GEONOR A/s

KALIBRERINGSDATA

AV P-100

P.O. BOX 99 RØA
0701 OSLO 7 – NORWAY
TELEPHONE: (02) 24 75 50
TELEX: 77306 genor n
TELEFAX: 24 58 46

KALIBRERING AV JORDTRYKKSMÅLERE

Til kalibreringen blir brukt en vannfylt tank forbundet med en skrukontroll for endring av trykket i tanken. Målerne blir satt ned i åpninger i tanken slik at målerens membran blir utsatt for vanntrykket i tanken. Tetningen mellom hullene i tanken og målerens hus skjer ved hjelp av O-ringer. Trykket i tanken blir målt med et kvikksølv-vannmanometer opp til 2,5 kg/cm^2. Ved større trykk benyttes en konstant trykkcelle hvor trykket kan varieres ved å belaste et stempel i et oljefylt kar med forskjellige vekter. Til måling av målerens frekvenser blir brukt en av GEONOR's standard frekvensmålere for svingende streng.

Kalibreringen ble utført på følgende måte:

(a) Trykket i kalibreringstanken ble økt fra 0 kg/cm^2 til det maksimale trykk som måleren er beregnet for og så redusert til 0 kg/cm^2 igjen Denne belastning og avlastning gjentas 10 ganger.

(b) Umiddelbart deretter blir trykket økt til målerens maksimale trykk og strengfrekvensen avleses ved passende trykkintervaller. Målinger foretas også under avlastningen. Denne serie av avlesninger av trykk og frekvens danner kalibreringsdataene for måleren.

I de følgende tabeller er gitt alle nødvendige kalibreringsdata for hver måler.

Målerne identifiseres ved hjelp av et nummer som er preget langs membranets kant. Målernummeret er identisk med det nummer som følger uttrykket GAUGE NR i overskriften på kalibreringsarket.

BRUK AV KALIBRERINGSDATA

For å nytte de vedlagte kalibreringsdata til å omgjøre et sett målinger fra frekvens til ønsket måleverdi, kan man velge en av følgende tre framgangsmåter:

(a) Man tegner en kalibreringskurve med belastningen P som funksjon av endringen i kvadratet av den svingende strengens frekvens, Δf^2. For de aller fleste målere med svingende streng blir denne kurve en rett linje gjennom origo.

For å bestemme hvilken belastning som svarer til en målt frekvens f, kvadreres denne, og man beregner $\Delta f^2 = f^2 - f_o^2$, hvor f_o er målerens begynnelse eller 0-punktets frekvens, og går inn på kalibreringskurven og finner belastningen som svarer til denne verdi av Δf^2.

(b) En annen metode er at man tegner en kalibreringskurve med belastningen P som funksjon av frekvensen f. Denne kurve vil være en del av en parabel. Er den målte begynnelsesfrekvens f_o forskjellig fra begynnelsesfrekvensen i kalibreringsskjemaet benyttes kalibreringsdataene til å beregne frekvensene ved de oppgitte belastninger i kalibreringsskjemaet, idet verdien av Δf^2 er konstant for en gitt belastning (uavhengig av f_o).

(c) En tredje framgangsmåte er å finne det matematiske uttrykk for den rette linje i første framgangsmåte, d.v.s. at man finner helningen av kurven som man kan kalle en kalibreringsfaktor.

For å bestemme belastningen multipliserer man den beregnede verdi av Δf^2 med kalibreringsfaktoren.

KALIBRERINGSDATAENE REPRESENTERT VED EN LINEÆR LIGNING

Som en illustrasjon på den tredje framgangsmåten beskrevet under BRUK AV KALIBRERINGSDATA, er en lineær ligning beregnet ut fra kalibreringsdataene. Denne ligning er også gitt på kalibreringsskjemaet.

Ligningen som er på formen

$$P = K \cdot f^2/1000$$

altså en rett linje gjennom origo, bestemmes etter minste kvadraters metode. Det er bare kalibreringsdataene for økende P som er brukt. Denne ligning er på kalibreringsskjemaet gitt på formen

P = K * DELTA (F*F)/1000

hvor den beregnede verdi av K er innført i ligningen.

Like under denne ligning er gitt en tabell som viser hvor godt kalibreringsdataene kan representeres ved denne ligning.

I første søyle, P(COMPUTED), er belastningen P beregnet etter den oppførte ligning for hver verdi av Δf^2 i kalibreringen. I den andre søylen (ERROR) er differansen mellom den målte og beregnede belastning oppført. I den tredje og siste søyle er den prosentuelle feil av den maksimale belastning oppført.

Den siste søylen er også et mål for kalibreringskurvens linearitet og altså den feil i prosent av maksimal belastning som kan forventes hvis den lineære ligning benyttes til bestemmelse av belastningen. Om denne ligning bør nyttes eller ikke, kan bare vurderes av brukeren selv.

Nederst til venstre på kalibreringsskjemaet er enhetene for belastningen angitt når frekvensen måles i Hz.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE
for
Transducer type: Earth Pressure Cell
Serial number: 34792

$$P = K(f_0^2 - f^2) + A$$

where:

P = Applied load on transducer in BAR
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1105.0	-0.3176	0.3176	0.64
5.00	1342.1	4.9312	0.0688	0.14
10.00	1539.9	10.0882	-0.0882	-0.18
15.00	1713.3	15.1914	-0.1914	-0.38
20.00	1868.6	20.2237	-0.2237	-0.45
25.00	2010.7	25.2105	-0.2105	-0.42
30.00	2142.2	30.1508	-0.1508	-0.30
35.00	2265.6	35.0714	-0.0714	-0.14
40.00	2381.7	39.9524	0.0476	0.10
45.00	2492.0	44.8156	0.1844	0.37
50.00	2597.7	49.6824	0.3176	0.64
40.00	2383.5	40.0300	-0.0300	-0.06
30.00	2146.0	30.2983	-0.2983	-0.60
20.00	1874.5	20.4234	-0.4234	-0.85
10.00	1547.2	10.2921	-0.2921	-0.58
0.00	1105.0	-0.3176	0.3176	0.64

K = -0.00000904647 = -9.0465E-06
A = -0.31762 = -3.1762E-01
f_0 = 1105.0

Max nonlinearity error.: 0.85% of full range
Project................: 144092
Tag no.................: P-100
Units of P.............: BAR
Calibration date.......: 6/11 1992
Signature..............: TE
Comment.....: Kalibrert v/temp.: 1 gr. C.

GEONOR

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 34892

$$P = K(f_0^2 - f^2) + A$$

where:

- P = Applied load on transducer in BAR
- f = output frequency from transducer measured in Hz
- f_0 = output frequency from transducer with no load

P	f	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1106.0	-0.3237	0.3237	0.65
5.00	1340.5	4.8954	0.1046	0.21
10.00	1537.6	10.0559	-0.0559	-0.11
15.00	1710.7	15.1710	-0.1710	-0.34
20.00	1865.9	20.2207	-0.2207	-0.44
25.00	2007.7	25.2175	-0.2175	-0.44
30.00	2139.0	30.1705	-0.1705	-0.34
35.00	2261.9	35.0909	-0.0909	-0.18
40.00	2377.8	39.9828	0.0172	0.03
45.00	2487.6	44.8426	0.1574	0.31
50.00	2592.2	49.6763	0.3237	0.65
40.00	2378.5	40.0131	-0.0131	-0.03
30.00	2140.5	30.2289	-0.2289	-0.46
20.00	1868.2	20.2988	-0.2988	-0.60
10.00	1535.9	10.0084	-0.0084	-0.02
0.00	1105.0	-0.3438	0.3438	0.69

K = -0.00000909709 = -9.0971E-06
A = -0.32367 = -3.2367E-01
f_0 = 1106.0

Max nonlinearity error.: 0.69% of full range
Project................: 144092
Tag no.................: P-100
Units of P.............: BAR
Calibration date.......: 6/11 1992
Signature..............: TE
Comment.....: Kalibrert v/temp.: 1 gr. C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 34992

$$P = K(f_0^2 - f^2) + A$$

where:

P = Applied load on transducer in BAR
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1061.5	-0.3248	0.3248	0.65
5.00	1299.8	4.8660	0.1340	0.27
10.00	1499.7	10.0284	-0.0284	-0.06
15.00	1674.7	15.1530	-0.1530	-0.31
20.00	1831.3	20.2178	-0.2178	-0.44
25.00	1974.0	25.2270	-0.2270	-0.45
30.00	2105.8	30.1873	-0.1873	-0.37
35.00	2229.0	35.1138	-0.1138	-0.23
40.00	2344.8	39.9997	0.0003	0.00
45.00	2454.5	44.8564	0.1436	0.29
50.00	2558.7	49.6752	0.3248	0.65
40.00	2345.4	40.0257	-0.0257	-0.05
30.00	2108.2	30.2806	-0.2806	-0.56
20.00	1835.0	20.3429	-0.3429	-0.69
10.00	1504.3	10.1559	-0.1559	-0.31
0.00	1061.0	-0.3345	0.3345	0.67

K = -0.00000922481 = -9.2248E-06
A = -0.32476 = -3.2476E-01
f_0 = 1061.5

Max nonlinearity error.: 0.69% of full range
Project................: 144092
Tag no.................: P-100
Units of P.............: BAR
Calibration date.......: 6/11 1992
Signature..............: TE
Comment.....: Kalibrert v/temp.: 1 gr. C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 36792

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1178.0	0.0	0.0000	0.0000	0.00
5.00	1330.9	152.9	5.0161	0.0161	0.03
10.00	1463.5	285.5	9.9577	-0.0423	-0.08
15.00	1584.4	406.4	14.9420	-0.0580	-0.12
20.00	1696.3	518.3	19.9622	-0.0378	-0.08
25.00	1800.9	622.9	25.0088	0.0088	0.02
30.00	1899.0	721.0	30.0523	0.0523	0.10
35.00	1991.0	813.0	35.0555	0.0555	0.11
40.00	2078.2	900.2	40.0418	0.0418	0.08
45.00	2161.2	983.2	45.0086	0.0086	0.02
50.00	2240.0	1062.0	49.9232	-0.0768	-0.15
40.00	2083.5	905.5	40.3525	0.3525	0.70
30.00	1905.0	727.0	30.3706	0.3706	0.74
20.00	1702.0	524.0	20.2284	0.2284	0.46
10.00	1466.2	288.2	10.0640	0.0640	0.13
0.00	1178.0	0.0	0.0000	0.0000	0.00

A = 0.03041779663 = 3.04178E-02
B = 0.00001562228 = 1.56223E-05
f_0 = 1178.0

Max nonlinearity error.: 0.74% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 1/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 36892

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1157.3	0.0	0.0000	0.0000	0.00
5.00	1297.0	139.7	5.0200	0.0200	0.04
10.00	1419.9	262.6	10.0109	0.0109	0.02
15.00	1531.2	373.9	14.9949	-0.0051	-0.01
20.00	1633.8	476.5	19.9801	-0.0199	-0.04
25.00	1730.0	572.7	24.9949	-0.0051	-0.01
30.00	1820.3	663.0	30.0019	0.0019	0.00
35.00	1905.8	748.5	35.0105	0.0105	0.02
40.00	1986.9	829.6	40.0019	0.0019	0.00
45.00	2064.6	907.3	45.0037	0.0037	0.01
50.00	2139.0	981.7	49.9945	-0.0055	-0.01
40.00	1989.1	831.8	40.1405	0.1405	0.28
30.00	1823.4	666.1	30.1790	0.1790	0.36
20.00	1636.3	479.0	20.1063	0.1063	0.21
10.00	1420.2	262.9	10.0238	0.0238	0.05
0.00	1157.5	0.2	0.0067	0.0067	0.01

A = 0.03344655152 = 3.34466E-02
B = 0.00001780579 = 1.78058E-05
f_0 = 1157.3

Max nonlinearity error.: 0.36% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 1/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 36992

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1115.0	0.0	0.0000	0.0000	0.00
5.00	1251.8	136.8	5.0321	0.0321	0.06
10.00	1372.6	257.6	10.0071	0.0071	0.01
15.00	1483.2	368.2	14.9992	-0.0008	-0.00
20.00	1585.6	470.6	19.9938	-0.0062	-0.01
25.00	1681.5	566.5	24.9961	-0.0039	-0.01
30.00	1772.0	657.0	30.0049	0.0049	0.01
35.00	1857.4	742.4	34.9880	-0.0120	-0.02
40.00	1939.1	824.1	39.9884	-0.0116	-0.02
45.00	2017.5	902.5	45.0013	0.0013	0.00
50.00	2092.8	977.8	50.0136	0.0136	0.03
40.00	1942.0	827.0	40.1701	0.1701	0.34
30.00	1774.2	659.2	30.1301	0.1301	0.26
20.00	1589.0	474.0	20.1657	0.1657	0.33
10.00	1374.7	259.7	10.0980	0.0980	0.20
0.00	1116.0	1.0	0.0345	0.0345	0.07

A = 0.03444747180 = 3.44475E-02
B = 0.00001708080 = 1.70808E-05
f_0 = 1115.0

Max nonlinearity error.: 0.34% of full range
Project.................: 150592
Tag no..................: P-105
Units of P..............: Bar
Calibration date.......: 2/12 1992
Signature...............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for

Transducer type: Earth Pressure Cell

Serial number: 37092

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coefficients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1150.6	0.0	0.0000	0.0000	0.00
5.00	1277.4	126.8	4.8858	-0.1142	-0.23
10.00	1397.6	247.0	9.9732	-0.0268	-0.05
15.00	1507.0	356.4	14.9890	-0.0110	-0.02
20.00	1609.2	458.6	20.0068	0.0068	0.01
25.00	1705.5	554.9	25.0284	0.0284	0.06
30.00	1796.6	646.0	30.0408	0.0408	0.08
35.00	1882.8	732.2	35.0184	0.0184	0.04
40.00	1965.5	814.9	40.0082	0.0082	0.02
45.00	2044.6	894.0	44.9774	-0.0226	-0.05
50.00	2121.3	970.7	49.9792	-0.0208	-0.04
40.00	1968.0	817.4	40.1624	0.1624	0.32
30.00	1799.4	648.8	30.1989	0.1989	0.40
20.00	1611.8	461.2	20.1386	0.1386	0.28
10.00	1398.8	248.2	10.0262	0.0262	0.05
0.00	1150.5	-0.1	-0.0037	-0.0037	-0.01

A = 0.03658517636 = 3.65852E-02
B = 0.00001535245 = 1.53525E-05
f_0 = 1150.6

Max nonlinearity error.: 0.40% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 3/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for

Transducer type: Earth Pressure Cell

Serial number: 37192

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1159.7	0.0	0.0000	0.0000	0.00
5.00	1301.6	141.9	4.9979	-0.0021	-0.00
10.00	1427.0	267.3	9.9958	-0.0042	-0.01
15.00	1540.9	381.2	15.0079	0.0079	0.02
20.00	1645.5	485.8	20.0071	0.0071	0.01
25.00	1742.9	583.2	25.0032	0.0032	0.01
30.00	1834.3	674.6	29.9908	-0.0092	-0.02
35.00	1921.1	761.4	34.9956	-0.0044	-0.01
40.00	2003.6	843.9	39.9946	-0.0054	-0.01
45.00	2082.6	922.9	45.0027	0.0027	0.01
50.00	2158.3	998.6	50.0047	0.0047	0.01
40.00	2005.1	845.4	40.0877	0.0877	0.18
30.00	1834.6	674.9	30.0077	0.0077	0.02
20.00	1644.1	484.4	19.9376	-0.0624	-0.12
10.00	1424.5	264.8	9.8908	-0.1092	-0.22
0.00	1159.5	-0.2	-0.0066	-0.0066	-0.01

A = 0.03276079761 = 3.27608E-02
B = 0.00001733828 = 1.73383E-05
f_0 = 1159.7

Max nonlinearity error.: 0.22% of full range
Project...............: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 4/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 37292

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1134.5	0.0	0.0000	0.0000	0.00
5.00	1260.1	125.6	5.1379	0.1379	0.28
10.00	1369.8	235.3	10.0490	0.0490	0.10
15.00	1472.3	337.8	14.9946	-0.0054	-0.01
20.00	1568.9	434.4	19.9711	-0.0289	-0.06
25.00	1660.1	525.6	24.9505	-0.0495	-0.10
30.00	1747.4	612.9	29.9726	-0.0274	-0.05
35.00	1830.8	696.3	35.0040	0.0040	0.01
40.00	1910.1	775.6	39.9997	-0.0003	-0.00
45.00	1986.5	852.0	45.0079	0.0079	0.02
50.00	2060.2	925.7	50.0206	0.0206	0.04
40.00	1913.2	778.7	40.1992	0.1992	0.40
30.00	1751.1	616.6	30.1910	0.1910	0.38
20.00	1572.6	438.1	20.1678	0.1678	0.34
10.00	1372.0	237.5	10.1515	0.1515	0.30
0.00	1134.5	0.0	0.0000	0.0000	0.00

A = 0.03884617551 = 3.88462E-02
B = 0.00001640845 = 1.64085E-05
f_0 = 1134.5

Max nonlinearity error.: 0.40% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 3/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 37392

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1160.0	0.0	0.0000	0.0000	0.00
5.00	1296.2	136.2	5.0770	0.0770	0.15
10.00	1416.1	256.1	10.0450	0.0450	0.09
15.00	1526.1	366.1	15.0136	0.0136	0.03
20.00	1628.4	468.4	19.9870	-0.0130	-0.03
25.00	1724.7	564.7	24.9793	-0.0207	-0.04
30.00	1815.7	655.7	29.9737	-0.0263	-0.05
35.00	1902.2	742.2	34.9704	-0.0296	-0.06
40.00	1985.0	825.0	39.9811	-0.0189	-0.04
45.00	2064.7	904.7	45.0145	0.0145	0.03
50.00	2141.1	981.1	50.0331	0.0331	0.07
40.00	1986.6	826.6	40.0801	0.0801	0.16
30.00	1816.8	656.8	30.0357	0.0357	0.07
20.00	1629.0	469.0	20.0172	0.0172	0.03
10.00	1415.7	255.7	10.0277	0.0277	0.06
0.00	1160.2	0.2	0.0070	0.0070	0.01

A = 0.03506405699 = 3.50641E-02
B = 0.00001623983 = 1.62398E-05
f_0 = 1160.0

Max nonlinearity error.: 0.16% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 4/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for
Transducer type: Earth Pressure Cell
Serial number: 37492

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_o) + B(f - f_o)^2$$

where:

P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_o = output frequency from transducer with no load

P	f	$f - f_o$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1146.0	0.0	0.0000	0.0000	0.00
5.00	1291.5	145.5	4.9904	-0.0096	-0.02
10.00	1420.6	274.6	10.0072	0.0072	0.01
15.00	1537.1	391.1	15.0095	0.0095	0.02
20.00	1644.0	498.0	19.9963	-0.0037	-0.01
25.00	1743.9	597.9	24.9996	-0.0004	-0.00
30.00	1837.6	691.6	29.9937	-0.0063	-0.01
35.00	1926.5	780.5	35.0016	0.0016	0.00
40.00	2011.0	865.0	40.0049	0.0049	0.01
45.00	2091.4	945.4	44.9858	-0.0142	-0.03
50.00	2169.2	1023.2	50.0099	0.0099	0.02
40.00	2013.0	867.0	40.1262	0.1262	0.25
30.00	1839.6	693.6	30.1035	0.1035	0.21
20.00	1645.4	499.4	20.0641	0.0641	0.13
10.00	1419.8	273.8	9.9744	-0.0256	-0.05
0.00	1146.0	0.0	0.0000	0.0000	0.00

A = 0.03188200992 = 3.18820E-02
B = 0.00001660865 = 1.66087E-05
f_o = 1146.0

Max nonlinearity error.: 0.25% of full range
Project...............: 150592
Tag no................: P-105
Units of P.............: Bar
Calibration date.......: 7/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR A/S
P.O.Box 99 Røa, 0701 Oslo 7, Norway
Office: Grinidammen 10, 1343 Eiksmarka
Telephone: 02-24 75 50
Telex: 77306 genor n
Telefax: 02-24 58 46
Bank account: 6233.05.06259
Postal account: 0808 5134176

CALIBRATION CERTIFICATE

for

Transducer type: Earth Pressure Cell

Serial number: 37592

Least square fit of curved line through datasets achieved by recording the changing frequency output from the transducer to find coeffisients A and B in the equation:

$$P = A(f - f_0) + B(f - f_0)^2$$

where:

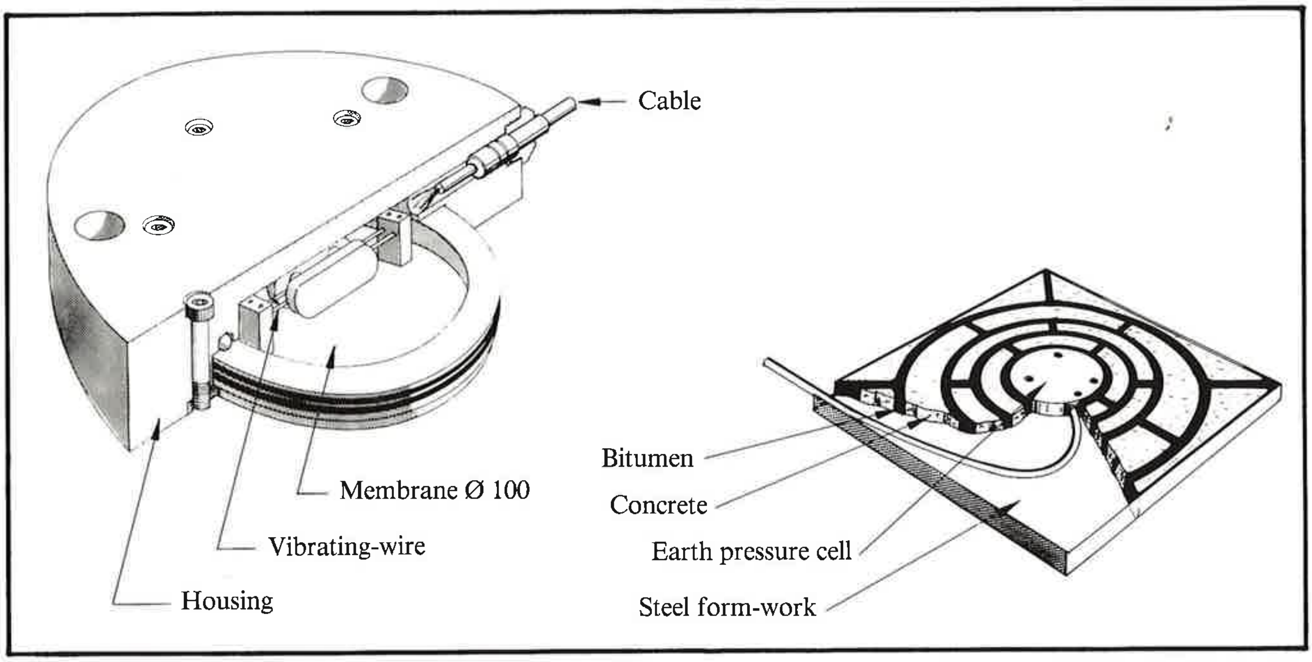
P = Applied load on transducer in Bar
f = output frequency from transducer measured in Hz
f_0 = output frequency from transducer with no load

P	f	$f - f_0$	$P_{computed}$	$P - P_{computed}$	% FR
0.00	1218.0	0.0	0.0000	0.0000	0.00
5.00	1343.5	125.5	5.0446	0.0446	0.09
10.00	1456.6	238.6	10.0043	0.0043	0.01
15.00	1562.1	344.1	14.9842	-0.0158	-0.03
20.00	1661.6	443.6	19.9934	-0.0066	-0.01
25.00	1755.4	537.4	24.9935	-0.0065	-0.01
30.00	1844.6	626.6	29.9986	-0.0014	-0.00
35.00	1929.8	711.8	35.0069	0.0069	0.01
40.00	2011.2	793.2	39.9997	-0.0003	-0.00
45.00	2089.6	871.6	45.0005	0.0005	0.00
50.00	2165.2	947.2	50.0011	0.0011	0.00
40.00	2015.0	797.0	40.2378	0.2378	0.48
30.00	1849.3	631.3	30.2691	0.2691	0.54
20.00	1665.7	447.7	20.2063	0.2063	0.41
10.00	1457.8	239.8	10.0590	0.0590	0.12
0.00	1217.5	-0.5	-0.0191	-0.0191	-0.04

A = 0.03827266515 = 3.82727E-02
B = 0.00001532478 = 1.53248E-05
f_0 = 1218.0

Max nonlinearity error.: 0.54% of full range
Project................: 150592
Tag no.................: P-105
Units of P.............: Bar
Calibration date.......: 8/12 1992
Signature..............: TE
Comment.....: Kalibr.v/temp.: 1 gr.C.

GEONOR P-100/P-105 VIBRATING-WIRE EARTH PRESSURE CELLS



P-105 earth pressure cell.

- **Rugged construction**
- **Long term stability**
- **Stainless steel membranes**
- **Reliable signal transmission (also with long cables)**
- **Inherent redundancy**

GEONOR A/S P.O.Box 99 - RØA - OSLO 7 - NORWAY - TELEPHONE (02) 24 18 97 - OSLO - TELEX: 17306 GENOR

Introduction

The P-100 earth pressure cell was originally developed and used for earth pressure measurements on sheet piles for strutted excavations. The primary requirement was a pressure cell that was robust enough to tolerate moderate pile driving and stable enough to permit long term measurements.

Subsequently the P-100 cell has been used to measure total pressure and/or pore pressure (filter required) acting on sheet piles, retaining walls, foundations, tunnels, and silos as well as stresses in earth dams.

The active membrane diameter of the P-100 cell (7,5 cm) limits the grain size of the soil to 1,5 mm. For larger grain size (e.g. 0–2 mm), earth/rock-fill dams and offshore applications, the P-105 with its active membrane diameter of 100 mm is recommended.

Because of their thickness/diameter ratio (0,28 for P-100 and 0,22 for P-105) the transducers are installed in special steel frames when used in earthfills for earth pressure measurements.

Application

P-100

The P-100 transducer is often used to measure total pressure or pore pressure acting on different kinds of walls.

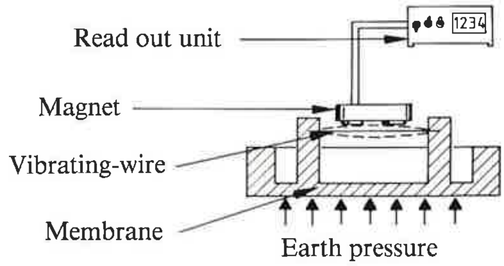
For low pressures, atmospheric pressure may be maintained inside the transducer through the PE tube encasing the lead wires. Normally earth pressure is measured, but snow pressure and pore pressure have also been successfully measured by this equipment.

P-105

The P-105 transducer is widely used in earth/rock-fill dams to measure total earth pressure. The very rugged construction makes it well suited for this purpose. Gauge redundancy has been provided for by installing two independent vibrating wire systems (wire and magnetsystem) inside the transducer. In offshore applications special versions of the P-105 sensor have been installed matching with even stronger demands for long term stability and accuracy. Such transducers are often tailor-made for each specific delivery. The P-105 transducer is not vented to atmosphere, hence variations in atmospheric pressure should not be ignored at low total pressures.

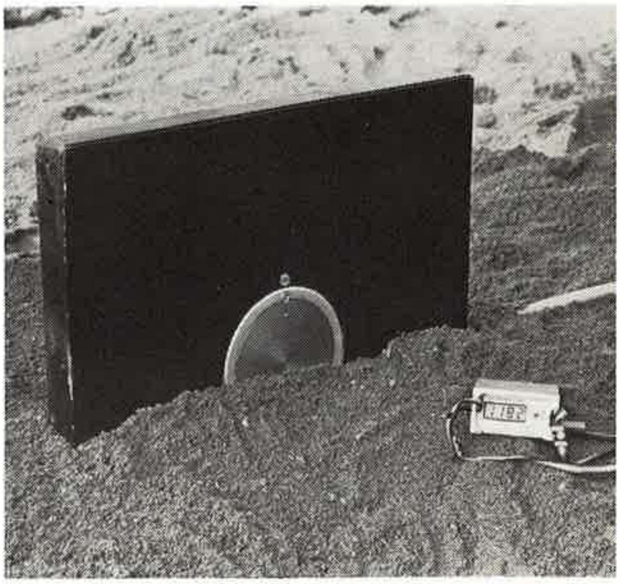
The ratio between the diameter of membrane and the grain size in contact with membrane, should be greater than 50.

Principle of operation



When an external pressure is applied to the membrane, to which the stretched vibrating-wire is rigidly attached, it causes a change in tension in the wire due to the deflection of the membrane posts. This causes a change of stress in the gauge-wire and hence a change in the natural frequency of vibration. Consequently the change in frequency of the gauge-wire vibrations is a measure of the change in external pressure acting on the membrane surface. The frequency signal is transmitted by the electrical cable to a read out instrument.

The change in earth pressure acting on the membrane surface is proportional to the difference of the squared frequency of vibration for the corresponding pressures.

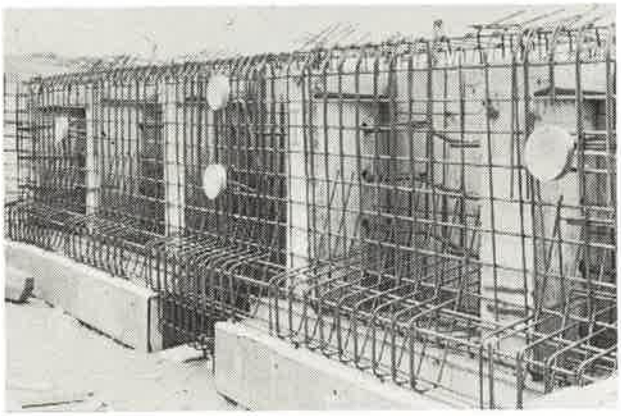


Vertical positioned P-105 cell in dam embankment.

GEONOR A/S P.O.Box 99 - RØA - OSLO 7 - NORWAY - TELEPHONE (02) 24 18 97 - OSLO - TELEX: 17306 GENOR

Installation

The P-100 transducer may be installed in many different ways in retaining walls, sheet piles etc.



P-100 installed in retaining wall prior to concreting.

When ordering, please indicate how the transducers are to be installed.

A special questionaire is also available. Ask for it, fill it out and return it to Geonor for better solutions of your specific problem.

The P-105 transducer may also be installed in retaining walls etc., but is normally installed together with the P-105-1 frame in earth/rockfill dams. The frame is concreted in situ after installation of the transducer in the frame. Fine grade sand is finally packed around the transducer.

Read out instruments

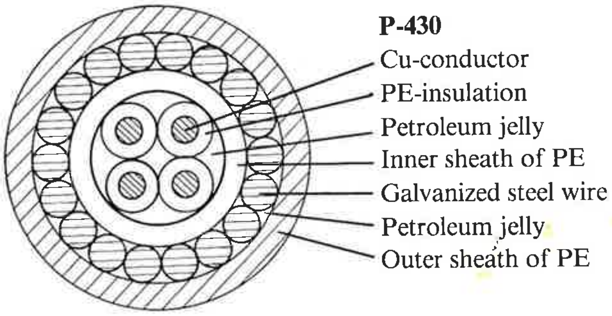
Reading of the P-100 and P-105 transducers may by performed either manually or by automatic recording equipment.

Manually the portable, battery operated frequency indicator P-520F, may be used. This is the general purpose read out unit for all Genonor vibrating-wire transducers. It may be connected directly to the transducer cable or to a switchbox. Automatic read-out can be obtained by means of a micrologger with digital printout of all data in engineering units or by low-cost 2–8 ch printers.

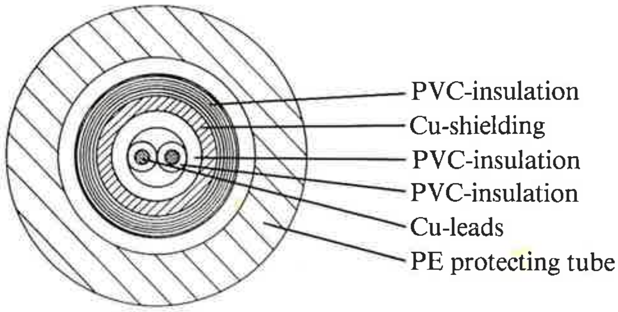
Equipment for transmission of data via a telephone line to the control center and alarm triggering are other options.

Cable

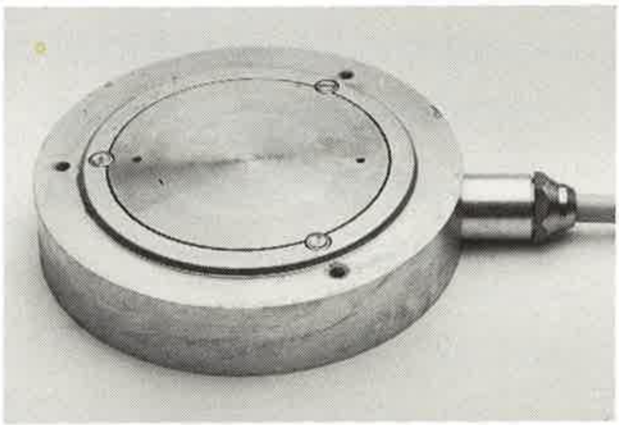
The P-430 cable is specially designed to withstand strong external forces. It is steel armoured and has a thick PE outside insulation. The space between cable cores and also between steel armour wires are filled with petroleum jelly to prevent longitudinal leakages caused by light surface damage to the cable.



An extra protecting PE tube for the P-430 cable (OD 25 × 3 mm) is sometimes used in adverse environments and where large settlements are expected.



The P-540 cable is made of a standard PPOP one pair shielded cable with OD 10 mm PE tubing outside as an extra protection and to maintain atmospheric pressure inside the transducer.



P-105 cell.

Specification

P-100 pressure transducer

Measuring range:	0–30 bar
Linearity and hysteresis:	1% FR or better
Frequency range:	1000 – 2000 Hz
Frequency span:	600 – 1000 Hz
Calibration:	Individual with 10% FR steps
Temperature operating range:	-30°C to +50°C
Material:	SIS 2324 stainless steel
Dimensions:	Ø 165 × 46 mm (standard) Modifications for sheet piles etc.
Thickness/diameter ratio:	0,28
Deflection/diameter ratio:	< 1/2000
Accessories for P-100:	P-100-2 Transducer housing protector for sheet piling P-540 Cable

P-105 pressure transducer

Measuring range:	0–50 bar
Linearity and hysteresis:	1% FR or better
Frequency range:	1000 – 2000 Hz
Frequency span:	600 – 1000 Hz
Calibration:	Individual with 10% FR steps
Temperature:	-30°C to +50°C operating range
Material:	Membrane: SIS 2324 stainless steel. Housing: St 37 ordinary steel, galvanized
Dimensions:	OD 230 × 50 mm
Thickness/diameter ratio:	0,22
Deflection/diameter ratio:	< 1/2000
Accessories for P-105:	P-105-1 frame for embankment installations P-430 Cable P-430-1 Cable with OD 25 mm extra PE tube

Cables

	P-540	P-430
Conductors	1 pair annealed, tinned copper 7 × 0,24 mm. White/blue	Annealed plain, solid copper 0,9 mm 2 pair blue/red/green/black
Shielding	Braided annealed copper	—
Insulation	PVC	PE (Polyethylene)
Armouring	—	15 × 1,6 mm galv. steel wires
Filling	—	Petroleum jelly
Outer diameter (mm)	5 (inside PE tubing)	16
Loop resistance	110 Ω/km	56, 1 Ω/km
Protective tubing	PE tubing, OD 10 mm	No (OD 25 mm PE, optional)

Read out equipment

	P-520F	Micrologger	2–8 ch frequency logger
Power	12 V NiCd 300 mAh 220 V (110 on request)	24 VDC, -6V, (+ 8V option) 255 VAC, ±15V, 50–60 Hz	220 VAC 5 VDC (12, 24 VDC optional)
Battery capacity (before recharging)	20 hours	—	—
Frequency range/display	0–9999 Hz (0–9999,9 Hz optional)	20 char. alphanumeric	0–9999 Hz (0–9999,9 Hz optional)
Temp. range	-10°C — +70°C	0—50°C	0—40°C
Size (w × d × h) in mm	95 × 175 × 50	19'' rack	340 × 250 × 140
Digital printer	—	Olivetti 1800 series Dot matrice	Termoprinter (channel-No + frequency)
Separate leaflets available	Yes	Yes	Yes
Channels	1	32 to 128 in blocks of 32	2, 4, 8

GEONOR A/S P.O.Box 99 - RØA - OSLO 7 - NORWAY - TELEPHONE (02) 24 18 97 - OSLO - TELEX: 17306 GENOR