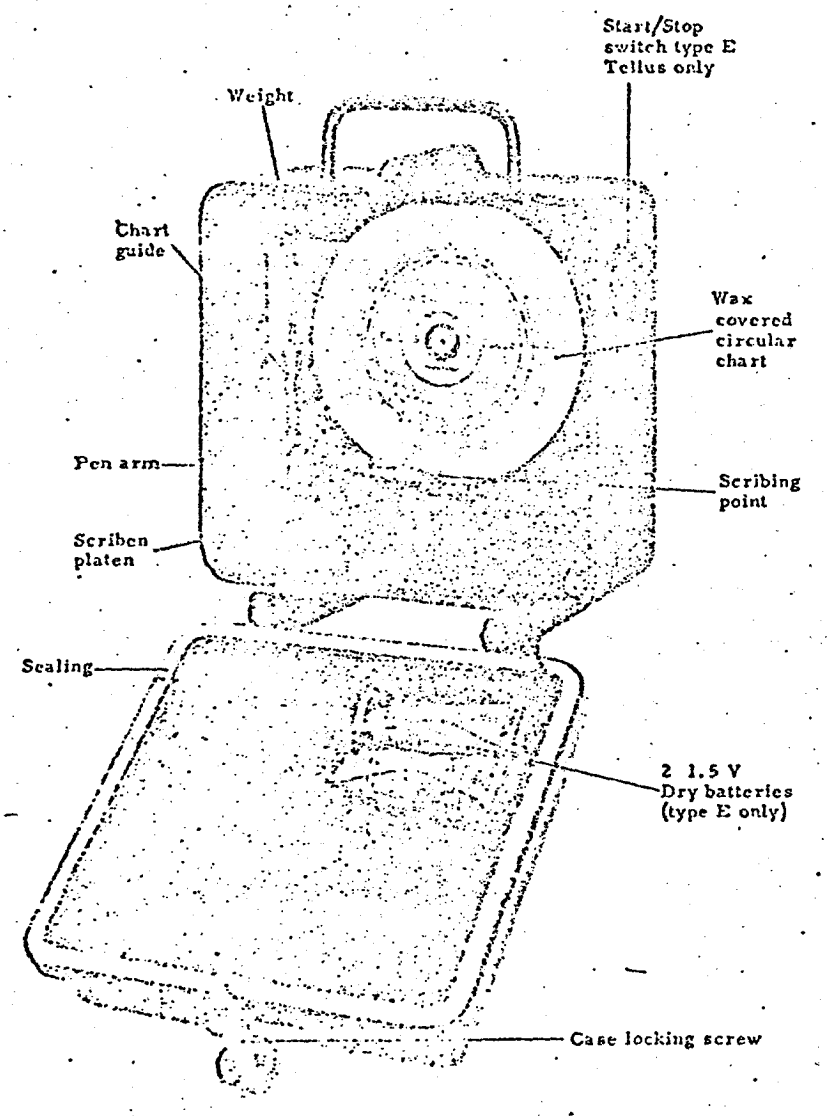
Tellus E (electrical) is driven by an electric motor and registers both amplitude and frequency of vibrations occurring during the period the motor is switched on. Two 1.5 V dry batteries are fitted into the lid; they have a working life of 2 hours which is sufficient for several hundreds of measurements. The recording is done on a single wax-covered paper disc which is rotating at a speed of 6 RPM. No synchronisation with the ignition of the blast is necessary.

Both models need a minimum of maintenance and attention.



Recording chart for KONGSBERG TELLUS type E. (Actual chart diameter is 11 cm (4 5/16"))





Both Tellus M and Tellus E instruments amplify the vibrations before these are recorded on the circular chart. Amplification is 7.15:1, meaning that a deflection of 1 mm represents 140 μ peak to peak amplitude. The scribing point gives clear sharp traces and permits the use of a magnifying glass for measuring. If the glass has a 1/10 mm scale, amplitudes can be read to an accuracy of 0.1 mm ± 0,05.

Each Tellus is individually calibrated before delivery and a calibration curve is provided. This makes it possible to convert chart registrations (U) to actual amplitudes (2A) according to the frequency of the vibration. Frequency determination (with Tellus E) is simple, and requires only the measurement of the distance between two adjacent peaks of one complete oscillation on the same side of the base line. This distance is converted to frequency by a simple substitution $f = \frac{\pi D}{10\ a}$ where D is the diameter of the base line circle, and a is the peak separation distance.

Complete and Continous Vibration Control is achieved when Tellus M and Tellus E are used together

Tellus M, driven by clockwork, runs for 7 days, and records amplitudes only on its circular spiral chart. The chart scale is hours (1-24) and vibration times are readable to plus/minus five minutes. If a number of Tellus M recorders are placed out in the vicinity of the blasting site, a continous record of the vibration amplitudes occurring during a 7 day period will be obtained. The Tellus E, battery driven, supplements the long period recording, and, in addition to amplitude, registers the frequency of the vibrations. The determination of frequency is of vital importance at positions that are particularly exposed. The Tellus E is switched on before blasting starts.

More than 60 Kongsberg Tellus instruments are now in use in Norway. A typical application of these reliable, robust recorders was their use in vibration control in connexion with the blasting of a double tunnel in Oslo, the Norwegian capital. The tunnels pass under a built-up area, and Tellus M recorders were placed fixed to the foundation wall in six of the houses. In house No. 4, the most exposed, a Tellus E was also installed. This layout gives a complete picture of the ground vibrations, their frequency, amplitude, and time of occurrence. An analysis of the charts confirms the correctness of the blasting technique and provides written confirmation of the damage factor, of vital importance in any question of complaints, damage or compensation.

WEIGHTS & DIMENSIONS

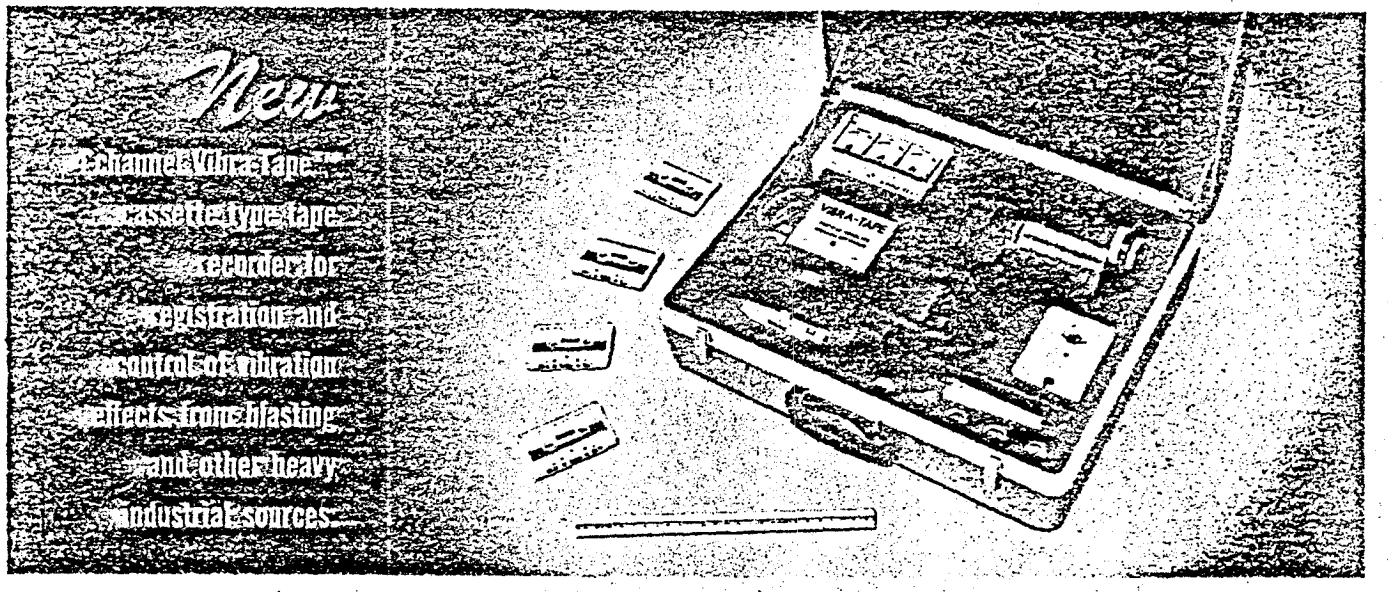
Each Tellus is provided with a wooden carrying case with holder for a set of spare circular charts. Dimensions are:

	Length	Depth	Height	Weight
Tellus instrument	190 mm 7 1/2 in	130 mm 5 1/8 in	168 mm 6 5/8 in	4,5 kg 10 lb
Carrying case	245 mm 9 5/8 in	160 mm 6 1/4 in	200 mm 7 7/8 in	
Batteries (Type E only)	2 1.5 V Transistor batteries (25 mm Ø; 50 mm long)			

In accordance with our policy of progressive development we reserve the right to alter specifications without notice.

The Kongsberg Tellus, developed in conjunction with the Norwegian Rock Blasting Institute, is marketed throughout the world by Craelius, a member of the Atlas Copco Group.

if you can pick up a suitcase...
you can carry blast protection with
VIBRA-TAPE T.M.



- Self-contained lightweight suitcase package
- Direct Particle Velocity recording
- Calibration pulse every record to certify equipment accuracy
- Three channels for 3-component vibration information
- Fourth channel -dB air concussion and noise recording*
- Peak meters for immediate results*
- Tape data played back by Vibra-Tech for analysis and report
- Size: 19½" x 7½". Overall weight: 24 lbs.
- Recording time: up to 1 hr. Standard "C" cells

Vibra-Tape™ advantages over conventional blast seismographs — Smaller size and weight — More portable and convenient — Simpler operation — Snap-in cassette loading — Data mailing more convenient and economical — Much longer recording time — Eliminates timing errors and missed blasts — More practical and effective for pile driving and industrial vibration recording —Voice data and/or sound effects recording — More sophisticated record analysis — Tape eliminates exposure risk and inconvenience of film and camera.

*Options — 3-component BLAST PEAK METER provides immediate vibration effects and comparison with occupational vibrations for more effective complaint settlement. Air blasts effects recorded on 4th trace in decibels and lbs. per sq. inch thru hand held SOUND LEVEL METER.

VIBRA-TECH

ENGINEERS INCORPORATED

1st & N. Church Sts. — Hazleton, Pa. 18201 — (717) 455-5861

for details contact

Pittsburgh, Pa. (412) 366-2773 • Charleston, W. Va. (304) 342-2894
Washington, D. C. (301) 762-8175 • Atlanta, Ga. (404) 939-8677
Poughkeepsie, N. Y. (914) 297-6305 • Philadelphia, Pa. (215) 363-1655

URRENT PRICE SCHEDULE U. S. A. EAST COAST VIBRA-TAPE® PLUS OPTIONAL VIBRA-TAPE®
QUIPMENT, CENTRAL PLAYBACK EQUIPMENT, RECORD REPRODUCER, AND RELATED ACCESSORIES, ETC.

ibra-Tape®

tandard "Vibra-Tape"® 3 data channels and 1 voice channel. Calibration
ulse every record. Includes carrying case and 5 cycle low limit 3
omponent transducer ---------- $3200.00

Same--with 2 cycle low limit transducer ---------- 3800.00)
We find 5 cycle transducer satisfactory for 90%+ of situations)

DDITIONAL VIBRA-TAPE® OPTIONS

3 component "instant" reading Blast Peak Meters - add ---------- 400.00

Air concussion microphone and input circuitry (Peak reading DB
pressure, subaudible and audible, 2 cycle low limit, fast rise
impact capability for 4th channel) - add ---------- 860.00

CENTRAL PLAYBACK SYSTEM FOR VIBRA-TAPES®

Standard central playback system ---------- 4050.00
To include playback air concussion 4th channel for 4 trace sound
record - add ---------- 228.00
(Can service many Vibra-Tape® Units)

* *

RECORD REPRODUCER

3 Galvanometer recorder for 3 component standard Vibra-Tape® records --- 1530.00
To include 4th Galvanometer for air concussion 4th trace add ---------- 60.00
(Can service many Vibra-Tape® Units)

"Direct write" record 3 5/8" paper - per 100' ---------- 10.50

ACCESSORIES

Sound Level Calibrator for periodic check of air concussion units ------ 400.00
(Can service many Vibra-Tape® Units with air concussion options)

"Super Dynamic" Cassettes (We use TDK C60 + C30--running time for our purpose
30 and 15 minutes). Head cleaner cassettes and cleaning fluids, "soft-pak"
plastic containers and padded mailing envelopes.
Demagnetizer to erase and reuse cassettes.

Note: We have annual rental prices for Vibra-Tape® in U. S. A.

Note: Items below asterisks may be available commercially in the open market.

VIBRA-TECH ENGINEERS, INC.

VIBRA-TAPE
Particle Velocity Analog Recorder

COMPREHENSIVE PROTECTIVE SERVICE

1st Month ----------$ 350.00 in advance plus record interpretation
2nd Month ---------- 250.00 " " " " "
Each additional month ---------- 150.00 " " " " "

Annual Contract ----------$1620.00 Plus record interpretation + taxes where applicable (Payable at $135.00 per month in advance).

Annual Payment in advance ----------$1506.60 (This is a 7% discount for advance yearly payment). Plus record interpretation + taxes where applicable.

WITH VIBRA-METER ONLY
Immediate Peak Particle Velocity Indicating Meter
To be used only in conjunction with recordings being analyzed from Vibra-Tape

1st Month ----------$ 375.00 in advance plus record interpretation
2nd Month ---------- 275.00 " " " " "
Each additional month ---------- 175.00 " " " " "

Annual Contract ----------$1920.00 Plus record interpretation + taxes where applicable (Payable at $160.00 per month in advance).

Annual Payment in advance ---------- 1785.60 (This is a 7% discount for advance yearly payment). Plus record interpretation + taxes where applicable.

WITH AIR BLAST RECORDING UNIT ONLY

1st Month ----------$ 385.00 in advance plus record interpretation
2nd Month ---------- 285.00 " " " " "
Each additional month ---------- 185.00 " " " " "

Annual Contract ----------$2040.00 Plus record interpretation + taxes where applicable (Payable at $170.00 per month in advance).

Annual Payment in advance ---------- 1897.20 (This is a 7% discount for advance yearly payment). Plus record interpretation + taxes where applicable.

WITH BOTH VIBRA-METER & AIR BLAST RECORDING UNIT

1st Month ----------$ 400.00 in advance plus record interpretation
2nd Month ---------- 300.00 " " " " "
Each additional month ---------- 200.00 " " " " "

Annual Contract ----------$2220.00 Plus record interpretation + taxes where applicable (Payable at $185.00 per month in advance).

Annual Payment in advance ----------$2064.60 (This is a 7% discount for advance yearly payment). Plus record interpretation + taxes where applicable.

VIBRA-TAPE RECORD INTERPRETATION

	Analysis in Peak Particle Velocity	With 4th Trace Air Blast Analysis
1st 10 records each month	$ 12.00 each	Add two dollars per record
2nd 10 records each month	10.00 each	
3rd 10 records each month	7.00 each	
4th 10 records each month	6.00 each	
Records over 40 each month	5.00 each	

1/1/73

If you plan a relatively large operation like ours with central playback system (s) you probably should have at central location (s) some standard test equipment--oscilloscope, wave generator, etc. All available in Spain, no doubt.

GENERAL COMMENTS

The very minimum you could start with would be 1 standard Vibra-Tape® $3200.00; or same plus "instant" reading 3-component Blast Peak Meters - Total $3600.00; or same plus Blast Peak Meter option, plus peak DB Air Concussion for 4th trace option - Total $4460.00.

With this you would have to airmail cassettes to us with shot data sheet for our analysis and report, and costs for such. We are assuming such mailing back and forth can be done without tariff difficulties. At your distance--except for preliminary testing and familiarization--this might not prove practical, even though we could turn out and mail you reports airmail back within a few days of the receipt of your cassette; also you would have the "instant" reading 3-component blast peak meter option for quick results.

Assuming mailing cassettes to us is impractical for your permanent general use and plans--for a central location, or locations, you would also need (a) at least 1 central playback system and (b) 1 record reproducer--with or without extra options as indicated above; and any desired or needed accessories also shown above--probably available in Spain. Remember (a) and (b) above can serve many Vibra-Tape® Units in the field and unit costs will decrease as divided by the number of Vibra-Tapes® they serve. You can record one or many blasts on one cassette as convenient and appropriate.

ELECTRIC POWER REQUIREMENTS

Vibra-Tape® and its options operate from "standard" C sized alkaline batteries. These batteries are good for many shot recordings and last for months depending on type of use, are cheap and readily replaceable here, and probably in Spain. Battery test meter on each Vibra-Tape® .

Both the central playback systems and record reproducer require 60 cycles--115 volts power source. If such power supply unavailable to you possibly this problem could be handled by transformer, or we could possibly have current requirements redesigned to conform to power supply in Spain.

ALTERNATIVE

As our Vibra-Tapes® over the last few years have begun to replace our former standard usage of battery operated 3-component Sprengnether blast monitoring seismographs, some of these self contained units may become available to you as "used" but reconditioned, good operating condition instruments. These

have standard 50 magnification and read out three traces--vertical, longitudinal, and transverse--on timing line paper film (also direct write) in amplitude and frequency. From such records various criteria can be calculated--velocity, acceleration (which we dislike for blast criteria) Energy Ratio, etc. These currently cost new $2700.00 F. O. B. St. Louis. As they are replaced by Vibra-Tape® we could make these available to you at approx. 1/2 new price plus or minus depending on age or condition, plus any extra cameras needed. They are self-contained units--25" by 10" by 8", weight 38 lbs. with interchangeable cameras.

Frankly, with advent of Vibra-Tape® we consider them "old fashioned"--but they will do an accurate, good all around blast effect measuring job--and more economical for you. They require more careful measurement and interpretation of amplitude and frequency to calculate into needed criteria.

These may be used by your own men or to rent to clients and have them mail the small camera back with undeveloped film intact and shot report for developing analysis, and report. We also shortly may be able to offer you some used but good operative condition Sprengnether Velocity Seismographs. These retail new $3770.00. We could furnish you these at at least $1000.00 discount, depending on exact condition and age.

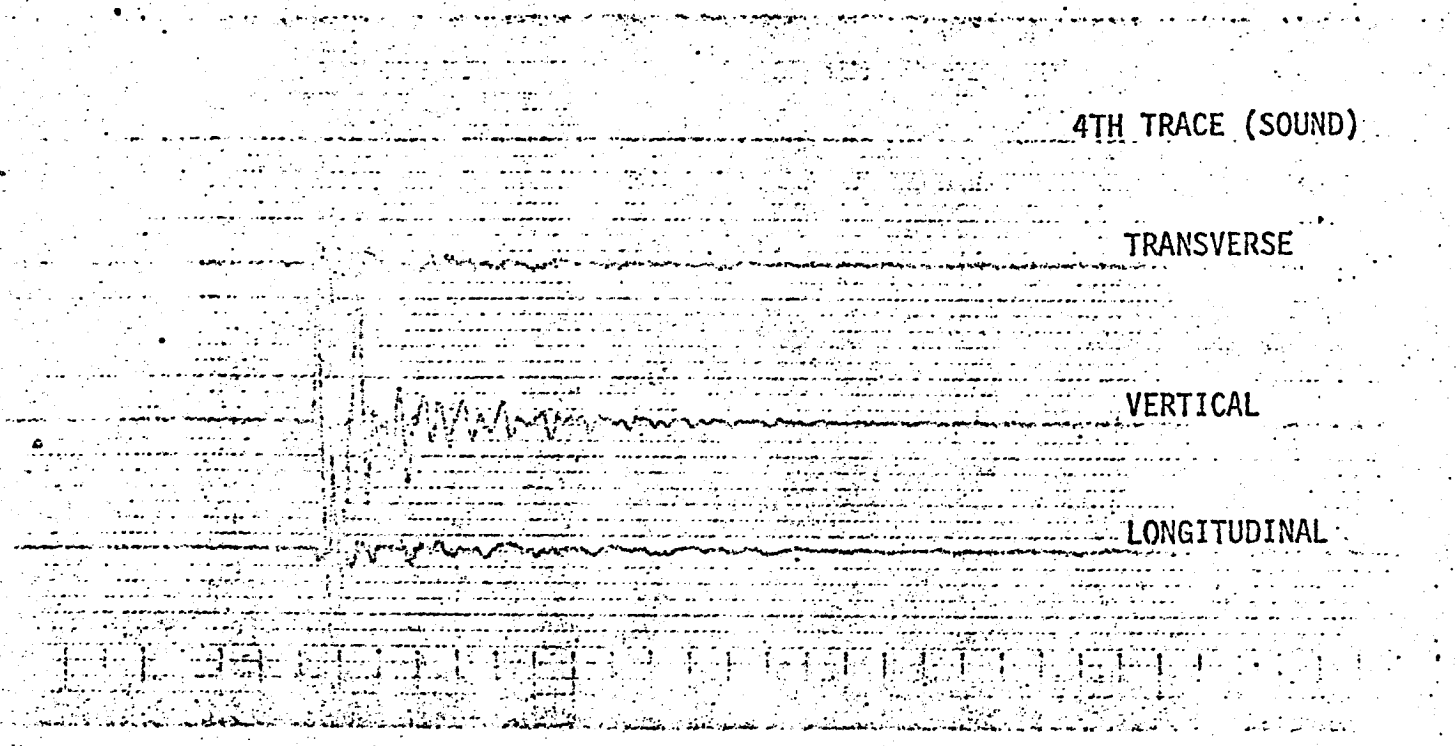
However, the convenience of mailing cassettes in vs mailing small cameras is so attractive to our customers, that they prefer the more costly Vibra-Tapes® almost universally. We prefer the "old" displacement instruments over Vibra-Tapes only occasionally for our own engineer personnel use where we need to examine some special low frequency blast vibration problems, and want a direct amplitude-frequency read out.

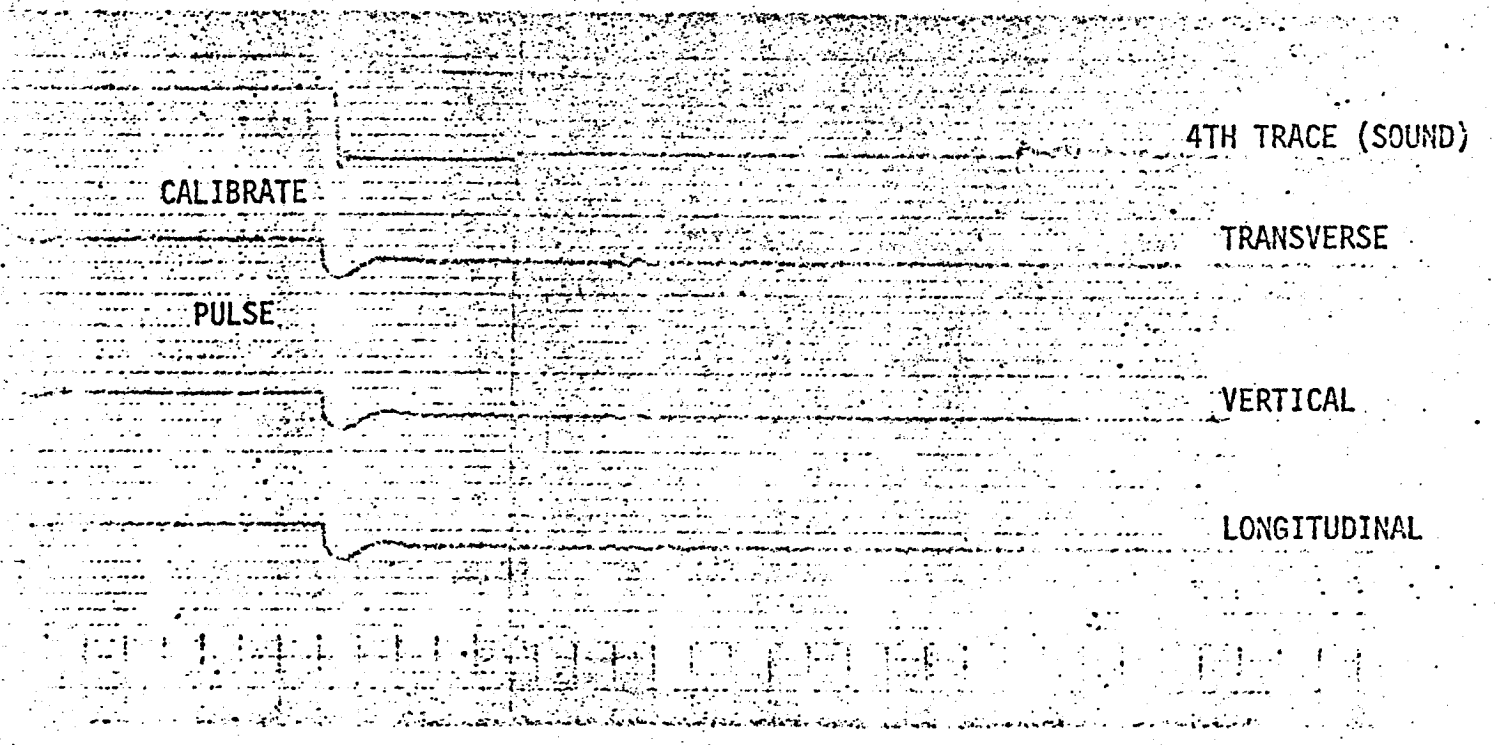
As stated before--so far as U. S. A. is concerned we almost entirely have gone to Velocity in/sec. criteria and the new Vibra-Tape® equipment is designed to read out Velocity directly, with resulting speed and convenience.

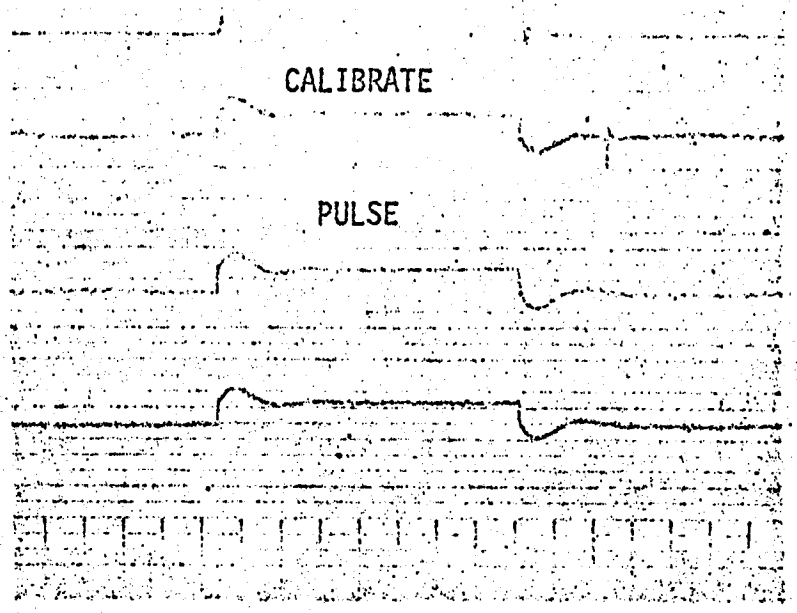
So, use of these "old" displacement instruments would have convenience disadvantages to you compared to Vibra-Tape®. They have advantage to you of low cost, and especially if your blast criteria requires direct amplitude and frequency records.

Vibra-Tapes® represent the very latest technology in the blast monitoring field. However, we mention possible availability of these "used" displacement-frequency and velocity seismographs as alternatives for your consideration should costs, power supply system problems, etc., so indicate.

Please consider and advise if clarification of any points needed, questions, etc.


4TH TRACE (SOUND)
TRANSVERSE
VERTICAL
LONGITUDINAL


4TH TRACE (SOUND)
CALIBRATE
TRANSVERSE
PULSE
VERTICAL
LONGITUDINAL



4TH TRACE (SOUND)

TRANSVERSE

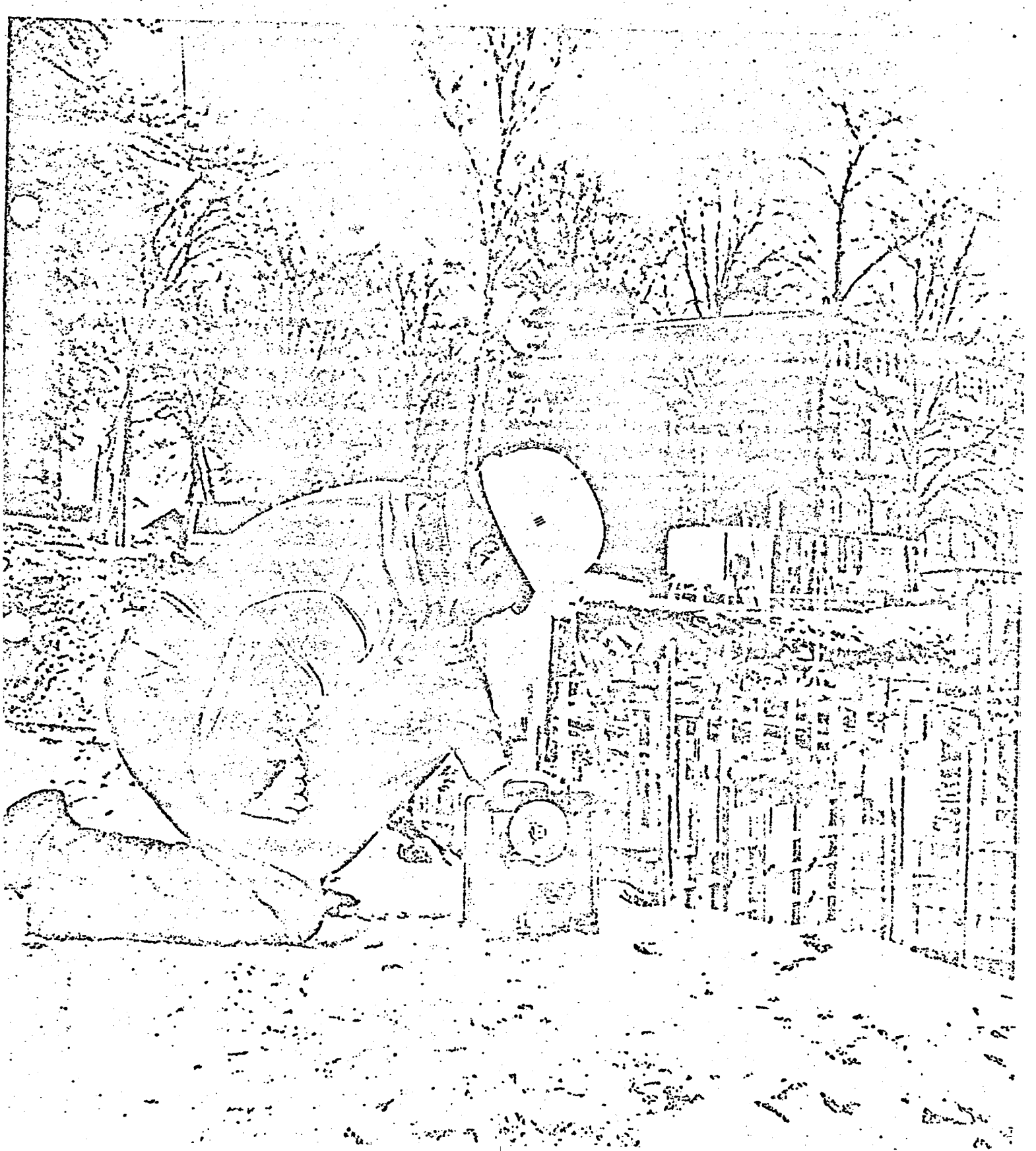
VERTICAL

LONGITUDINAL

KONGSBERG TELUS

ABEM

a low cost insurance against expensive claims for blast damage compensation



Continuous recording of ground vibrations means safer blasting and increased production

Thanks to developments in rock blasting techniques, building contractors, quarry owners, and civil engineers are today able to excavate rock material more efficiently and much closer to buildings than for a few years ago. The increased use of explosives in built-up areas calls for careful planning of the blasting operations to avoid damage and irritation.

Excessive ground vibrations will cause damage to property. People living or working near the blasting site experience discomfort . . . even when the vibrations are far below the level that will cause damage. This leads to complaints, claims for damage compensation, official inquiries, risk of work stoppage and loss of production.

Safe blasting in a damage sensitive environment calls not only for careful planning and execution of the blasting program but also for accurate and continuous measurement and analysis of ground vibration levels. This is the only way to eliminate unnecessary claims for damage compensation and to ensure that the blasting program meets specified safety requirements.

How is damage factor determined?

There are four factors to consider when assessing the damage effect of ground vibrations caused by blasting:

Amplitude, Velocity, Frequency, Acceleration

A v f g

For vibrations in the range 15–150 Hz (c/s) – usual in rock blasting – it has been shown that

1) Damage factor is directly proportional to amplitude (A) and frequency (f), but inversely proportional to compressional wave velocity (c)

$$D = K \cdot \frac{A \cdot f}{c}$$

2) It is only necessary to measure the vertical component of the ground vibration, since this as a rule is the significant factor.

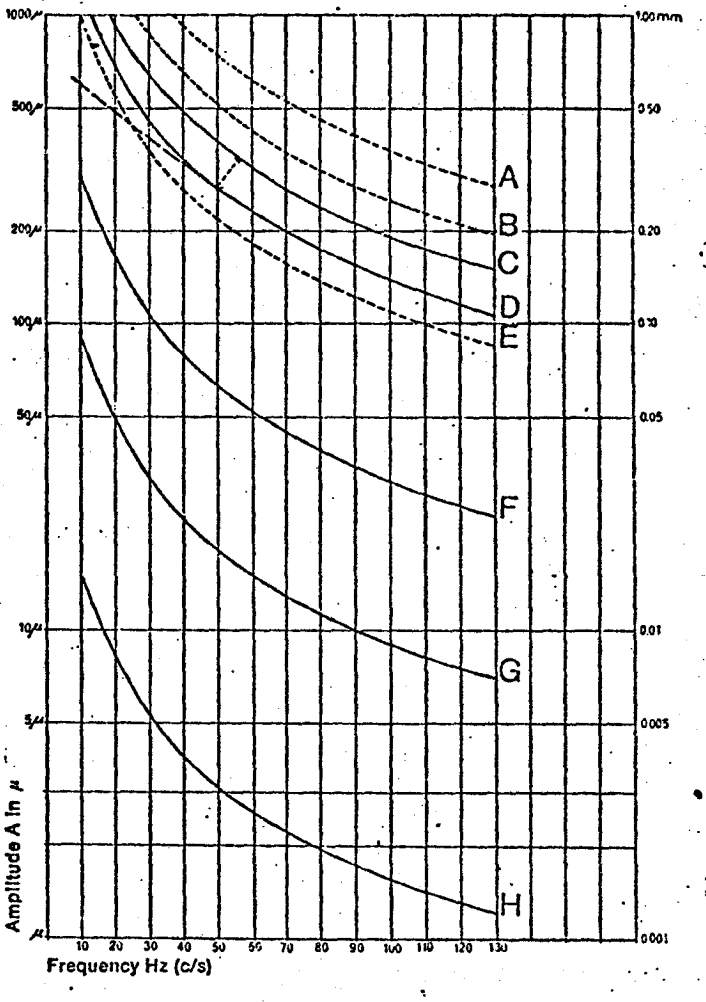
3) Measurement of amplitude alone does not give a sound basis for correct assessment of damage risk.

This is clearly seen from the results obtained at two measuring points on buildings some 30–50 m (100–165 ft) from a tunnel construction. The charge was 45 kg (100 lb) with ½ second detonators with maximum 6 seconds delay. Charge was divided into 12 parts, detonated at ½ second intervals.

	Point 1	Point 2
in μ	200	180
in Hz (c/s)	15	110
in g	0.177	8.59
in mm/sec	18.84	124.34

The vibration velocity at point 2 was 6.6 times as large as that at point 1, although the measured amplitudes had the same magnitude. The need to know both amplitude and frequency is even more clearly seen when the above vibration data is entered in figure 1.

EFFECTS OF VIBRATIONS ON BUILDINGS & PEOPLE



A V = 230 mm/s Considerable cracking A = $\frac{36.7}{f}$ mm

B V = 160 mm/s Cracking A = $\frac{25.8}{f}$ mm

C V = 120 mm/s Danger for some cracking A = $\frac{19}{f}$ mm

Uncertain sector

D V = 85 mm/s – possible fine cracks & plaster fall

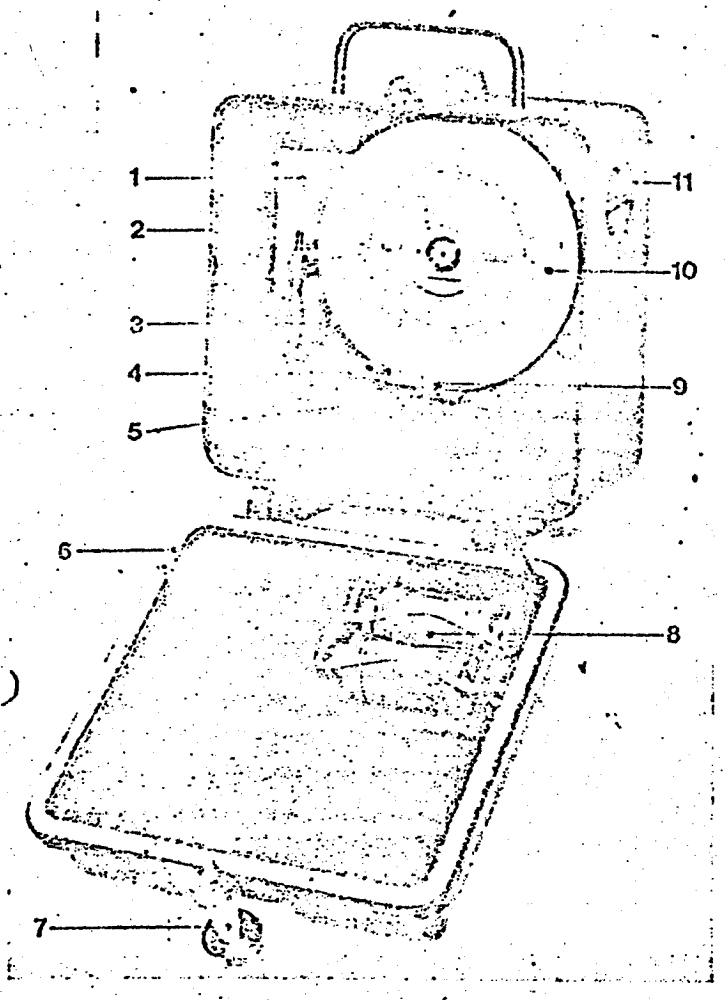
E V = 70 mm/s Usually no risk of cracking A = $\frac{11}{f}$ mm – $\frac{13.5}{f}$ mm

F Powerful effect on man A = $\frac{3.05}{f}$ mm

G Uncomfortable effect on man A = $\frac{0.90}{f}$ mm

H Barely noticeable by man A = $\frac{0.16}{f}$ mm

Fig 1



1 Weight
2 Transport clamp
3 Chart guide
4 Pen arm
5 Writing platen
6 Sealing
7 Case locking screw
8 2 1.5 V Dry batteries (type E only)
9 Scribing point
10 Wax covered circular chart
11 Start/Stop switch Tellus E only

A simple instrument for continuous vibration measurements

The Kongsberg Tellus is a single channel, direct writing, robust, and simple recorder that takes continuous measurements of vertical vibrations caused by blasting. It complements the various types of more complicated vibration recorders that are in use, in that it requires no specialist training to set-up and operate.

The Tellus consists of a suspended weight 1.2 kg (2.65 lb) with friction damping, whose movement is recorded on wax covered paper by a scribing point mechanically linked to the weight. The measuring system is fitted in a waterproof, cast-silumin case that, with its holder, may be bolted to vertical or horizontal surfaces. Total weight is only 4.5 kg (10 lb). Two versions, both for continuous recording, are available:

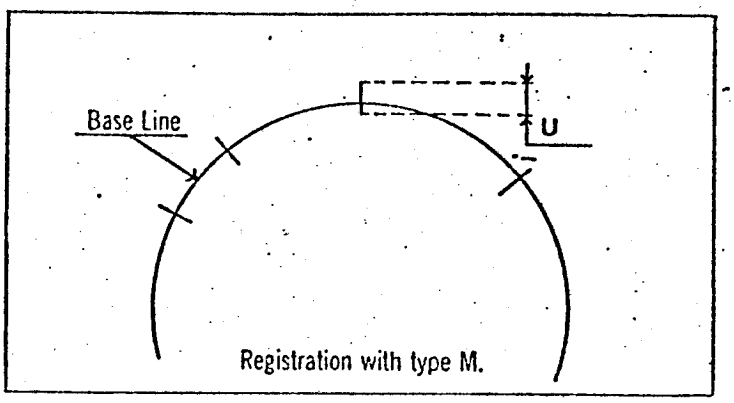


Fig 2

Tellus M has clockwork drive and records unattended for 7 days on a helical chart. It records only maximum amplitude variations. The chart is hour graduated and vibration times are readable to within ± 5 minutes. Tellus M is primarily for use in areas where vibration frequency is known and where low cost, long period supervision is needed.

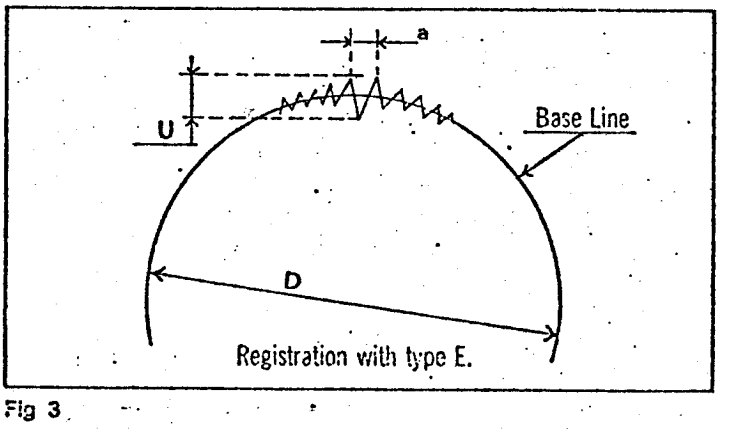


Fig 3

Tellus E has a battery driven electric motor, and records on a single wax covered paper disk that rotates at 6 rev/min. It register both amplitude and frequency of the vertical vibrations that occur while the disk is rotating. Tellus E may be switched on up to 5 minutes before detonation takes place, whereafter it is switched off. A new chart is required for each shot.

Accurate reading of amplitude and frequency

Figures 2 & 3 show how simple it is to analyse a Tellus record, whether amplitude only from Tellus M, or amplitude and frequency from Tellus E. The fine lines etched in the wax by the scribing point are easy to read. Each Tellus is factory tested on a Ling vibrator and an individual frequency/amplitude calibration curve is provided. This means that recorded amplitudes (U in fig 2 & 3) are quickly and easily converted to actual peak-to-peak displacement values (2 A) with respect to the frequency of the vibration. Determination of frequency from a Tellus E record involves only the measurement of the distance between 2 adjacent peaks on the same side of the base line, and the conversion of this distance to frequency by using the formula:

$$f = \frac{\pi \cdot \text{baseline diameter } D}{10 \cdot \text{peak distance } a}$$

Technical specifications, including operating ranges, of the two versions are shown overleaf.

May be set-up and used by non-skilled persons

Thanks to its compactness, robustness and simplicity, the Tellus recorder is quickly moved between and set-up at different measuring points. Its holder bolts to vertical or horizontal surfaces; it needs no special protection against weather or flying debris. It requires no supervision during recording, and little or no training is required in its operation. Tellus is the vibration recorder for the man-on-the-job.

Records continuously and gives on-the-spot control of blasting safety

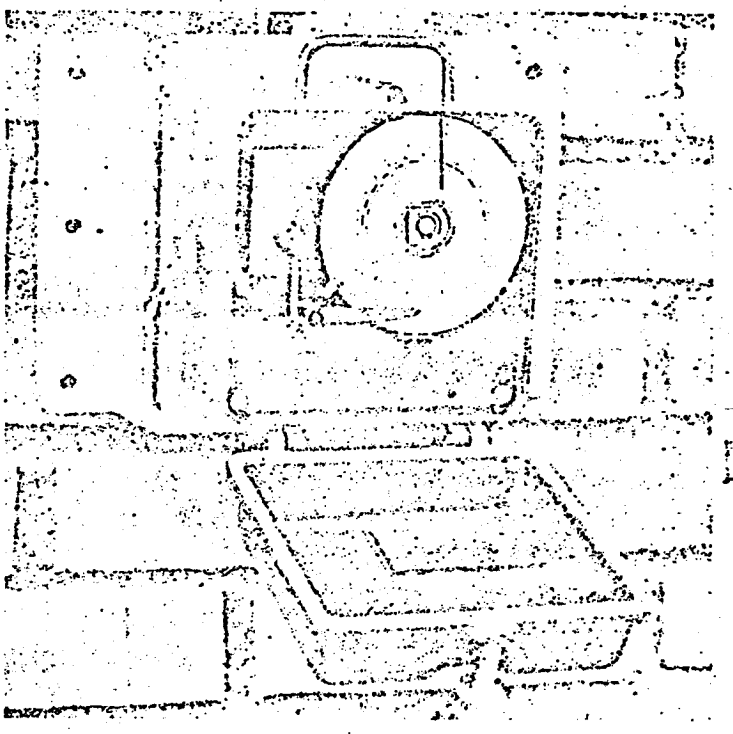
Direct and continuous recording on wax covered paper cuts down data analysis time, and makes it possible to adjust a blasting program as work proceeds. Rate of production goes up since maximum effective charges may be used without risk for exceeding accepted threshold values of vibration levels.

Low cost insurance against damage compensation claims

There is very little to go wrong in a Tellus recorder; there are few moving parts; maintenance is easy; service life is long and troublefree. All this means a low cost insurance that provides written evidence to meet unwarranted claims for damage compensation. With the increasing emphasis on preservation and improvement of our natural environment, the Tellus vibration recorder is an insurance that no building contractor, quarry operator or civil engineer can do without.

A Tellus chart take no more than three minutes to remove, read and analyse. Using the 8x magnifying glass with 0.1 mm scale divisions gives amplitude pick-off down to 10 μ without difficulty.

The recorder is delivered in a wooden carrying box complete with magnifying glass, a set of disks for 100 records or a set of helixes for 70 days measuring, and a silumin holder for bolting to vertical or horizontal surfaces.



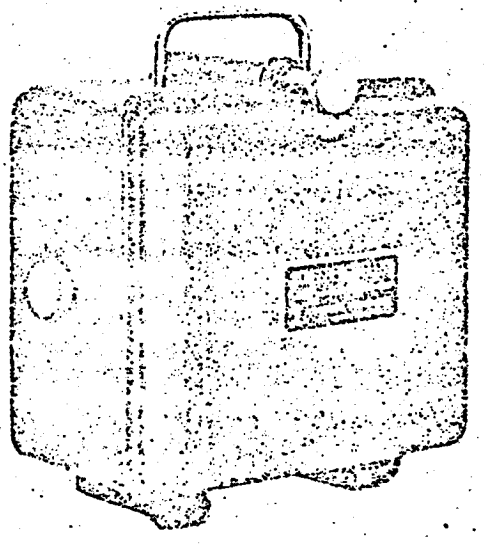
Use the Tellus for accurate vibration control

The Tellus E gives spot measurements of vibration amplitude and frequency, while the Tellus M gives continuous amplitude measurements over a 7-day period. Combined use of the two types gives a complete picture of the vertical vibrations occurring during a blasting operation. Tellus recorders complement the more advanced vibration measuring instruments that are in use, and make it possible to widen the net of measuring points . . . with one of the lowest capital investments for this type of equipment.
The Tellus operating range covers most, if not all, of the range of vibration frequencies and amplitudes met with in rock blasting.

	Tellus range	Ground vibration magnitudes
Frequency	15–170 Hz	5–500 Hz (c/s) Loose sand, clay 5–20 Hz Loose rock 30–40 Hz Hard rock 40–100 Hz
Amplitude	10–500 μ	5–800 μ (1 μ = 0.001 mm)
Acceleration	Up to 7 g	0.01–10 g

	Length	Depth	Height	Weight
Tellus instrument	190 mm 7 1/2 in	130 mm 5 1/8 in	168 mm 6 5/8 in	4.5 kg 10 lb
Carrying case	245 mm 9 5/8 in	160 mm 6 1/4 in	200 mm 7 7/8 in	1.5 kg 3 1/4 lb
Silium holder	245 mm 9 5/8 in	160 mm 6 3/4 in	240 mm 9 5/8 in	3.5 kg 7 3/4 lb

Batteries (Type E only) 2 1.5 V Transistor batteries (25 mm Ø; 50 mm long)



Let a Tellus recorder cut the costs and time of your ground vibration measurements

Get in touch with ABEM to-day, either direct or through your local ABEM representative, and get more information about vibration measurements. Learn how you also can get a low cost insurance against unwarranted damage claims.

ATLAS COPCO ABEM AB
Box 20086, S-161 20 Bromma 20, Sweden
Telephone 08-98 05 35
Telex 1459 Diabor S

REPRESENTANTE EN ESPAÑA
Guzmán el Bueno, 121 - Madrid-3

MAN EL BUENO, 121
ORID (3)
F. 253 42 00

VEGARADA, S.A.

OFERTA N.º 11/3

CSA NACIONAL ADARO

Fecha Pag.

División COMERCIO EXTERIOR Dept.º

idad	CONCEPTO	Precio unitario	TOTALES
	REGISTRADORES DE VIBRACIONES KONGSBERG TELLUS.		
	MODELO "E"		
1	Registrador TELLUS E, accionado por bateria para registro de amplitud y frecuencia, completo con caja de transporte de madera, 2 pilas de transistor de 1'5 V, 100 gráficos circulares, 1 curva de calibración, instrucciones de funcionamiento y 1 soporte de siluminio fundido para acoplamiento vertical u horizontal, ref.: 3364546, y 1 lupa de 7 aumentos, con escada de 0'1 mm., ref.: 4361212.	PESETAS	101.050'-
	Repüestos		
0	Gráficos de registro para TELLUS E, ref.: 4361180 ..	PESETAS	1.284'-
1	Juego de piezas de repuesto recomendadas para TELLUS E y TELLUS M, ref.: 3364, comprendiendo: - 1 Brazo de escritura, ref.: 3364526. - 1 muelle para peso, ref.: 3364538. - 1 muelle para articulación de pluma, ref.: 3364532. - 2 aros de sujeción de papel, ref.: 3364521.	PESETAS	2.953'-
1	Soporte de siluminio fundido para acoplamiento vertical u horizontal, ref.: 3364546	PESETAS	4.623'-
1	Lupa de 7 aumentos, con escala 0'1 mm., ref.: 436121 2	PESETAS	2.825'-
1	Motor eléctrico para TELLUS E, ref.: 3361155	PESETAS	12.583'-
1	Soporte de bateria para TELLUS E, el par, ref.: 4361 156	PESETAS	1.027'-
	Pilas de transistor 2 x 1'5 V para TELLUS E, ref.: 4361175	PESETAS	308'-
1	Interruptor arranque/parada para TELLUS E, ref.: 436 0474	PESETAS	258'-
	TOTAL PESETAS		126.911'-

GUZMAN EL BUENO, 121
MADRID (3)
TELF. 253 42 00

VEGARADA, S.A.

OFERTA N.º

	Fecha	Pag.
	División	Dept.º

Cantidad	CONCEPTO		Precio unitario	TOTALES
	MODELO "M" - Hoja nº 2 -			
1	Reloj TELLUS M, 7 días, para registro de amplitud, completo con caja de transporte de madera, 10 gráficos helicoidales de 7 días, curva de calibración, - instrucciones de funcionamiento, 1 soporte de siluminio fundido para acoplamiento vertical u horizontal, ref.: 3364546, y 1 lupa de 7 aumentos, con escala de 0'1 mm., ref.: 4361212.		PESETAS	101.050'-
	Repuestos			
10	Gráficos de registro, 7 días cada uno para TELLUS M, ref.: 4361180		PESETAS	1.284'-
	Juego de piezas de repuesto recomendadas para TELLUS E y TELLUS M, ref.: 3364, comprendiendo: - 1 brazo de escritura, ref.: 3364526. - 1 muelle para peso, ref.: 3364538. - 1 muelle para articulación de pluma, ref.: 3364532. - 2 aros de sujeción de papel, ref.: 3364521.		PESETAS	2.953'-
	Soporte de siluminio fundido para acoplamiento vertical u horizontal, ref.: 3364546		PESETAS	4.623'-
	Lupa de 7 aumentos, con escala 0'1 mm., ref.: 436121 2		PESETAS	2.825'-
	Máquina de reloj para TELLUS M, ref.: 3365016		PESETAS	8.475'-
	TOTAL PESETAS			121.210'-

- Precios: Almacén Madrid.
- Plazo de entrega: 60/90 días.
- Validez oferta: 90 días.

S-2

VIBRATION MONITOR

- Direct Print-Out for Immediate Data Analysis
- Self Contained Rechargeable Batteries
- Portable
- Rugged Construction

GENERAL DESCRIPTION

SINCO manufactures the S-2, a two-station, three-component, portable velocity meter designed expressly for vibration monitoring. The system will record three components of vibration at two locations simultaneously on a single chart. The locations may be separated by as much as 2000 feet.

The recording oscillograph uses direct-writing, dry photographic chart paper providing a permanent record that is immediately legible. The chart speed may be varied to suit individual conditions.

The system is self-powered and may be used in any location. A rechargeable 12-volt battery will operate the system for several days under normal conditions.

A remote control enables the instrument operator to have greater freedom of movement to coordinate operations.

VIBRATION MONITORING

Vibration monitoring aid the control of damage problems caused by such factors as blasting, pile driving or the operation of heavy equipment. These mining, construction and engineering methods can create ground vibrations severe enough to damage structures, or to create the fear of damage.

The measurement of vibrations is accomplished b sensitive, portable, electronic meters, providing permanent, visual record that can be judged agains standard damage levels. These levels have been deter mined through extensive search by federal, state an private organizations and are acceptable legal stan dards.

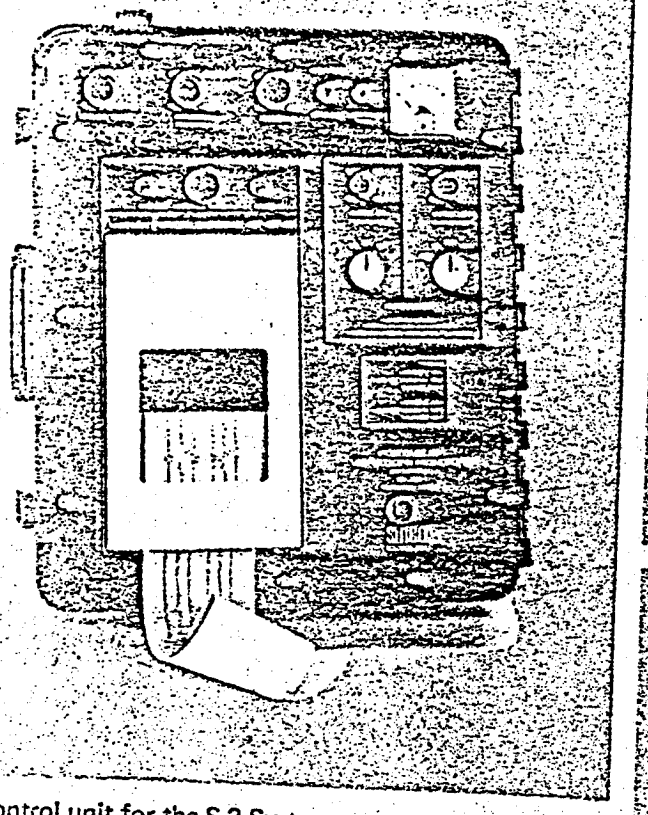
As a planning aid, vibration monitoring is effectively applied by determining the safe limits of explosives that can be used. During actual operations it is the definitive tool for measuring vibrations and in invaluable as a legal safeguard against damage claims.

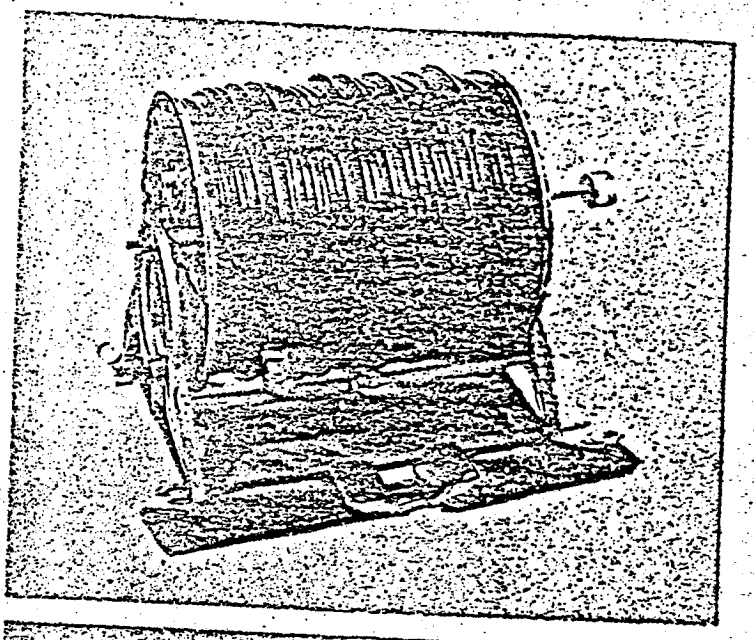
Measurements can be recorded quickly and accurately in any location, under all conditions. The equipment is portable, yet rugged, and can be transported to any location or installed semi-permanently at a specific site.

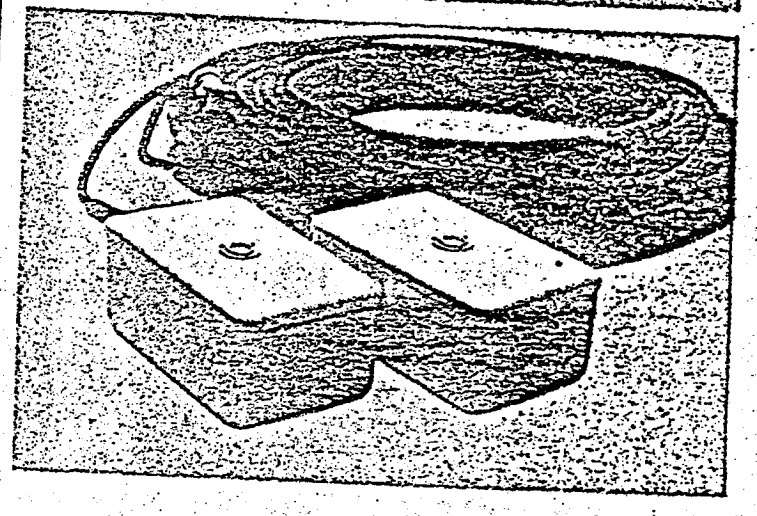
The intensity of earth vibrations is commonly expressed in one of two ways:

1. Energy Ratio (ER) — calculated from frequency and displacement or acceleration.

2. Particle Velocity — scaled directly from the record of velocity meter.







above: control unit for the S-2 System

above right: optional 1000-foot transducer cable with breast reel

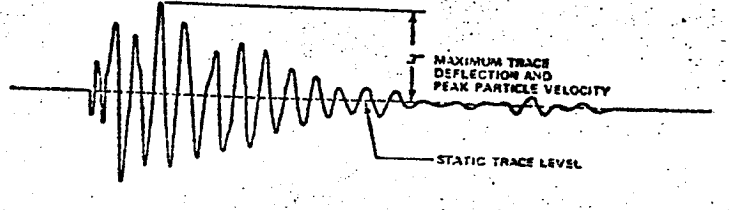
right: two transducer packages

Particle Velocity and Energy Ratio are directly proportional; e.g., a particle velocity of 1.8 in/sec = ER 1.0. The direct measurement of particle velocity is most convenient because it does not require frequency analysis of complex wave forms and can be scaled directly from a velocity recording by non-technical personnel.

The S-2 VELOCITY METER visually and permanently records the actual net change in particle velocities of the vibration or shock waves at the location of the detector package.

The three velocity detectors within each package are located along orthogonal axes. This coordinate system designated as L-V-T orients the actual direction of particle displacement or ground motion in space in terms of particle velocity. The longitudinal or L axis is in the long direction of the transducer package. The transverse or T axis is normal to the L axis and lies in the short direction of the package. The vertical or V axis is normal to both the L and T axes (i.e., at 90 degrees). This gives two horizontal and one vertical direction. The system may thus be treated mathmatically as the conventional X-Y-Z orthogonal axes system.

The individual detectors within each package record a trace upon the oscillograph chart. Maximum particle velocity is indicated by the maximum displacement of the trace from the static level, that is, the maximum peak rise of the trace from its normal position. This is illustrated in the following diagram:



The maximum peak rise of the trace from the static trace level is measured directly on the chart in inches. This value is multiplied by the sensitivity setting (clearly marked on the control knob) at which the recording was made. The result is V, particle velocity.

S-2
VIBRATION MONITOR

Price List
all prices f.o.b. seattle

November 1, 1972

Complete Model S-2, two station Portable Vibration Monitor including two sets of triaxial transducers, two 100-foot lengths of transducer extension cable, internal rechargeable battery power supply, and operator's manual.	$5,950.00/each
1000-foot lengths of transducer extension cable mounted on portable aluminum breast reels.	$ 575.00/each
Recording Chart Paper 3-5/8" x 100'	$ 9.00/roll

Model S-2 RENTAL SYSTEM

Complete Model S-2, two station Portable Vibration Monitor including two sets of triaxial transducers, two 100-foot lengths of transducer extension cable, internal rechargeable battery power supply, and operator's manual.	$ 600.00/month
Mininum charge: $100.00 per day or $200.00 per week plus $50.00 per day after first week up to a maximum of $600.00 per month.	
1000-foot lengths of transducer extension cable mounted on portable aluminum breast reels.	$ 40.00/month

SERVICES OF STAFF

Engineer to operate instrument or train client's personnel in use of instrument.	
Field time and travel time (Seattle to job site and return)	$ 18.00 per hour
Expenses: Transportation, per diem and misc. travel expenses, at cost.	
Engineer to train client's personnel at our Seattle Office, approximately 4 hours.	$ 75.00

3668 Albion Place North, Seattle, Washington, 98103
(206) 633-3073, cable: SINCO, Seattle
Foundation and Structural Instrumentation

SINCO
Slope Indicator Company

ECIFICATIONS

equency response:
Flat within ±10% in terms of vibrational particle velocity from 6 Hz to 150 Hz

nsitivity:
Individual controls for each set of transducers 0.5, 1.0, 2.0, 5.0 and 10.0 in/sec of particle velocity per inch of trace deflection of (1/2 peak to peak)

corder: 6 channel recording oscillograph

art Paper: Direct-writing, dry photographic chart

art Size: 3.62" x 100'

art Speed: Adjustable to 1, 5, 10 or 50 in/sec

Transducer Package Size:
Height: 2.5" Width: 4.0" Length: 8.0"
Weight w/o cable: 1.0 lb.

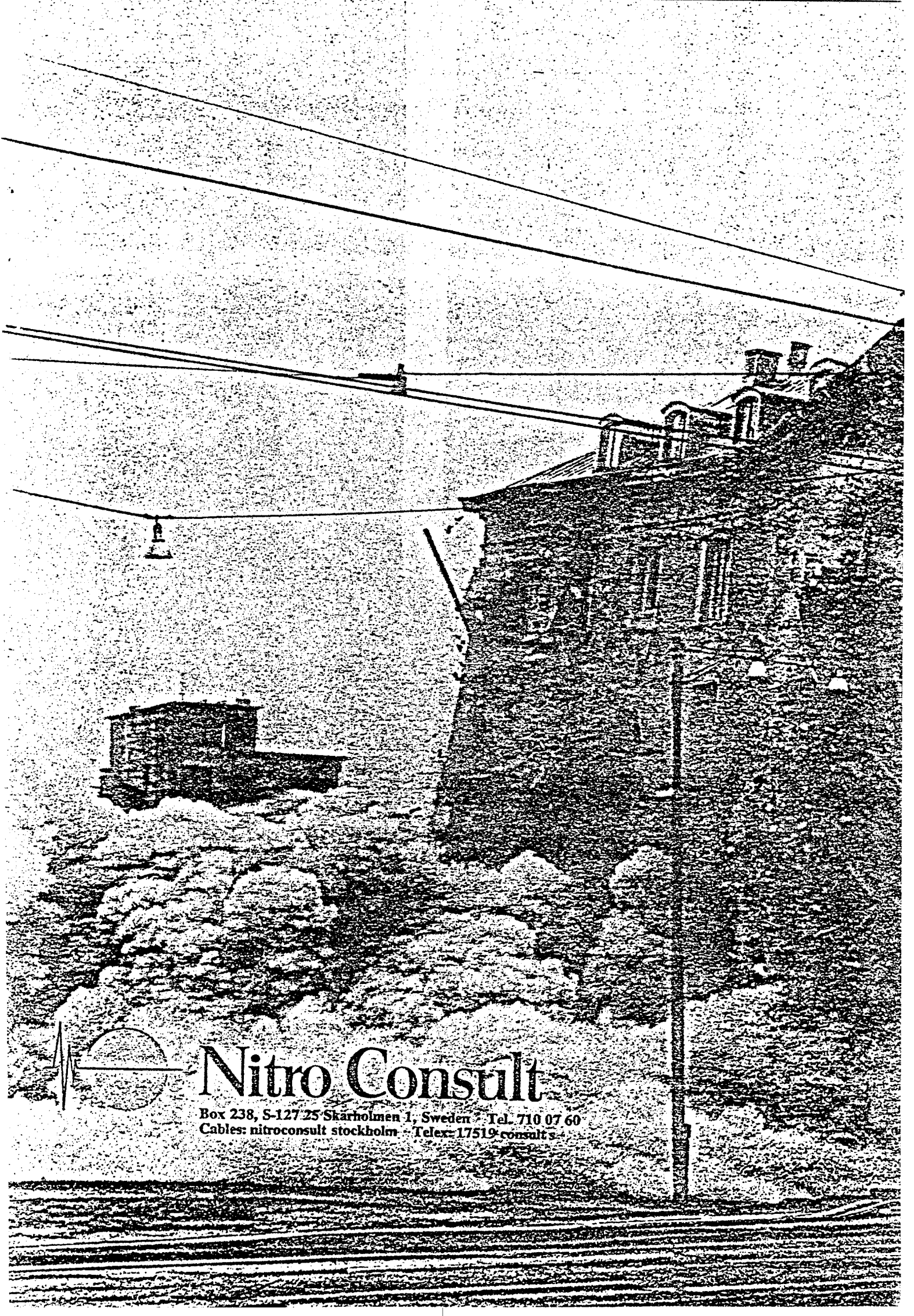
Transducer cable: Each transducer is furnished with a 100 ft. cable

Power Requirement: 117 VAC for battery charger

Instrument Case Size:
Height: 8.75" Width: 19.50" Length: 15.625"
Weight: 45 lbs.

Accessories:
1000 ft. transducer cable mounted on portable cable reel.
Remote control.

Slope Indicator Company
3668 Albion Place North, Seattle, Washington 98103
(206) 633-3073, cable: SINCO, Seattle



Nitro Consult

Box 238, S-127 25 Skarholmen 1, Sweden - Tel. 710 07 60
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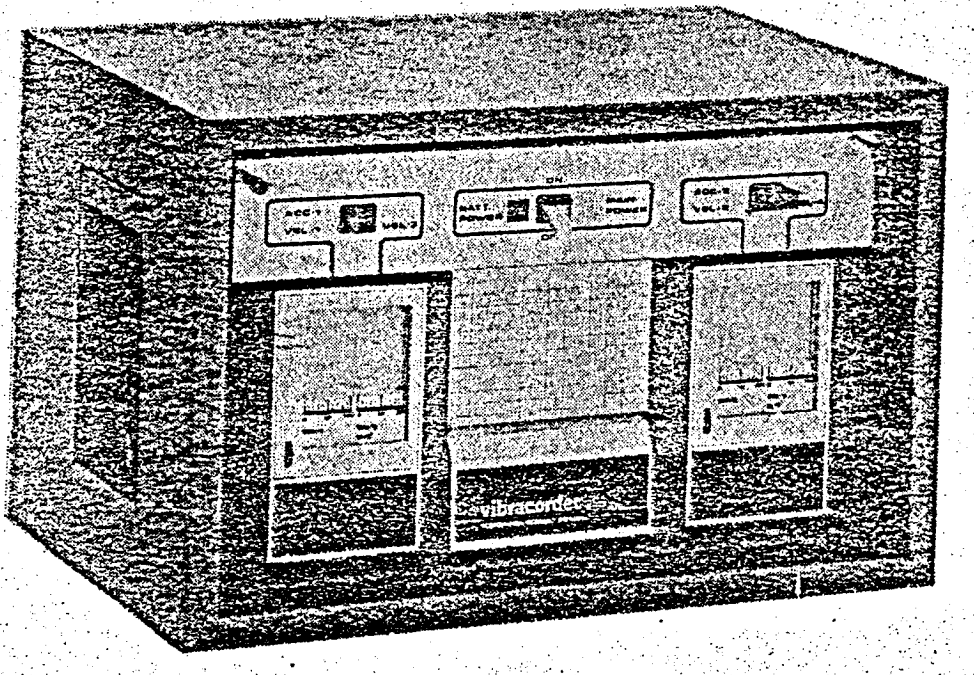
Nitro Consult flash bulletin



The basis for advanced blasting technique or cautious blasting with controlled rounds which are fitted to surrounding grounds and buildings was made after the second world war by introducing the short delay blasting technique and by the development of ground vibration instruments.

The necessity of a technique for controlled blasting has been accentuated through the intensive construction activities in large communities.

The demands for careful and quick measurings increase when
the knowledge about the technique is spread,

more and more "intricate" blasting sites will become actual (e.g. close to monumental-buildings, churches, ruins and other cultural monuments),

the electronic equipment in buildings becomes more and more refined and sensitive for ground vibrations,

the demand rises to be able to make use of largest possible rounds up ta a controlled maximum charging level.

In order to be able to meet the mentioned demands and at the same time develop the technique, a new ground vibration instrument has been developed which in comparison with the already existing equipments has the following advantages:

1. Measures ground vibrations on several points at the same time. (Earlier one instrument=one measuring point.)
2. Calculates itself the values to desired magnitudes. These are the vibration velocity and the acceleration of ground vibrations (These must be calculated from the values from other instruments.)
3. Watches the measuring place (=working place) continuously one month without supervision. With the other instruments a combination of a weekly control of the ground vibrations and a special control measurement on each shooting occasion is applied.
4. Easy to read for the attendants at the premises so that they can check that the blastings are made below the admitted limit values.
5. Possible to develop in the way that transmission of data can be made by phone to a central for judgement of the results.
6. Possible to develop in the way that the measuring instruments can be exchanged for measurement of other disturbances.

The name Vibracorder is a combination of the words "vibration" and "recorder". In other words an abbreviation of ground vibration measuring instrument.
With this complement to the earlier instruments, the Ampligraph and the Combigraph, we should be able to meet the demands at the premises in a still better way.

Stockholm 1970

Nitro Consult Ltd

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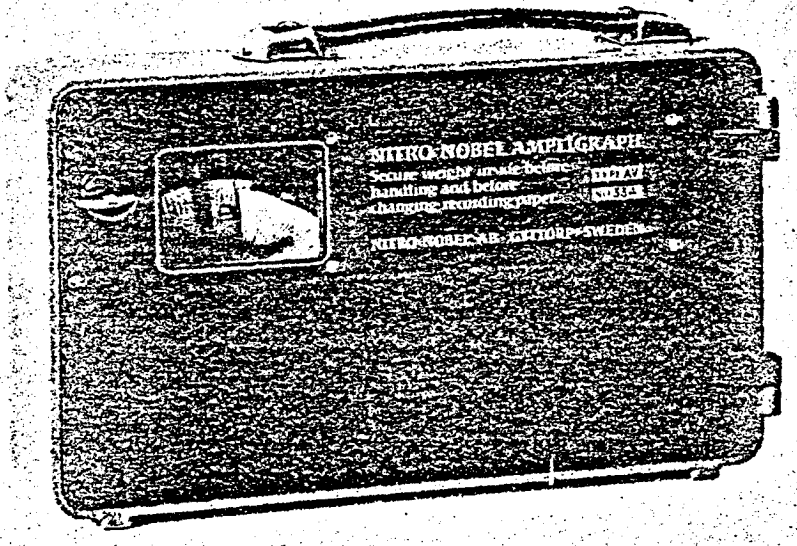
Bank
Stockholms Enskilda Bank

ampligraph



How it operates and how it should be used

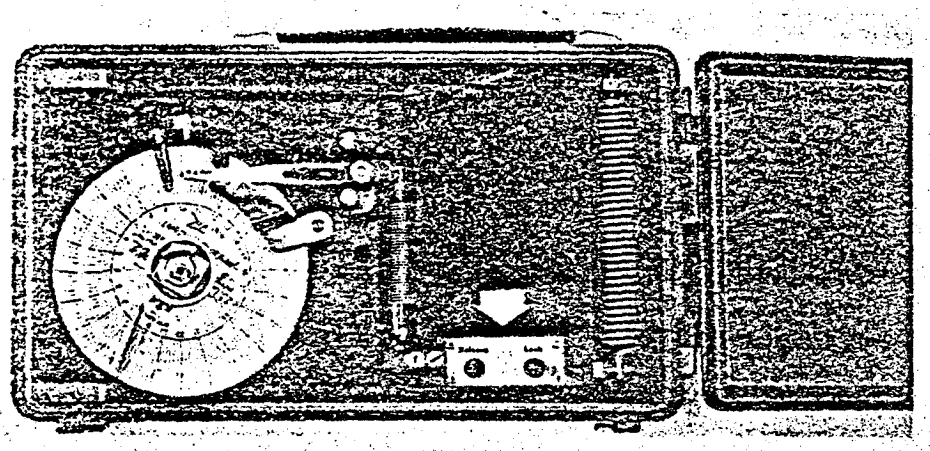
The Ampligraph is a vibrograph designed for long periods of recording which has been developed for continuous registration and mapping of ground vibrations caused by blasting and pile-driving or other vibrations of a similar type. Because of the long periods of continuous recording, the speed of registration is low and this means that only the amplitude of the vibrations and the times at which they occur are noted.

When more detailed investigations are being made in critical cases, supplementary measurements must be made with instruments on which both the frequency and velocity of vibration can be calculated. These instruments are known as "Combigraph", "UV Recorder" and "Vibracorder".

Technical data

Reference weight	4.3 kg
Natural period of vibration	during vertical measurement 3.1 cycles/sec, during horizontal measurement 2.7 cycles/sec
Amplification factor	5
Continuous recording time	8 days
Movement of recording paper	0.2 mm/min
Resolution time	10 seconds
External dimensions	width × height × depth = 285 × 175 × 70 mm
Total weight	7 kg

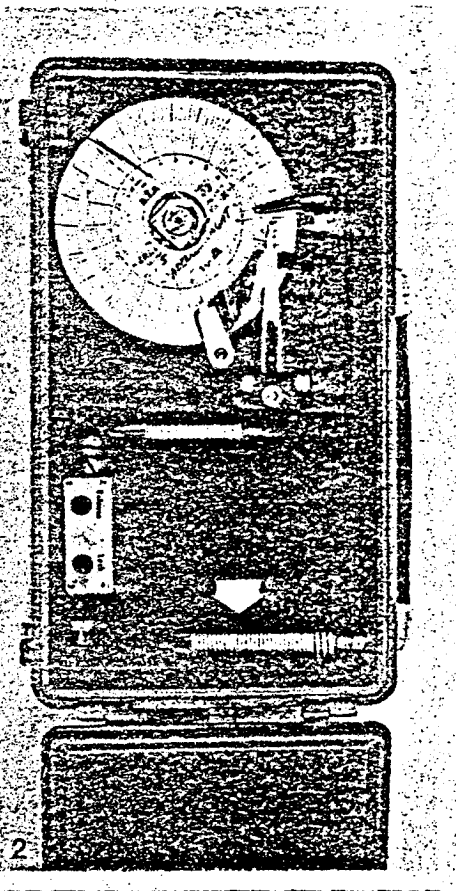
The instrument is firmly screwed onto a wall, beam or other supporting structure in the building where measurements are to be made.



1

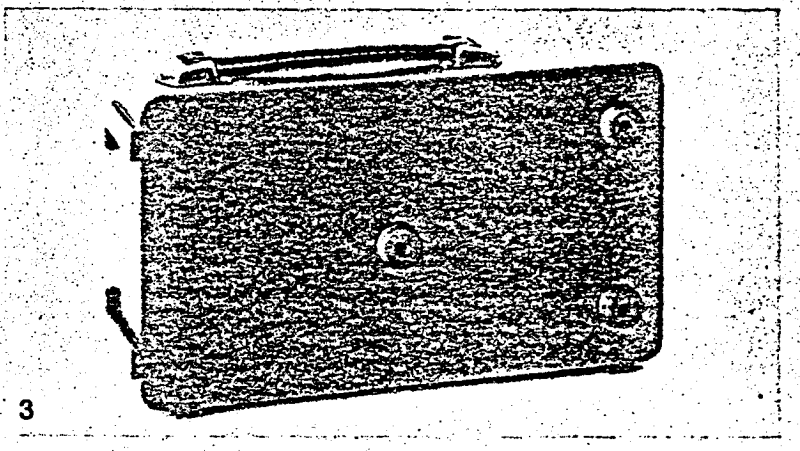
Instrument installed for vertical measurement.
In the case of vertical vibration measurement the instrument is installed with the carrying handle upwards. For vertical measurements the weight must hang in the spring.

Instrument installed for horizontal measurement.
In the case of horizontal vibration measurement the instrument is installed with the end where the lock is fitted facing upwards. When the instrument—with the weight still secured—has been firmly attached to the wall, the large spring at the arrow is unhooked from the bright pin on the weight.



2

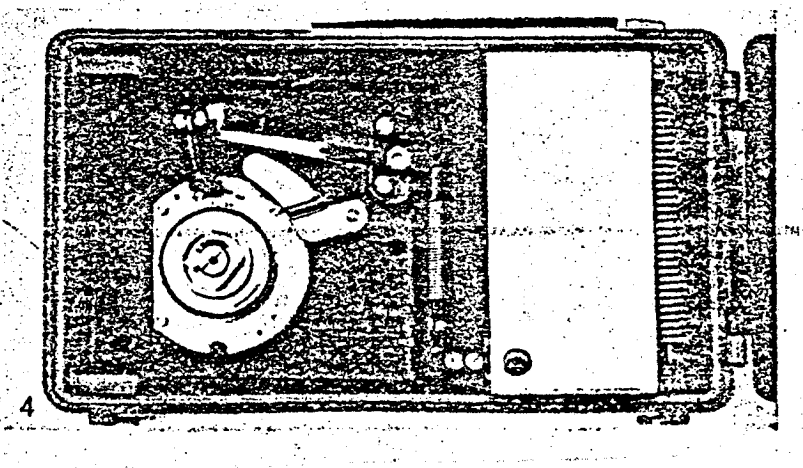
A template can be used when the holes are drilled for the attaching screws. This template together with screws and expander bolts with screws and special nuts, is supplied. It is essential for the instrument to be firmly screwed in position if the correct readings are to be obtained. If plastic plugs and wood screws are used, then the screws must have countersunk heads.



3

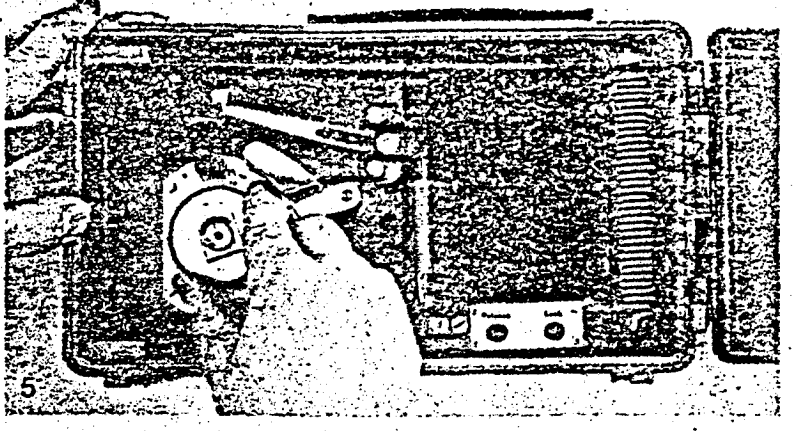
The Ampligraph must be blocked when it is being moved, while the clockwork mechanism is being wound up and while the recording paper is being inserted. (The locking buttons can be seen at the arrow on Fig. 1.)

While the instrument is being transported, it is extremely important to ensure that the wooden support block is in position. If this block is not correctly located, the instrument can be damaged.

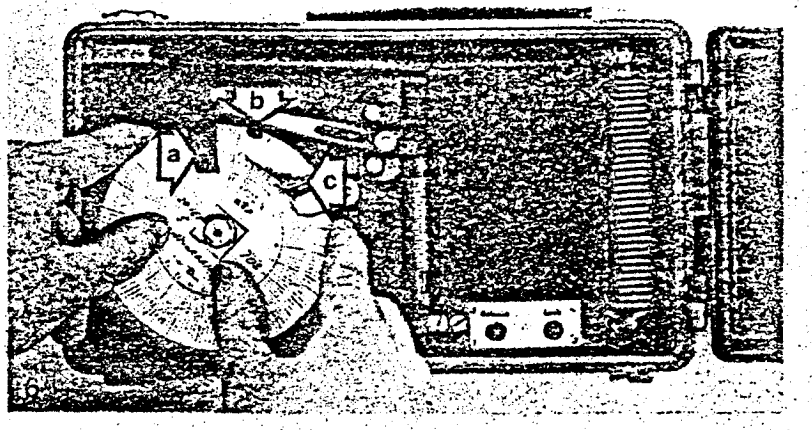


4

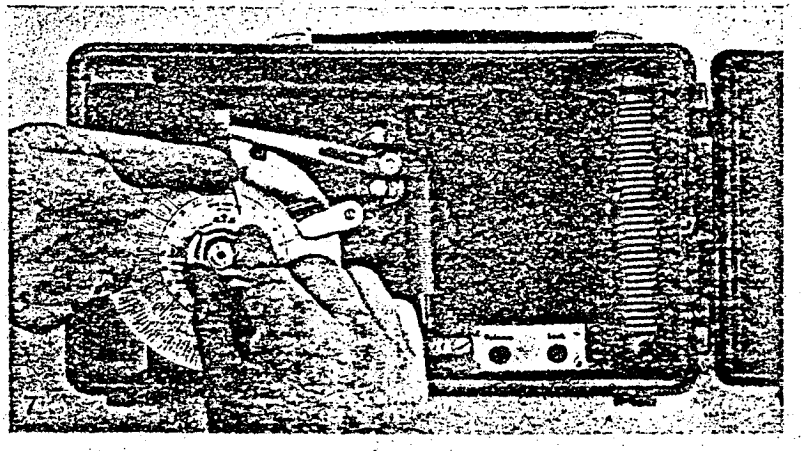
The clockwork mechanism is wound up by turning the serrated cover over the clockwork housing in a clockwise direction until fully wound.



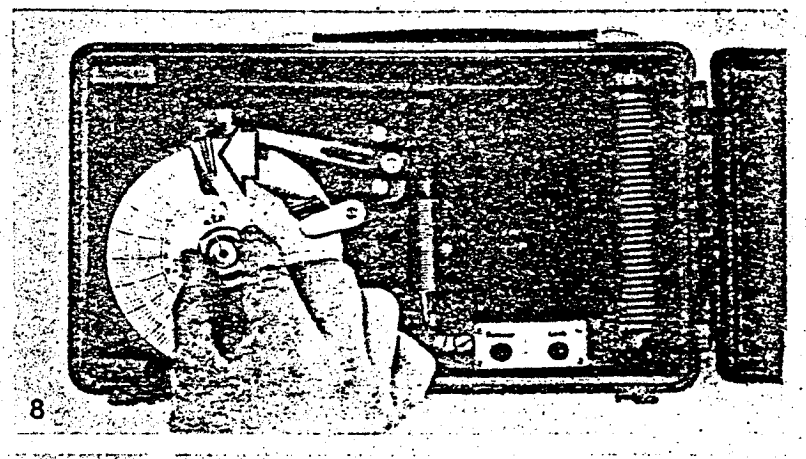
The recording paper helix is fitted as follows. Remove the lock ring from the square head on the clockwork mechanism. Lift up the black tapered roller from the recording plate. Fit the recording paper—which consists of eight waxed discs taped together—on the square head of the clockwork mechanism. See the illustration. NOTE. The recording paper is located under the recording plate a) the guide plate b) and the guide arm c).



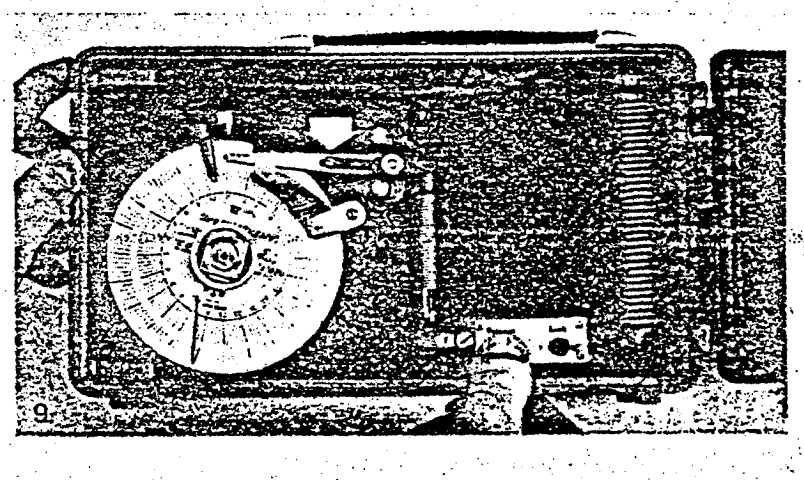
Press the lock ring firmly into position and move up the initial tab on the first recording paper disc between the guide plate and the actual recording plate.



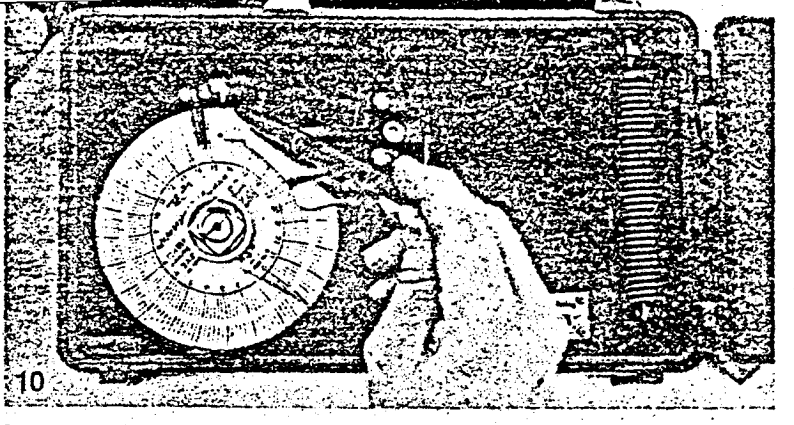
Turn the outer disc forward so that it completely covers the recording plate and then lower the thrust roller at the arrow so that the disc is pressed against the plate.



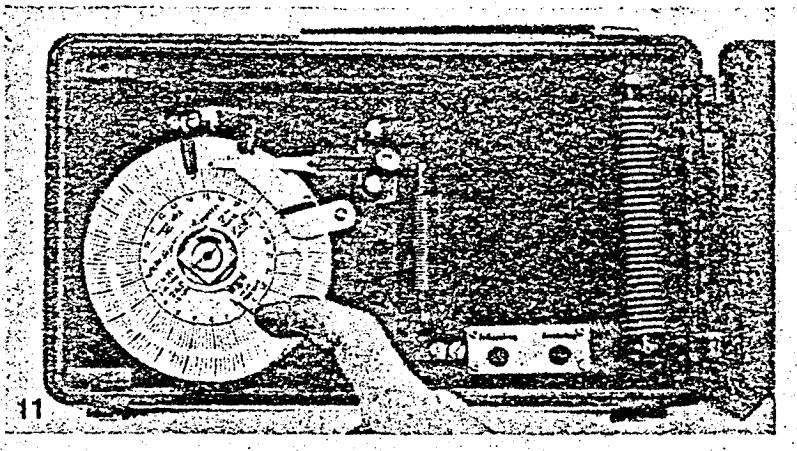
Release the weight by pressing in the green button on the weight so that registration can occur. If necessary, adjust needle pressure by using the adjuster screw on the recording arm at the arrow so that the line marked is only just visible to the naked eye.



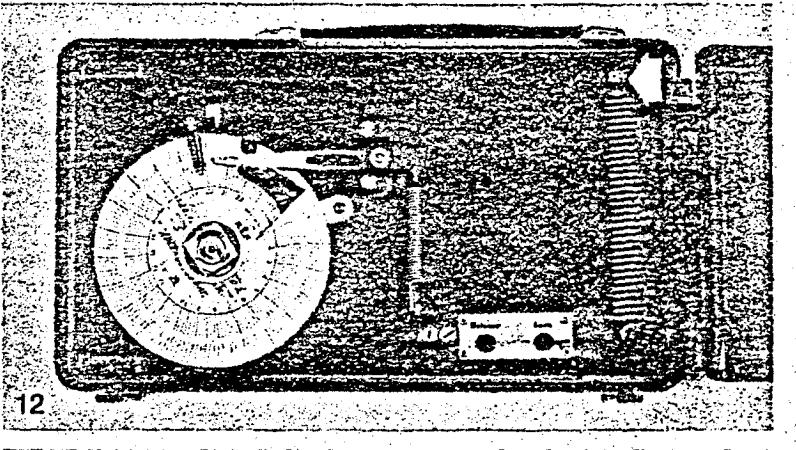
Use the graduations on the recording disc to set the recording needle at the correct time marking. This is indicated by a fixed pointer. (See the point of the recording needle in the illustration.)


10

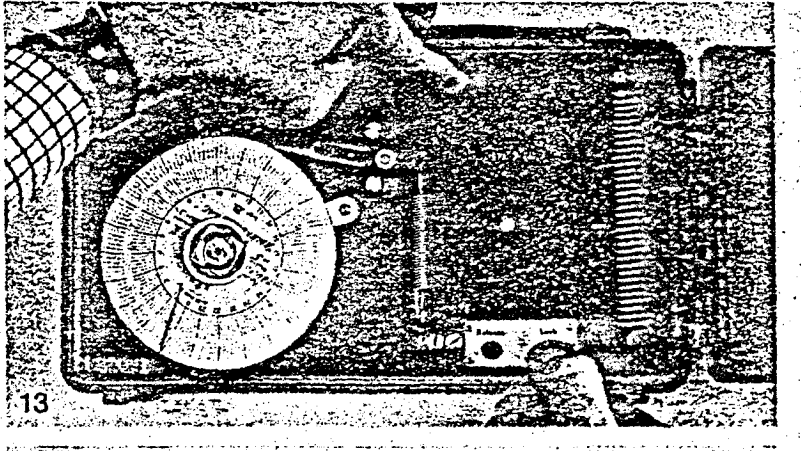
Make sure that the initial tab on the first recording disc is bent forwards so that it is definitely taken in front of the guide arm. The point on the tab must be bent so that it cannot jam on the underside of the cover while the instrument is operating.


11

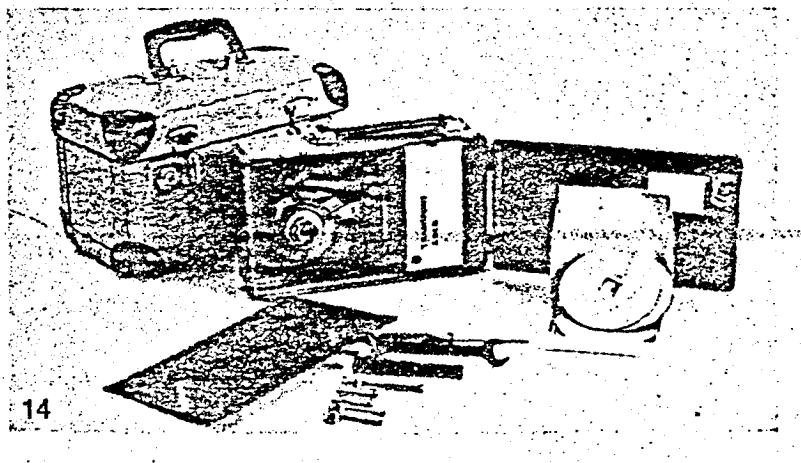
The instrument in operation.
The position of the zero line during vertical measurements can be adjusted by raising or lowering the main spring suspension nut. (See arrow.) First loosen the lock nut and then turn the screw.


12

When changing recording discs and when taking down the instrument—do not forget to block the weight by pressing in the red button.


13

When preparing for transportation, make sure that the wooden support block is in position and that all the accessories have been replaced in the case.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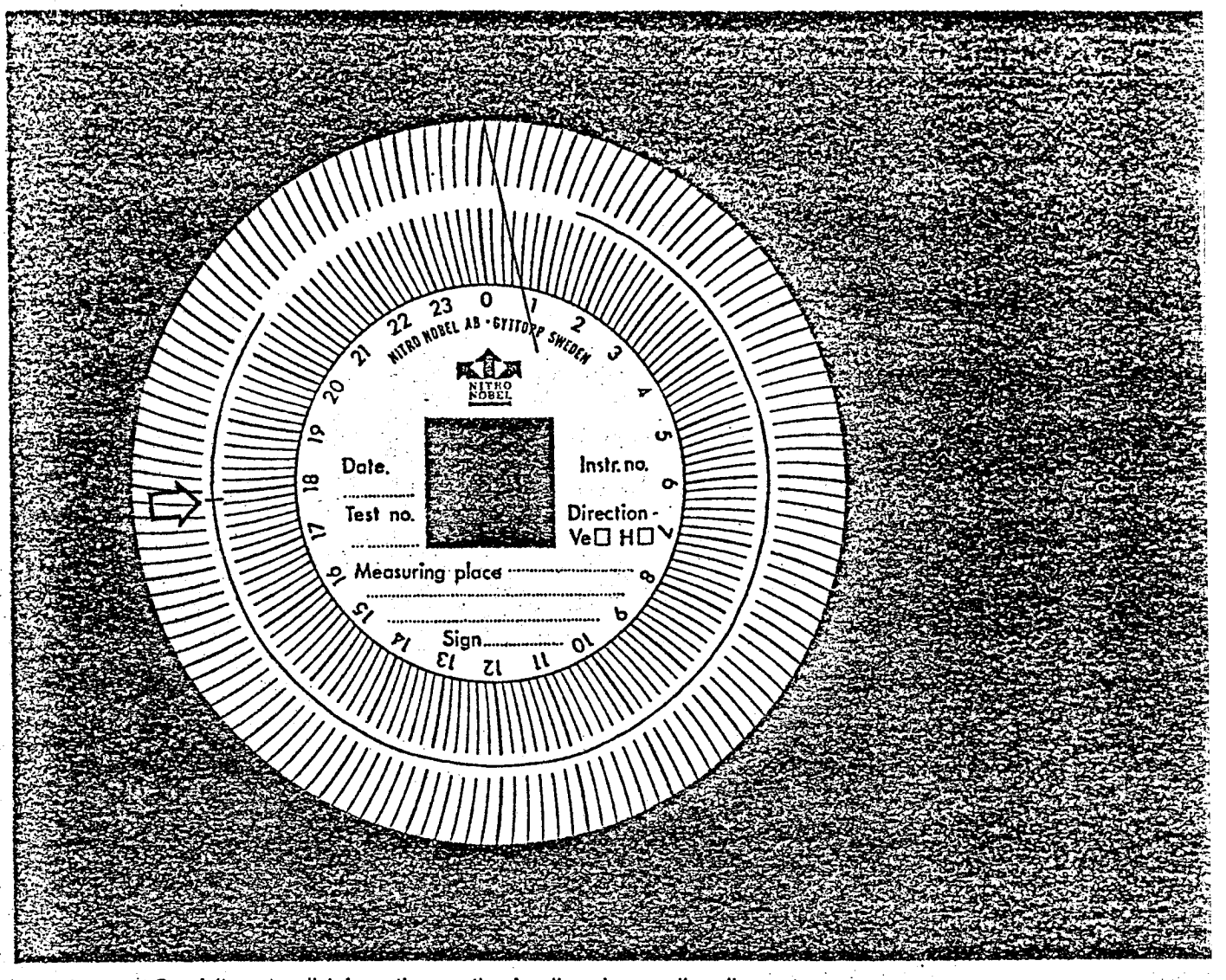

Carefully note all information on the Ampligraph recording disc.

Some practical hints

When carrying out evaluation, it is convenient to cut the recording disc helix at the taped joints. Before cutting, note the date and other information on the Ampligraph recording disc.
When the Ampligraph is started, the time at which this is done should be marked in some way on the recording disc, for example by rocking the weight so that there is a transverse line (see arrow) on the zero line.

Evaluating the Ampligraph discs:

When the Ampligraph is operating and no vibrations occur, there is only a light marking (zero line) in the direction of rotation of the paper. Each vibration registered by the Ampligraph takes the form of a transverse marking on the zero line. The length of this transverse line indicates double the amplitude (2A) multiplied by the degree of instrument amplification (5 times).
The actual amplitude of the vibrations (A) is obtained by dividing by 10.
Example: A registered value of l = 0.7 mm, then the actual amplitude is

$$A = \frac{0.7}{2 \times 5} = 0.07 \text{ mm}$$

The amplitude is often expressed in μ and since 1 μ = 1/1000 mm, then A in this example becomes 70 μ.
An amplification factor of five is usually sufficient in all practical measurements of vibrations from blasting. If a magnifying glass is used, this amplification factor enables vibration amplitudes of down to 5 μ to be read off with a satisfactory degree of accuracy.

Some instructions concerning the use of the Ampligraph

In order to obtain long periods of registration, the recording speed is low and this means that only the amplitude of the vibrations can be registered. Information concerning distance and prevailing ground conditions can be used to estimate the frequency of the vibrations and a maximum amplitude can be stated as permissible. If vibrations attain or exceed the maximum permissible values, supplementary measurements should be carried out by using instruments capable of recording the frequency of the vibrations so as to obtain more exact values in this connection. Several instruments are available for this purpose in the form of the "Combigraph", "UV Recorder" and "Vibracorder".
We should be very pleased to provide you with more detailed information concerning the use of the Ampligraph and the evaluation of Ampligraph recordings.

Nitro Consult AB

rock blasting techniques · vibration measurements

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Cables: nitroconsult Stockholm. Telex: 17519 consult s

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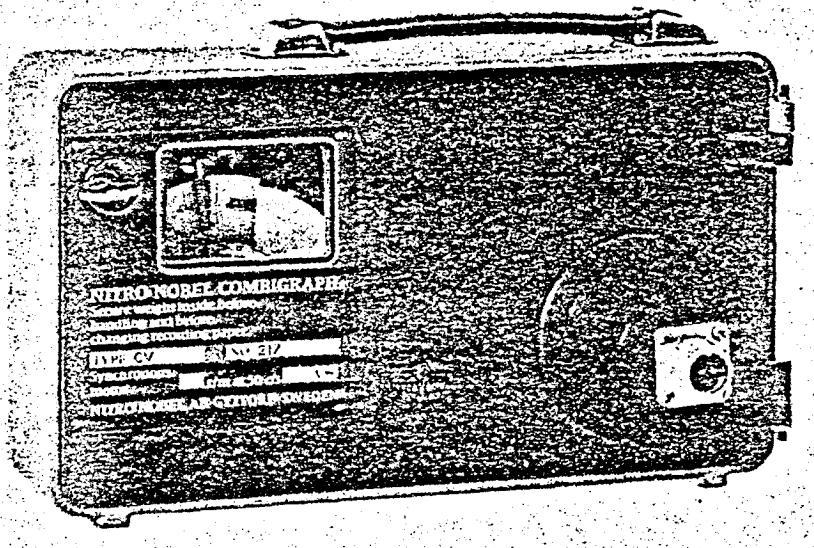
combigraph



How it operates and how it should be used

The Combigraph is a vibrograph of the combination type. It consists of a low-speed registration section for long periods of recording of the same type as that in the Nitro Nobel Ampligraph and also has a high-speed registration section.

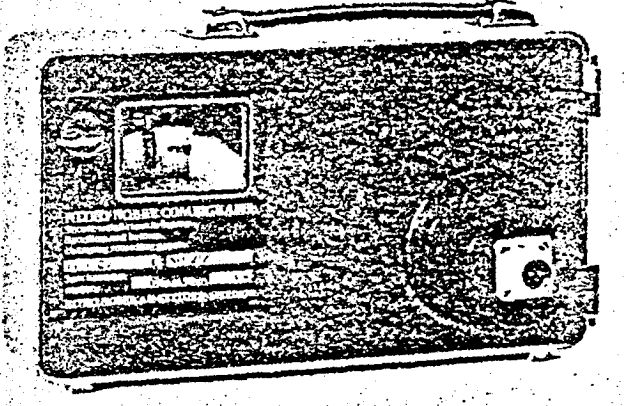
The low-speed registration section is for continuous registration and mapping of ground vibrations caused by blasting and pile-driving.

The high-speed registration section is for the measurement of vibrations during critical blasting operations and registers the appearance of the complete vibrations from which amplitude and frequency can be calculated as well as the rate and acceleration of oscillation.

The instructions for the Ampligraph apply to the low-speed registration section of the Combigraph.

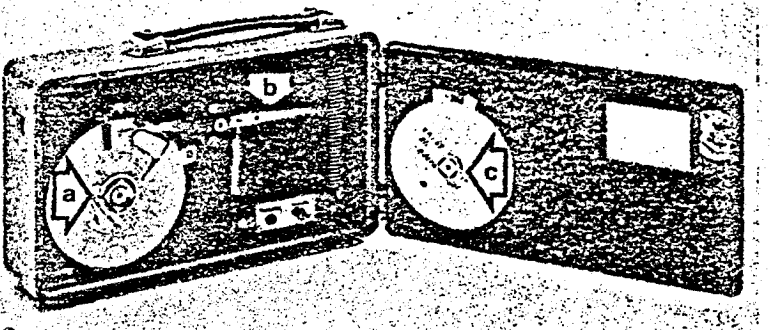
The high-speed registration section of the Combigraph has the drive motor located in the cover of the instrument. The recording paper—known as a combigram—is located on the inside of the cover.

Reference weight		4.3 kg
Natural period of vibration		
during vertical measurement		3.1 cycles/sec
during horizontal measurement		2.7 cycles/sec
Amplification factor		5
Continuous recording time		8 days
Movement of recording paper		0.2 mm/min
Resolution time		10 seconds
External dimensions		width × height × depth = 285 × 175 × 70 mm
Total weight		7.5 kg
Rotation speed, high-speed section	type CV 5 = 5 revolutions/min	
	type CV 10 = 10 revolutions/min	
	type CV 15 = 15 revolutions/min	



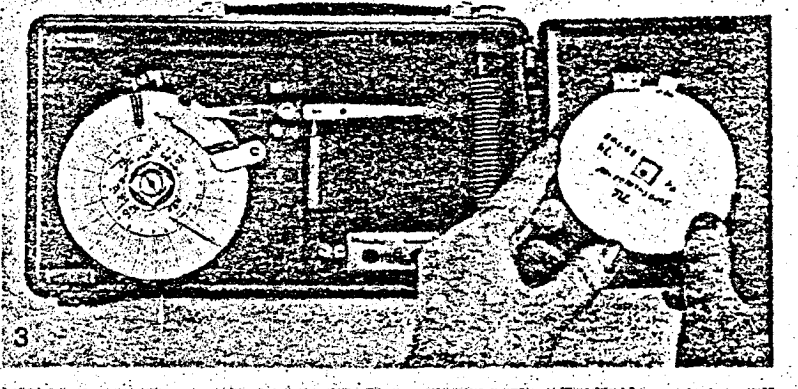
1

Low-speed registration section at arrow a.
High-speed registration section in the cover at arrow c.
The right-hand recording arm in the instrument housing at arrow b registers on this paper disc, which is fitted on the square head in the cover.



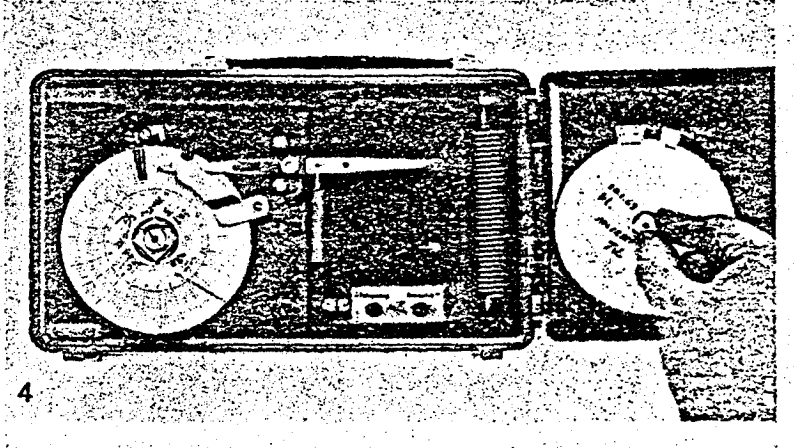
2

The disc must be inserted into the slot at the top of the recording table and in the guide slot to the right on the recording table.



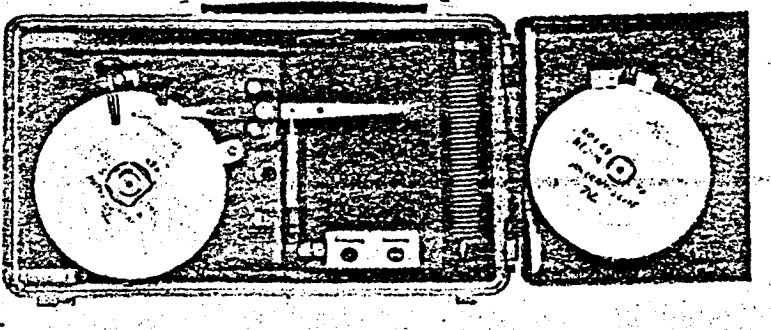
3

Press the lock ring firmly into position and write the location and time of the measurement on the recording disc.



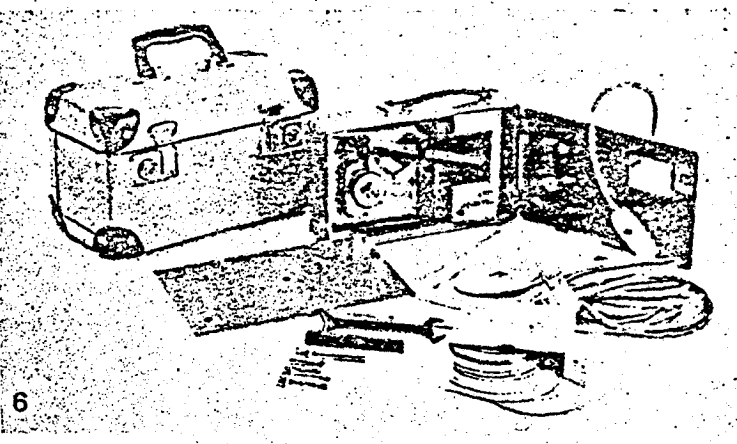
4

An example of a registered vibration (exaggerated in the picture).



5

When taking down the instrument for movement or transportation, the wooden transport block must always be correctly located. If this is not done, the instrument can be damaged.
Make sure that all the accessories are packed in the transport case.



Connection and adjustment
The mains cable supplied is connected to the plug in the motor casing and to an earthed power mains outlet. The motor is started by means of the switch on the cable.
Needle pressure must be adjusted so that even if the recording disc rotates several revolutions during one registration period, only a thin circular line is obtained. The instrument is designed for this. If the combigram rotates several revolutions before vibrations are registered, then the vibrations can be noted in the form of a curve on a zero line.

The instrument cover must be properly closed and locked before the recording arm registers on the recording disc.

Evaluation
The rapidly rotating disc in the type CV 5 Combigraph turns one revolution in 12 seconds, in the type CV 10 one revolution in 6 seconds and in the type CV 15 one revolution in 4 seconds. Registration speed is then dependent on the circumference of the circle registered and the rotational-speed of the recording disc.

The frequency
In order to determine the frequency of the vibrations, then the length of the cycle concerned, where the maximum values for frequency and amplitude are located, must be measured. In cases of doubt, measurement is carried out at several points on the combigram. The frequency is determined by dividing the distance for one second by the length of one cycle. The answer is in cycles per second. Remember when calculating frequency at high frequencies or large amplitudes that respect must be taken to the curvature occurring during registration. This curvature occurs since the registering arm is the radius of a circle with the registering arm bearing as centre.

Calculation of frequency (f) in cycles/sec

$$f = \frac{\pi \cdot d \cdot n}{60 \cdot 2\,t_2}$$

d = diameter of zero line circle in mm
n = speed of recording paper in revolutions/min
$2\,t_2$ = the registering speed for a cycle in mm

The amplitude
The amplitude is registered with an amplification factor of 5 on the combigram. The amplitude is the distance between an imaginary zero line and the maximum positive or negative value of the vibration. It is often difficult to determine the zero of vibration curves. In such cases it is best to measure amplitude by noting the distance between positive and negative peak values and then dividing by two. This figure is then divided by the amplification factor 5 of the Combigraph.

Calculation of amplitude (A) in mm

$$A = \frac{2\,A_{rec}}{2 \cdot 5}\ mm$$

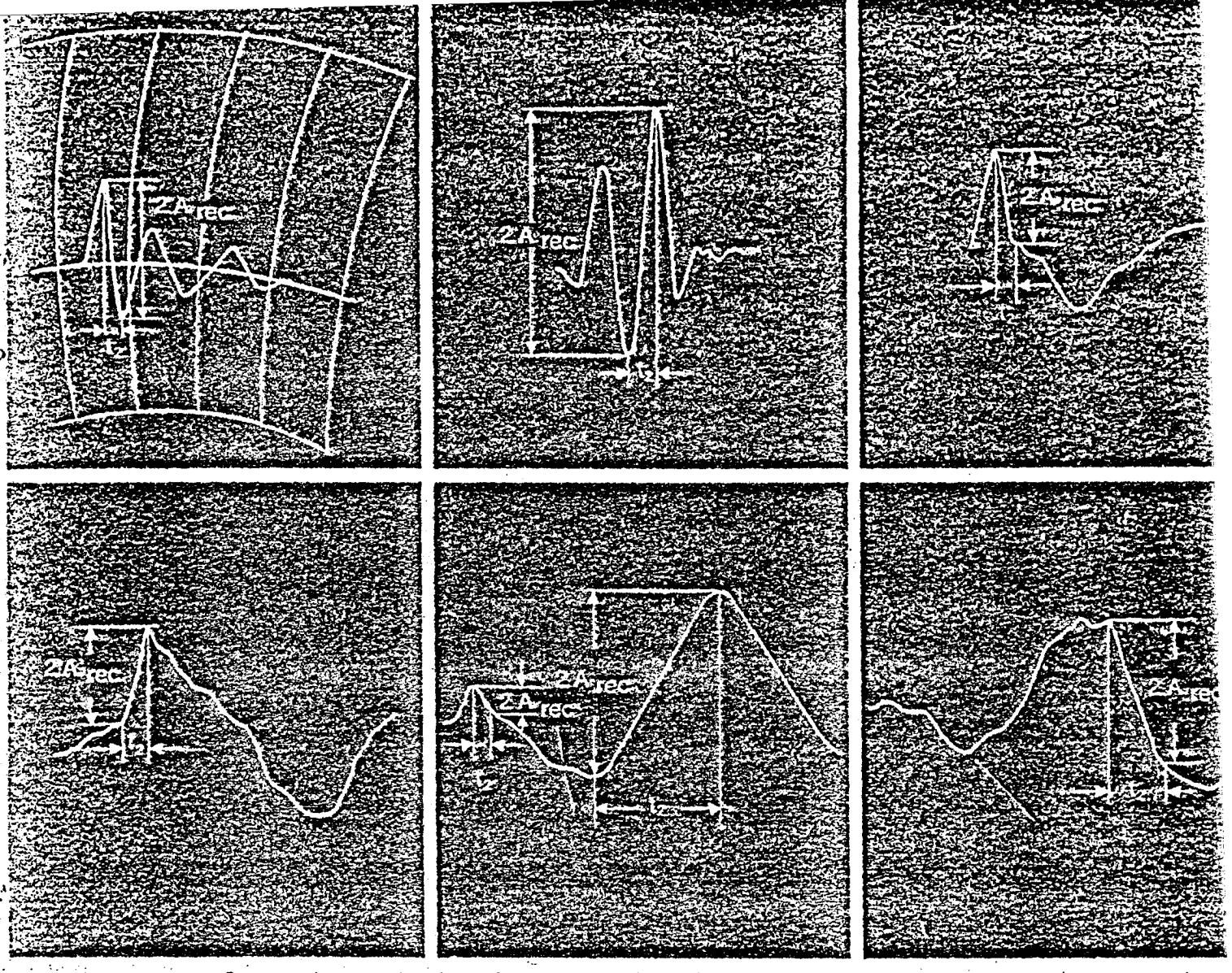
$2\,A_{rec}$ = Double the amplitude registered

Vibration velocity
The formulae below indicate the procedure when calculating the vibration velocity and acceleration of the vibrations.
Calculation of vibration velocity (v) in mm/sec

$V = 2\pi \cdot f \cdot A$ mm/sec
f in cycles/sec
A in mm

Acceleration
Calculation of acceleration (a) in m/sec²

$a = 4\pi^2 \cdot f^2 \cdot A$ m/sec².
f in cycles/sec
A in metres
(10 m/sec² = 1 g)



Compare the examples above showing vibrations with different appearances. ($2A_{rec}$ = Double the amplitude registered)

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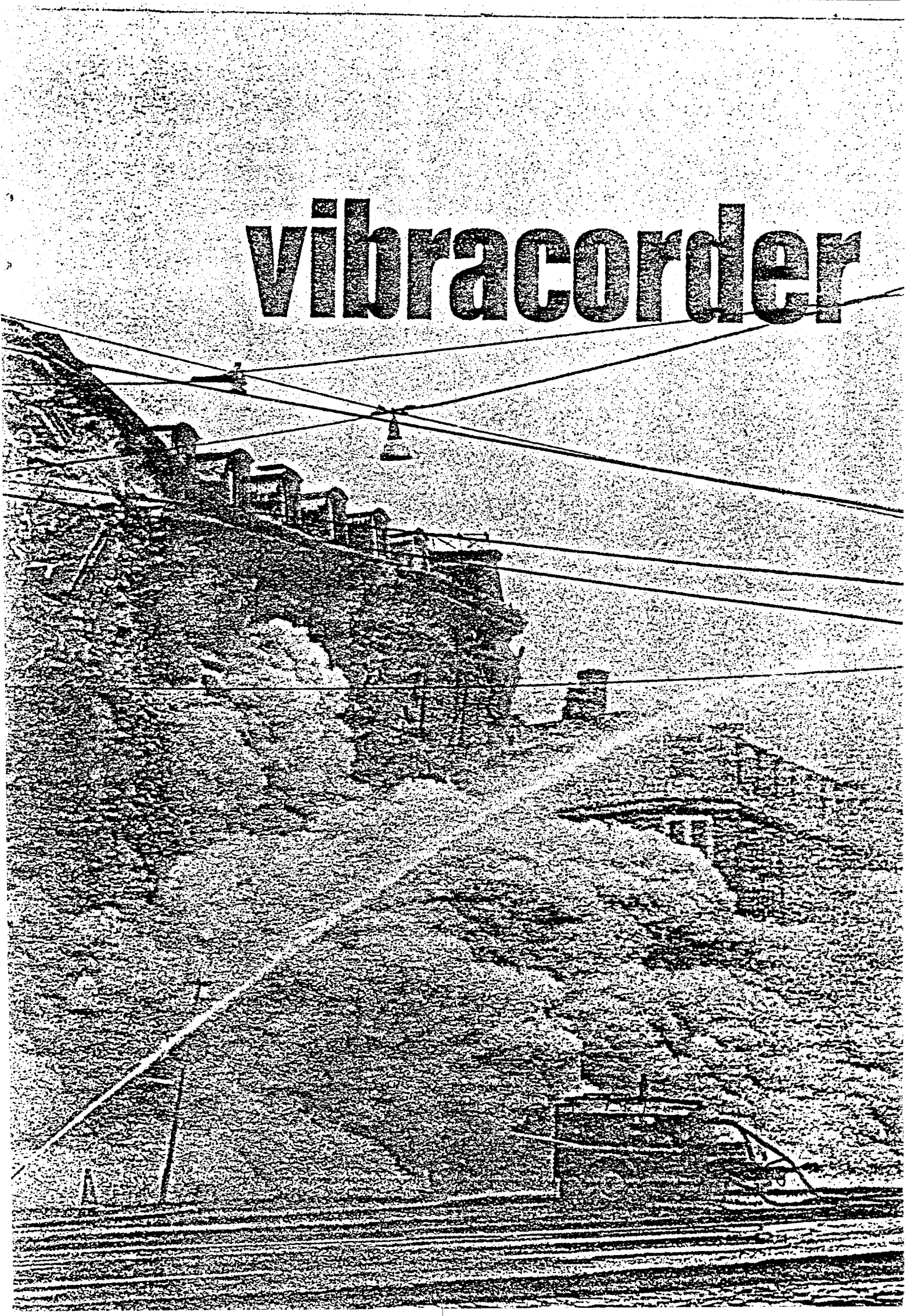
vibracorder



Vibracorder

The Vibracorder is a universal vibration recording instrument for civil engineering, construction, mining.
Blasting, demolition, pile driving, highway and rail-traffic, all cause vibration. Engineers, builders, architects and authorities require complete data on this vibration for a wide variety of reasons; safety, work planning, design, environment protection, research, legal requirements and damage claims.
New problems continually arise. The widespread and increasing installation of computers—extremely sensitive to shock—is an extra factor to be considered, especially in municipal or industrial areas. New construction materials, often lighter than conventional materials, need revised vibration considerations.
Modern blasting techniques enable engineers and builders to keep vibration to a minimum. Nevertheless, constant measurement and recording of velocity and acceleration of vibration are very essential.
Vibration velocity measurements are used mainly for studies of damage to buildings and structures. Vibration acceleration measurements are used in connection with blasting and construction that can affect delicate electric or electronic installations, such as computers, telephone exchanges, switching apparatus, etc.

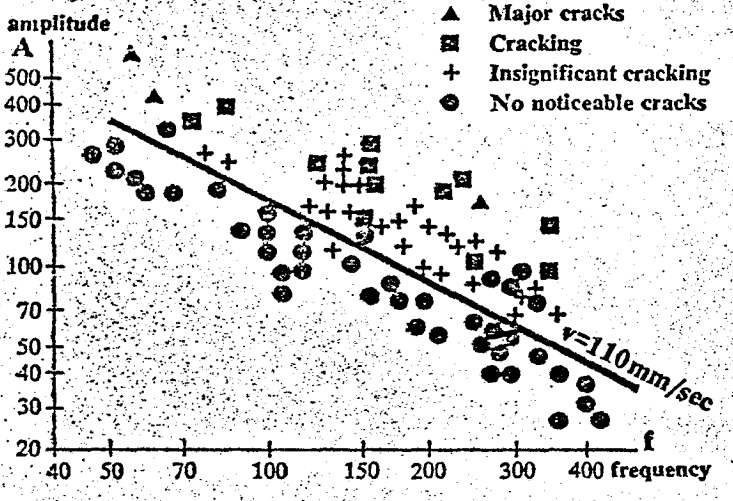
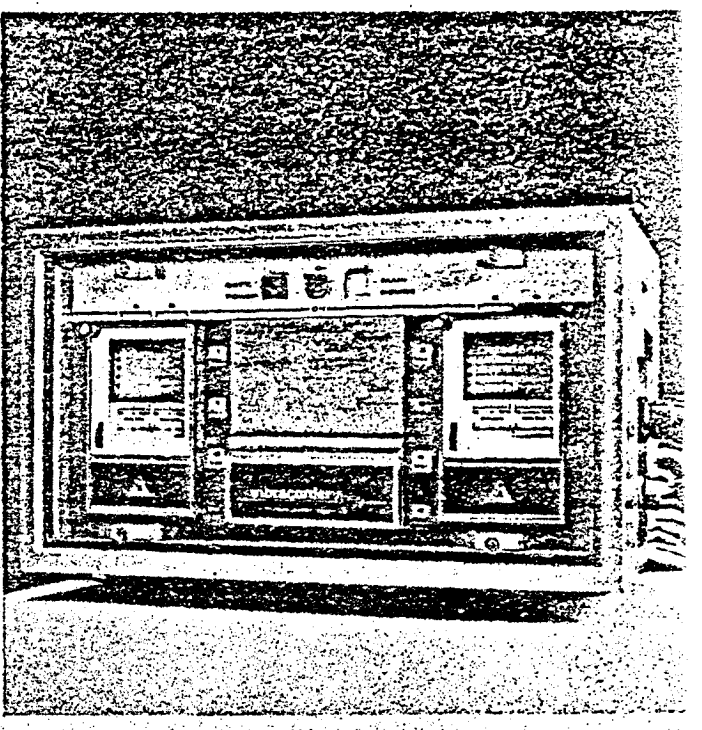
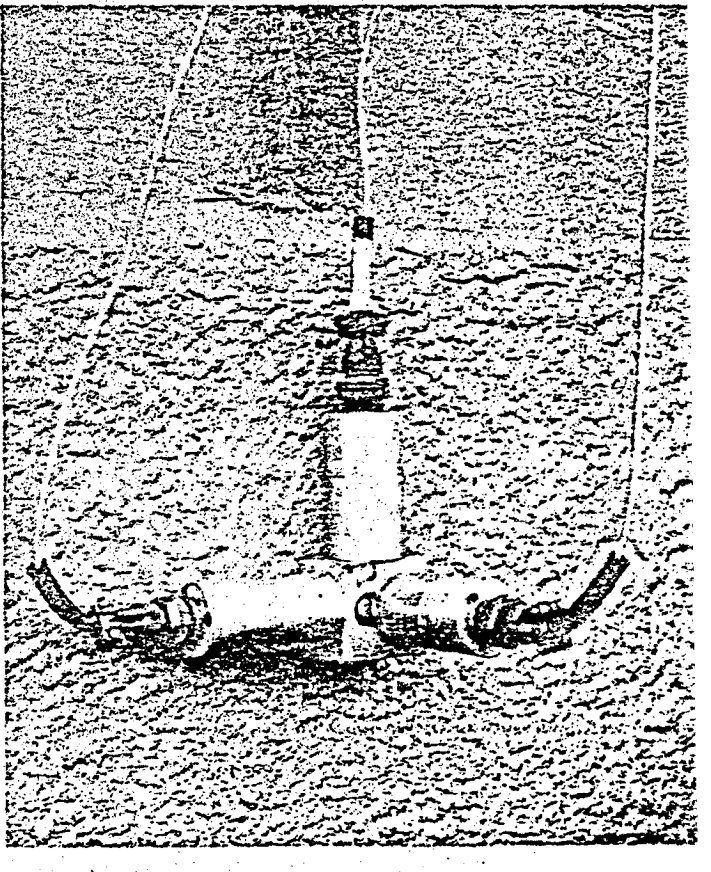


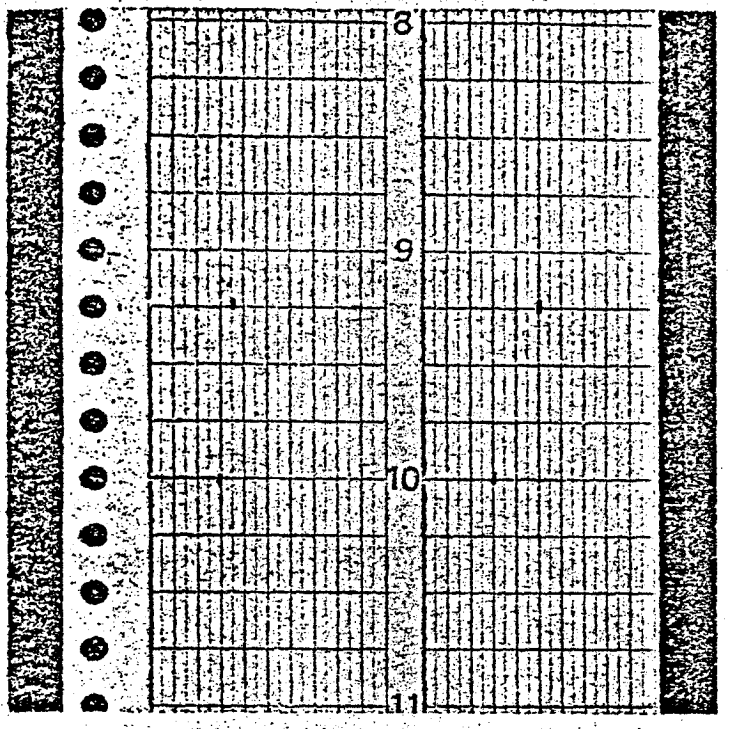
Diagram above is an example of damage occuring to standard dwellings, with foundations on granite rock, when vibration velocity reaches v=110 mm/sec. Other diagrams are obtained when measuring other structures and foundations.

Nitro Consult AB, international consultants in blasting, have completed some 250,000 vibration measurements over the years, while working on some of the world's most sensitive construction jobs. This experience lies behind Nitro Consult's development of a series of vibration measurement and recording instruments.
The Vibracorder is a four channel recording unit, allowing constant measurement and recording of vibration velocity or acceleration from one to four separate points. The unit works automatically. It can be set up quickly and easily, and is built for robust handling. Results are displayed in terms of time and magnitude, with both horisontal and vertical vibration recorded. The Vibracorder operates continually for up to four weeks without attention.
Technicians can be trained quickly to set up and operate the Vibracorder. It is supplied fully equipped, including a testing system insuring correct operation for each installation.



Photograph shows an actual installation, with contact below, attached to a wall. The Vibracorder itself, picture above, presents results on graph paper. Results can b quickly and easily interpreted. Vibration results are show in photo at right. Using this information, engineers ca determine vibrations resulting from various blasting charg quantities in relation to distance from the blast. Such in formation can be charted in graphs as that on the left.





Technical data

Vibration velocity measurement:	0—100 mm/second (For special purposes, 0—200 mm/second also available)
Acceleration:	0—10 g's (For special purposes, 0—20 g's also available)
Frequency range:	5—500 Hz
Power:	220 V/50 Hz, or battery operation for approx. 8 hours during main power interruption (110, 115 V/60 Hz system can be supplied)

Rechargeable batteries built into gas-tight container.
Also wired for long distance transmission of vibration information by cable or telemetry.
Instrument is dust-proof.

Size of recording instrument:	440×265×300 mm
Net weight:	22 kilogram
Gross weight (including all accessories)	35 kilogram

Recording instrument designed for easy carrying.
(Shipped in special carton for air-freight handling).

Cover: Photo shows demolition, supervised by Nitro Consult, of a building in the centre of Gothenburg, Sweden.

Delivery specifications

The Vibracorder is supplied fully equipped and is delivered ready for immediate operation. The complete Vibracorder system includes the following:

Vibracorder
Power cable
Earth cable
4 geophones, vertical type and/or horizontal type
4 geophone attachment blocks
4 cable reels, each with 65 meters of screened cable
3 balancing plugs
4 rolls of diagram paper
Expander bolts (for geophone attachment blocks)
Set of tools for operation and adjustment
Testing unit and test data sheets
Locking and sealing equipment
Instruction manuals

Extra accessories: Additional cable, connectors, geophone, service kits, testing equipment and frequency absorbers.

Leasing

The Vibracorder can also be leased or rented when this suits a customer's requirements. This can be particularly advantageous when measurements are to be carried out on a short-term basis.

Subsidiary companies

Oy Finnrock Ab
Alexandersgatan 21 A, Helsinki 10, Finland

Nitro Consult S.R.L.
Via G. Fara 39, 20124 Milano, Italy

Agents

Vibration Measurement Engineers
1732 Central Street, Evanston, Illinois 60204, USA

Imperial Chemical Industries
Nobel House, Stevenston, Ayshire, Scotland

Terrexpert AG
Schlachthofweg 130, 3014 Bern, Switzerland

Schaffler
15 Sturzgasse 34, 1150 Vienna, Austria

Heine Brothers
14 Berry Street, North Sidney, Australia

E. SPRENGNETHER
INSTRUMENT CO. INC.

4567 SWAN AVENUE
Telephone: 314 535-1682

SAINT LOUIS, MISSOURI 63110 U.S.A.
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PRICE LIST — NOVEMBER 1972 - E

Seismographs
-1-

MODEL	DESCRIPTION	UNIT PRICE
VS-4000	Blast Seismograph with Direct-Write	$2,970.00
	Options	
VS-4000-D	Fourth Trace Event Marker	275.00
	Modification (Instrument Returned to Factory)	
	Fourth Trace Event Marker	3,190.00
	Direct-Write	385.00
	Accessories	
	VS-4000-A Spare Camera	60.00
	VS-4000-B Standard Photographic Paper (150' Roll Kodak 1884) 1-10 Rolls	7.70
	VS-4000-C Direct Write Paper (150' Roll Kodak 2022) 1-10 Rolls	9.35
	VS-4000-E 12 Volt Rechargable Battery	32.00
VS-1100	Engineering Seismograph	4,150.00
	Options to VS-1100	
	Fourth Signal Channel	300.00
	Accessories to VS-1100	
	VS-1100-AS Spare Paper Supply Magazine	40.00
	VS-1100-AT Spare Paper Take-Up Magazine	60.00
	VS-1100-B Standard Photographic Paper (150' Roll Kodak 1884) 1-10 Rolls	7.70
	VS-1100-C Direct-Write Paper (150' Roll Kodak 2022) 1-10 Rolls	9.35
	VS-1100-D X100 External Signal Amplifier	275.00
	VS-1100-E Refraction Cable	185.00
	VS-1100-F Origin Time Geophone	125.00
	VS-1100-G 100 Ft. Shielded Seis. Extension Cable	130.00
	VS-1100-H 200 Ft. Shielded Seis. Extension Cable	195.00
	VS-1100-J 500 Ft. Shielded Seis. Extension Cable	360.00
	VS-1100-K 10 Ft. Remote Control Cord with Switch and Plug	19.50
	VS-1100-L 10 Ft. Remote Control Cord Only	3.00
	VS-1100-M 10 Ft. Remote Control Switch Only	8.35
	VS-1100-N Leveling Screw Assembly	17.50
	VS-1100-R Time Mark Generator Module	200.00
	VS-1100-S Dual Speed Option	325.00
	SM-1 Air Wave Detector	300.00

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STRUMENT CO. INC.

MANUFACTURERS OF SEISMOLOGICAL, GEOPHYSICAL AND ENGINEERING INSTRUMENTS

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Cable: SPRENCO

PRICE LIST — NOVEMBER 1972 - E

Seismographs
-2-

MODEL	DESCRIPTION	UNIT PRICE
VS-1200	Engineering and Research Seismograph.	$5,275.00
	Options	
	Fourth Signal Channel	300.00
	Accessories	
	VS-1200-A ± 10 Attenuator	140.00
	VS-1200-B Tape Output	105.00
	VS-1200-C Shear Wave Discriminator	275.00
	VS-1200-D Energy Ratio Module	305.00
	VS-1200-E Dual Speed	305.00

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Telephone: 314-535-1682
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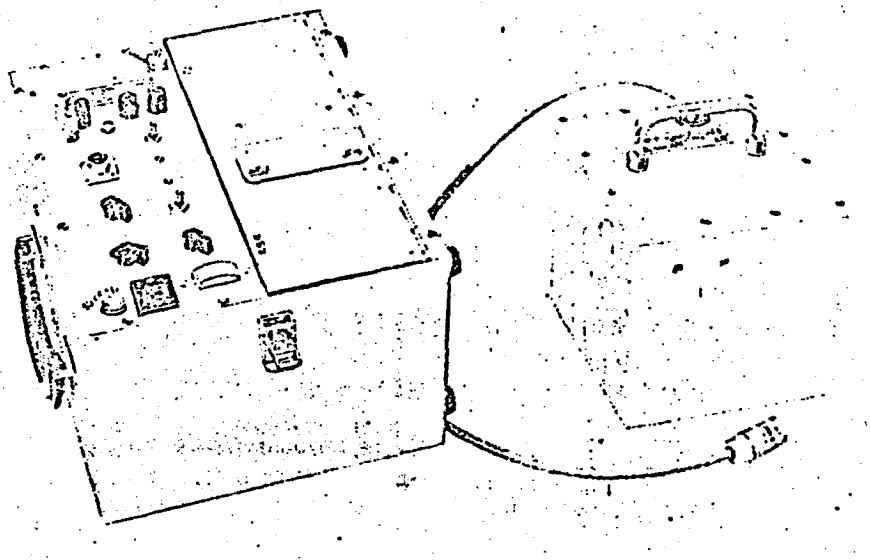
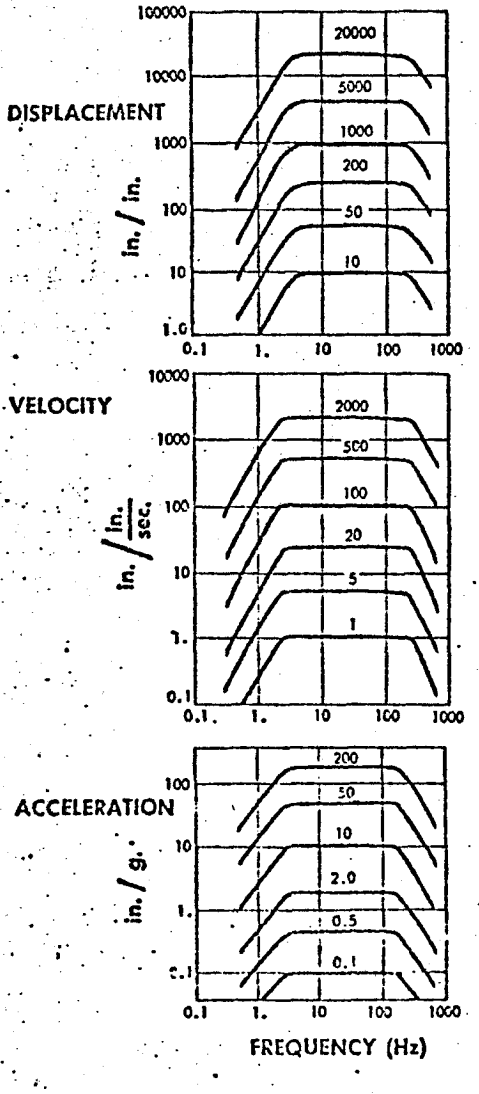
- **High Gain TRI-MODE Seismograph**
  - Displacement to 20,000 in./in.
  - Velocity to 2000 in./in./sec.
  - Acceleration to 200 in./g.
- **Shallow Refraction System**
  - Hammer or Charges
- **Fourth Channel Options**
  - Sound Pressure Level
  - Direct Energy Ratio
  - Shear Wave Discriminator
  - Low Gain Trace
  - Auxiliary Sensor
  - Time Break
- **Direct-Write Photographic Recording**
- **Optional 1v Outputs for Tape Recording**



SPRENGNETHER ENGINEERING AND RESEARCH SEISMOGRAPH VS-1200

RESPONSE CHARACTERISTICS



The new VS-1200 ENGINEERING AND RESEARCH SEISMOGRAPH is the most versatile portable seismograph system available. The proven field-worthiness and precision of the VS-1100 unit is expanded to provide a system capable of answering virtually every demand for seismographic instrumentation arising in vibration analysis or geophysical engineering.

Advancements incorporated in the VS-1200 are basically three:

An increase in sensitivity of 100X over the VS-1100 with attendant wider application capability such as shallow refraction surveys.

The TRI-MODE feature of 2-200 hz. flat response to Displacement, Velocity, or Acceleration, selectable by switch.

A wide range of optional data presentations for the fourth channel including a new Sound Level Sensor. Energy Ratio and Shear Wave Discriminator modules are being developed as additional options.

HIGH SENSITIVITY VS-1200

Increased sensitivity in the VS-1200 results in a 3-component seismograph which can be operated at its highest sensitivity only in very quiet areas. This results in the capability to use the highest possible sensitivity level at any given site. Magnification at a velocity sensitivity of 2000 will be some 20,000 at 2 hz. which is equivalent to the operating characteristic of many observatory grade instruments. Thus, vibration studies can be conducted far below the perceptibility threshold level.

An immediate application of such increased sensitivity lies in the addition of shallow refraction capabilities to the system. In addition to the capability of conducting point by point surveys with the standard 3-component sensor, another system is offered. To effect a convenient refraction system, an accessory refraction cable is offered which connects to the

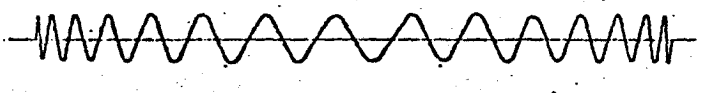
recorder unit in place of the standard seismometer cable. Outputs from three vertical geophones are thus displayed on the records in place of the usual L,V,T traces. The fourth trace presents the source time from a single geophone at the impact or shot position. This source geophone and cable is also available as a VS-1200 accessory. The direct-write mode of recording is particularly advantageous in field monitoring of results and modification of survey procedures.

TRI-MODE VS-1200

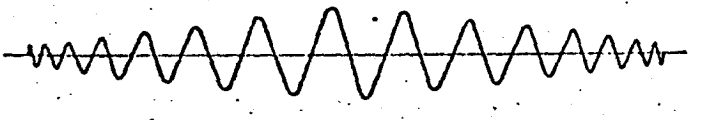
Perhaps the greatest advancement presented by the VS-1200 lies in the TRI-MODE feature of selectable response characteristics, flat to Displacement, Velocity, or Acceleration at high gain levels. Maximum sensitivities of 20,000 in./in., 2000 in./in./sec., and 200 in./g, are available, with an attendant range of 5 additional lower gains in each mode.

For the wide variation of energy levels and frequency content encountered in the signals considered by the general field of structural and ground vibration measurement, a need has long existed for a wide-band, multiple sensitivity, multiple response detector. In some states building vibration safety codes are written in terms of maximum permissible ground displacement in various frequency ranges, while in others the specification is in terms of ground velocity as recommended by the U.S.Bureau of Mines (R.I. 5968). The building codes for these same states may, however, require design for a specified value of ground acceleration. The study of normal modes of structural vibration, on the other hand, generally involves the measurement of building displacement at various levels. Identification and study of wave types (compressional, shear, surface, air) rely heavily on particle motion diagrams constructed from displacement seismograms. The frequency band of interest in these applications ranges from less than 1 cycle per second to hundreds of cycles per second. Consequently, this wide variety of requirements in vibration studies may necessitate that any one or combination of displacement velocity, or acceleration be determined over a wide frequency spectrum.

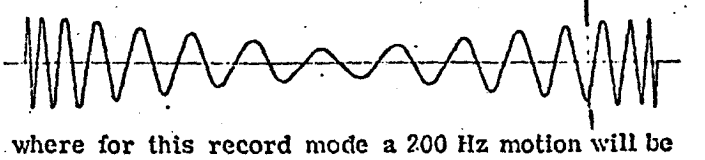
The same motion recorded in the three different modes will produce strikingly different records. Small displacements at high frequency will yield the same acceleration as a larger displacement-lower frequency combination. Or, in other words, a constant displacement will produce a velocity proportional to frequency and an acceleration proportional to frequency squared. Consider the case of a constant maximum particle velocity ground motion spanning some range of frequencies. The seismogram from a Velocity Seismograph would resemble:



A Displacement Seismograph would yield a seismogram of the same ground motion as:



where, for example, a 2 Hz component of motion will be 100 times as large as the 200 Hz component. An Accelerometer would write the motion as:



where for this record mode a 200 Hz motion will be 100 times as large as the 2 Hz motion.

With the TRI-MODE one has the capacity to select at will any of these three modes of measurement simply by turning a switch. The acceleration mode is most often used in building design and machinery vibration types of problems where specification of the value of the acceleration is required. The velocity mode has been associated with structural vibration damage criteria while displacement measurement enters into structural normal mode analysis, blasting monitoring, and investigations that requires particle motion diagrams.

FOURTH CHANNEL VS-1200

Several options are available for utilizing the fourth trace in the VS-1200. The conventional inputs as offered on the VS-1100, where either an external signal or an external contact closure will activate the fourth galvanometer, are available at the input terminals on the VS-1200 control panel.

A low frequency sound level transducer is offered as a new accessory input device for this auxiliary channel. This sensor provides 2.0 mm. of trace displacement at the 100 db. acoustic level and 20.0 mm. of deflection at the 120 db. level.

Two new special function modules, internal to the recorder unit, are being developed for the VS-1200 fourth channel. Energy Ratio (Crandell, F.J., Journ. Boston Soc. Civil Eng., 1949, pp. 222-245) will be presented directly as a continuous function of time throughout the record interval by this module. Perhaps even more valuable, especially in the case where in situ estimates of the elastic moduli are being based on shear velocities, is the option of presenting the product L x V. This product is an excellent discriminate between compressional and shear motion (G.H. Sutton and P.W. Pomeroy, Journ. of Geoph. Res., Vol. 68, n. 9, 1963, pp. 2791-2815) and can be of great value in studies relying on positive identification of S wave motions.

GENERAL FEATURES

The VS-1200, like the VS-1100, is a completely self-contained and portable system. Operation is from an internal, rechargeable battery with 3 hours capacity at continuous run. The three-component seismometer is in a separate 7 inch cube for remote emplacement. For refraction work, two light weight cables are furnished and they connect to the existing panel connections. Several accessories using the fourth trace option are available. Also available optionally are 1 volt outputs for driving auxiliary tape recorders, alarms, etc.

Start time in recording is virtually instantaneous, and a remote starting connection is provided. The camera accepts standard (for archival quality records) or direct

write (for immediate inspection) 70 mm. photographic paper. The supply magazine is capable of holding 200 feet of paper while the take-up magazine is light-tight for field removal of records if desired. The automatic calibration feature at instrument turn-on of the VS-1100 has been retrained and cal-pulse shape defines the mode of operation or well as sensitivity setting. Timing lines are standard at .02 sec. with a paper speed of 100 mm/sec. For refraction applications, the camera speed is readily changed to 400 mm./sec. with .005 sec. timing line separation.

The versatility of the VS-1200 ENGINEERING AND RESEARCH SEISMOGRAPH is unsurpassed. From precision research projects relying on accurate particle trajectory definition to destructive g value measurements lies a nearly unlimited range of applications for this instrument. In this small, portable, self-contained instrument lies the capability to deal with virtually every seismographic problem in Engineering Seismology.

SPECIFICATIONS

SYSTEM

Frequency Response:	Flat (3db) 1.8 Hz to 250 Hz
Sensitivities:	
Displacement: . . .	10,50,200,1000,5000,20000 inch/inch
Velocity:	1,5,20,100,500,2000 inch/inch/sec
Acceleration: . . .	0.1,0.5,2,10,50,200 inch/g
Fourth Channel: . .	Voltage Sensitivity of 30mv/inch
Calibration:	Step in acceleration (33 ma in calibrate coils) automatically applied 1 second after start of recording or can be applied manually at any time

PHYSICAL

	Seismometer	Camera Case
Size:	7x7x7 inches	9x11x13 inches
Weight:	19.5 lbs	33 lbs
Density:	1.6 gm/cc	

SEISMOMETER

Three Orthogonal Components with Identical Characteristics

Natural Frequency: .	2 Hz
Inertial Mass:	0.5 kg
Range of Motion: . . .	6 mm peak-to-peak
Signal Coils:	300 ohms-45 volts/m/sec
Damping:	0.6 critical
Calibration Coil: . .	0.44 newtons/ampere
Temp. Range Between Stops: . .	-20°F to 140° F

CAMERA

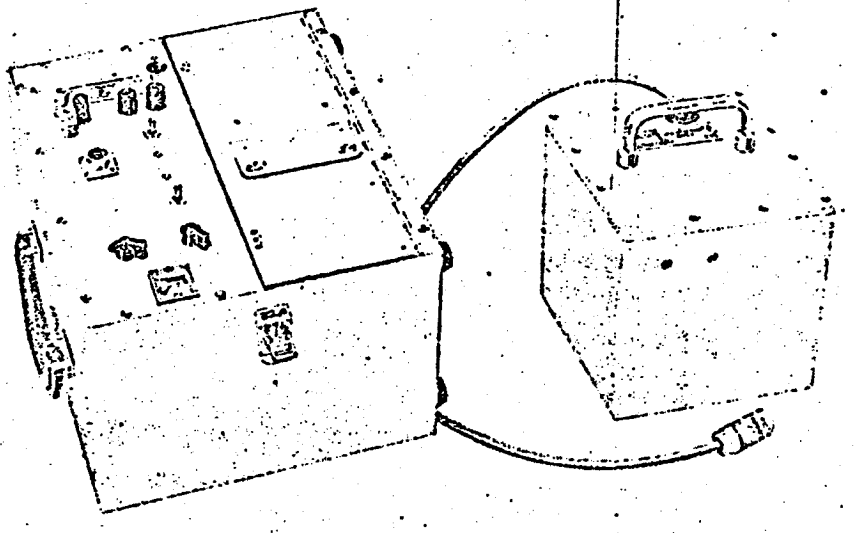
Paper:	70mm (2.75") standard photographic or direct write in up to 200 ft rolls
Paper Speed:	100 mm/sec (Approx 10 minutes recording)
Timing Lines:	Standard - Each 0.02 sec
Galvanometer: . . .	200 Hz
Power:	12V DC Internal Battery (Approx 3 hours or 15 rolls (200') continuous recording) Built-in 110V, 60 Hz charging unit

MANUFACTURERS·OF
·SEISMOLOGICAL·GEOPHYSICAL·AND·ENGINEERING·INSTRUMENTS···4567·SWAN·AVE·

W. F. SPRENGNETHER INSTRUMENT CO. INC.

·SAINT·LOUIS·MO·63110·U·S·A·
Telephone: 314-535-1682
Cable: SPRENCO

- *Records Particle Velocity Directly*
- *Uses Either Standard or Direct-write Photographic Paper*
- *High Sensitivity with 4 Gain Ranges*



SPRENGNETHER
ENGINEERING SEISMOGRAPH VS-1100

VS-1100 RESPONSE CHARACTERISTICS

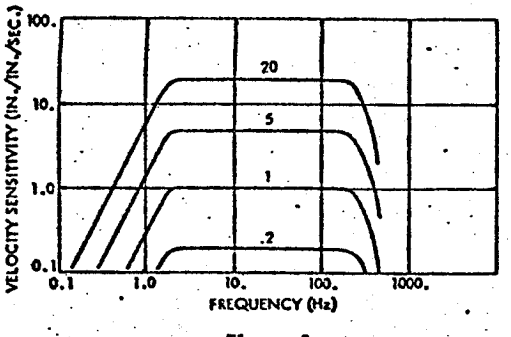


Figure 1

The rapidly expanding application of geophysical techniques to subsurface exploration and surface vibration monitoring in engineering, quarrying and construction projects has led Sprengnether Instrument Company to develop a completely new ENGINEERING SEISMOGRAPH, the VS 1100. This new instrument has been developed by Sprengnether specifically for these modern applications. The major design features of the system are the detector module and high speed camera. The detector consists of three orthogonal ELECTROMAGNETIC TRANSDUCERS contained in a seven inch cube weighing 19.5 pounds (soil-matching density of 1.6 gm/cc). The camera features both standard and direct-write photographic recording in a portable unit operating from a self-contained rechargeable battery with panel mounted footage counter and system voltage level meter.

An outstanding characteristic of the VS-1100 is the flat (3 db) response to ground particle velocity in the 1.8 to 250 Hz vibration ranges (see Figure 1). By virtue of this FLAT VELOCITY SENSITIVITY, the seismograph fulfills a need for a monitoring system in blast and vibration work that directly records particle velocity, the recommended criterion for vibration damage to structures. (U.S. Bureau of Mines, Report of Investigations 5968: Review of Criteria for Estimating Damages to Residences from Blasting Vibrations). Uncertainties in numerical differentiation to obtain ground particle velocity are thus completely eliminated. Particle displacement or acceleration, however, are obtainable from the record by a single numerical integration or differentiation, respectively.

The complete VS-1100 system consists of the Sprengnether three-component short period seismometer as the sensing unit and a compact control unit (33 pounds) containing the new 4 channel constant speed camera using high frequency galvanometers. The seismometer unit, approximately a seven inch cube, is separated from the control unit case for convenience in remote emplacement and to avoid noise generated by the operator. In addition, use of a connector provided on the panel allows

remote starting from any distance. The seismometer unit may be buried if desired and has been designed with the density of an average soil to reduce resonances frequently troublesome in soil emplacements. Because of the wide excursion range of the sensors, only rough leveling by means of a coarse level bubble on the case top is required. The entire system is very rugged -- NO CLAMPING MECHANISMS are necessary in either seismometer or camera. The camera accepts light-tight supply and take-up magazines holding up to 200 feet of 70 mm (2.75") photographic paper (approximately 10 minutes continuous recording). The camera can be loaded in the field using these magazines. DIRECT-WRITING PAPER may also be employed thereby permitting immediate evaluation of results. Paper speed is 100 mm/sec with timing lines impressed at 0.02 second intervals. A high sensitivity fourth trace is available optionally for external event or time marking or another transducer signal such as an air wave device. The system is entirely self-contained, operating from a rechargeable internal battery and built-in charging unit.

VS-1100 RESPONSE CHARACTERISTICS

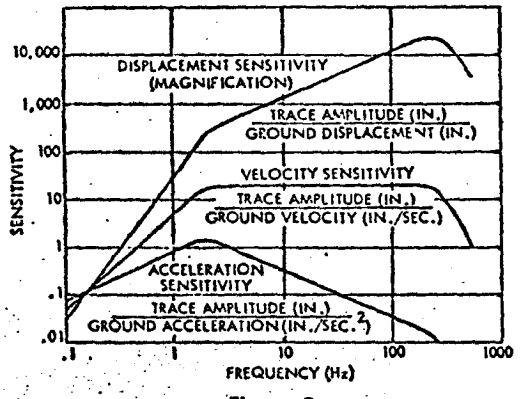


Figure 2

FOUR SENSITIVITY RANGES, selectable by a switch on the control panel, provide from 0.2 to 20 inches record motion per inch/sec ground velocity. With this flat velocity sensitivity the magnification (record motion per inch ground displacement) increases linerarly with frequency. At a velocity sensitivity of 20 in/in/sec, magnification ranges from 250 to 25,000 in the 2 to 200 Hz interval and is 2500 at 20 Hz (see Figure 2). CALIBRATION PULSES are automatically impressed on the record each time the instrument is turned on, thereby identifying the sensitivity setting in use and insuring normal operation (Figure 3). Manual actuation of the calibrate circuitry, as a check, can be accomplished at any time by means of a switch.

VS-1100 CALIBRATION PULSE RECORD

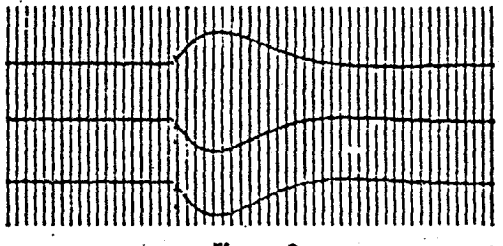


Figure 3

No electronic amplification is used in the standard VS-1100, the battery powering only lights and camera motor drive. Available gain ranges are a result of seismometer and galvanometer basic sensitivities, thus eliminating any concern over variations in gain due to electrical malfunctions or deterioration of amplifier performance.

For applications requiring greater sensitivity, an accessory amplifier module (VS-1100-D) is available which connects in the seismometer cable at the camera. With the amplifier module in use the four sensitivity ranges are increased by exactly a factor of 100.

The VS-1100 can be used in SHALLOW REFRACTION surveying in two ways, depending upon information required. In both techniques, the fourth trace is used for origin time from either hammer or small explosive sources. This may be accomplished using the accessory origin time geophone and cable (VS-1100-F). In one application, where only the conventional first-motion profile is needed, an accessory cable with three vertical geophones (VS-1100-E) replaces the three-component sensor and the three traces present signal arrivals at the three geophone locations in the standard manner. The alternate refraction technique uses the standard VS-1100 sensor and a three component record is produced at each distance. This permits the determination of additional engineering information over that ordinarily obtained from single-component (vertical) refraction method. Information that can be derived from three component recording, in addition to conventional layer depth data, includes SHEAR VELOCITIES of the underlying layers, which together with COMPRESSIONAL VELOCITIES, lead to in-situ estimates of ELASTIC MODULI, POISSON'S RATIO, ROCK RIPPABILITY, SOIL FIRMNESS, etc.

The new VS-1100 is the most versatile engineering seismograph available. New design features yield a light-weight, portable, rugged, self-contained, accurate, three component system which is extremely reliable and simple to operate. The latest concepts in vibration measurement and blasting damage investigation have been incorporated into a wide range of sensitivity and frequency response presented in a direct recording of particle velocity.

SPECIFICATIONS

SYSTEM

Frequency Response:	Flat (3 db) 1.8 Hz to 250 Hz
Sensitivities:	0.2,1,5,20 inch/inch sec
Calibration:	Step in acceleration (33 main calibrate coil) automatically applied approximately 1 sec after start of recording or can be applied manually
Options:	Fourth channel for event marking or auxiliary input signal
Accessories:	X100 amplifier module Refraction cables Air wave detector

SEISMOMETER

Natural Frequency:	2 Hz
Inertial Mass:	0.5 kg
Range of Motion: . . .	6 mm peak-to-peak
Signal Coils:	300 ohms-45 volts/m/sec
Damping:	0.6 critical
Calibration Coil: . . .	0.44 newtons/ampere
Temp. Range Between Stops: . . .	-20° F to 140° F

CAMERA

Paper:	70 mm (2.75") standard photographic or direct writing in up to 200 ft. rolls (Approx. 10 minutes continuous recording)
Timing Lines:	Each 0.02 sec
Galvanometers:	200 Hz
Power:	12 VDC-Internal Battery allowing approx. 3 hours or 15 rolls (200' each) continuous recording. Built-in 110 V 60 Hz charging unit.

PHYSICAL

	Seismometer	Camera Case
Size:	7x7x7 inches	9x11x13 inches
Weight:	19.5 lbs	33 lbs
Density:	1.6 gm/cc	

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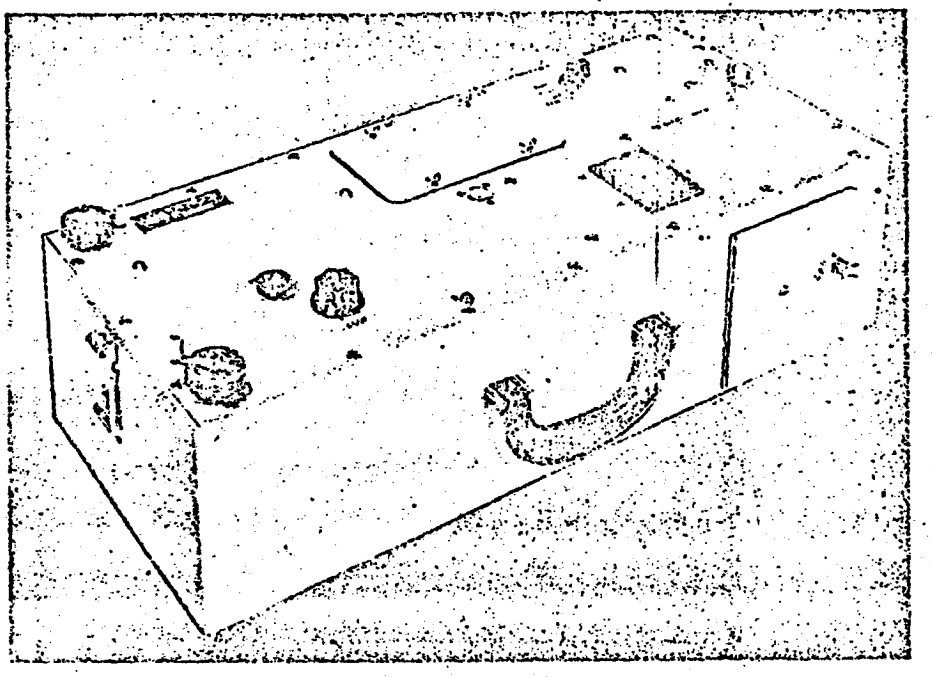
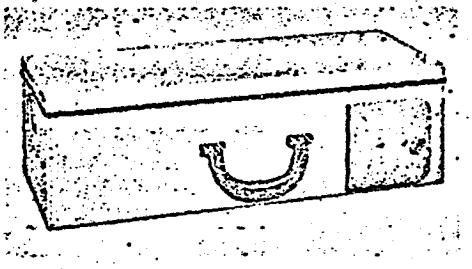


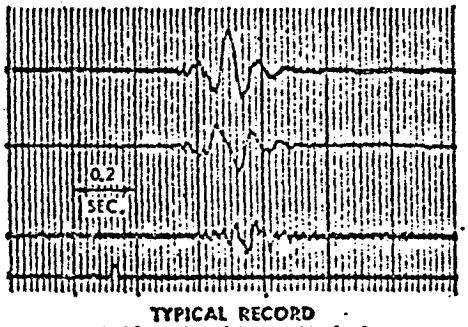
- *Displacement Recording*
- *Uses Either Standard or Direct-write Photographic Paper*
- *Rechargeable Battery*

SPRENGNETHER

PORTABLE BLAST AND VIBRATION SEISMOGRAPH

VS-4000





TYPICAL RECORD
(with optional Event Marker)

The Sprengnether Portable Blast and Vibration Seismograph is a complete, self-contained, three-component seismograph system. It has been specifically designed for recording ground motion caused by blasting and industrial operations, in the frequency range from 1 to 100 cycles per second. Hundreds of these units are in service in various applications requiring precise measurements of ground displacements.

PORTABILITY AND EASE OF OPERATION

The entire seismograph is self-contained in a rigid aluminum case measuring 25 x 10 x 8 inches. The unit weighs only 38 pounds, and requires no external connections of any kind.

The instrument can be set up leveled, and made ready to operate in a few minutes at any reasonably level location, indoors or out. The necessary controls for adjusting and operating the unit are all easily available and plainly marked on the top panel. Only brief instruction is required to teach the operator the use of the equipment.

Tests intentionally subjecting the seismograph to jarring shocks far beyond any that would be encountered in ordinary use have proven the ruggedness and field-worthiness of the design and construction.

SEISMOMETER SYSTEM

The basic seismometer system consists of two inverted pendulums which respond to perpendicular components of the horizontal ground motion, and a spring-supported vertical motion pendulum for recording the vertical motion of the ground. All three components are adjusted to a natural period of 0.75 second.

Eddy current damping is provided by a damping vane, fixed to the pendulum, moving in the field of an Alnico V magnet. Damping on all components is 0.55 critical.

The clamping mechanism, which securely locks the entire assembly when it is not in use, also provides a limiting device during operation, so that excessively large excursions of the pendulum cannot occur.

The motion of the pendulum mass relative to the frame is transmitted to a precision mirror system for recording.

THE RECORDING SYSTEM

Motion of the ground, as detected by the seismometer, is recorded photographically, with all three components appearing on a single strip of photographic paper 2.75 inches (70 mm) wide. Either standard or direct-write photographic paper can be used.

The camera magazine and take-up spool are enclosed in a light-tight container, which, after loading in a darkroom, is simply inserted into the instrument. A number of these cameras can be pre-loaded and carried as spares in the event that it is desired to run a series of records without returning to the darkroom. The camera is driven by a precision electric motor, with a recording speed of about 70 millimeters per second.

The ground motion is magnified by a mechanical-optical lever system by a factor of between 50 and 500. This magnification factor may be specified by the purchaser to suit his particular needs. The most widely used magnification is 50. The recording light spots are visible to the operator just as they appear on the record, through a frosted viewing screen. This feature not only simplifies the procedure for setting up the instrument, but also enables the operator to observe the behavior of the seismometer while a record is being made.

Also available, at extra cost, is a dual magnification system, in which two magnifications, one exactly twice the other, are included. This feature adds further versatility to the instrument by broadening the sensitivity range.

Another option is a fourth trace event marker (see figure on front page of this sheet) for recording external timing or other signals.

THE TIMING SYSTEM

Timing lines are impressed on the record at intervals of 0.02 second, each 0.2 second being accented by a slightly heavier line. The timing precision essential for accurate determinations of ground frequencies is assured by the use of a special chronograph-controlled motor.

POWER REQUIREMENTS

As stated above the freedom from any external power source makes this seismograph especially attractive for portable field use. The simple power requirements are met with a single rechargeable battery enclosed within the instrument. The battery is charged by simply connecting the instrument to the 110v line overnight.

ACCURACY

The seismograph magnification is derived from a precision mechanical-optical system. It is thus not possible for the static magnification to gradually change due to aging or use. Magnification changes due to damage of the system would be readily noticeable. The instruments are accurately calibrated at the factory and the calibration data are furnished to the user.

INTERPRETATION

Since the response of the system is flat above 1.5 cycles per second, simple division of the trace amplitude by the magnification yields ground displacement. See the magnification curve on this sheet. Velocity and acceleration may be obtained by differentiation of the displacement trace.

SPECIFICATIONS

STATIC MAGNIFICATION

50 Standard - up to 500 available

NATURAL PERIOD ..... 0.75 second

DAMPING ..... 0.55 critical

BATTERIES

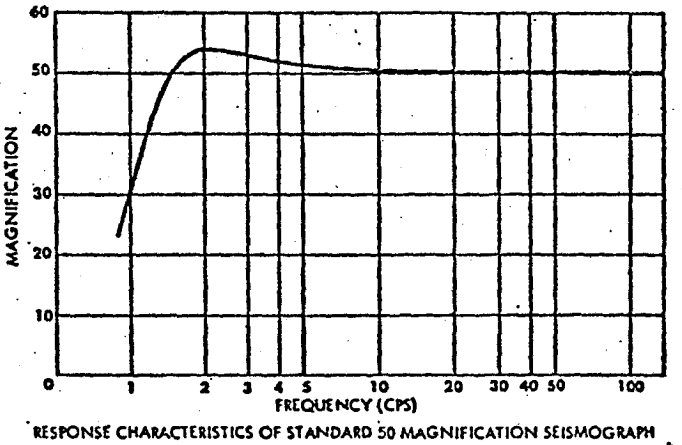
12 volt rechargeable unit and charger contained within instrument

WEIGHT ..... 35 pounds

DIMENSIONS ..... 25 x 10 x 8 inches

OPTIONS

Dual Magnification (VS-4002)
Event Marker Trace



RESPONSE CHARACTERISTICS OF STANDARD 50 MAGNIFICATION SEISMOGRAPH

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