



INSTRUCTION MANUAL

VIBRATING WIRE SURFACE STRAIN GAUGE

Model SM-5B

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Tel.: 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33.1.64.06.40.80 (France) • 41.91.610.1800 (Switzerland)

www.roctest.com

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1 DESCRIPTION

The SM-5B vibrating wire strain gauge is used to measure surface strains over long periods of time under adverse environmental conditions. The SM-5B strain gauge is intended primarily for long-term measurements on steel structures such as arches, joists and prefabricated tunnel linings. It is also used to monitor strain changes on concrete or rock surfaces using mounting blocks grouted or embedded in the surfaces.

The gauge consists of a length of high strength wire clamped at both extremities into two threaded end pieces. Two hex nuts on each threaded end piece are used to fasten the gauge to anchor blocks. The anchor blocks hold the gauge in place on the structure under study. They are welded, bolted, bonded or mechanically clamped in place. A waterproof removable coil/magnet assembly fits on a construction at the center of the stainless steel tube in which the wire is enclosed. A thermistor is incorporated as a standard feature inside the coil/magnet assembly. Changes in length between the two anchor blocks and gauge temperature are measured with a digital readout.

The initial gauge reading can easily be adjusted by the operator on-site to optimize gauge reading in tension or in compression.

The relevant dimensions of the SM-5B vibrating wire surface strain gauge attached to its mounting blocks are shown in Figure 1.

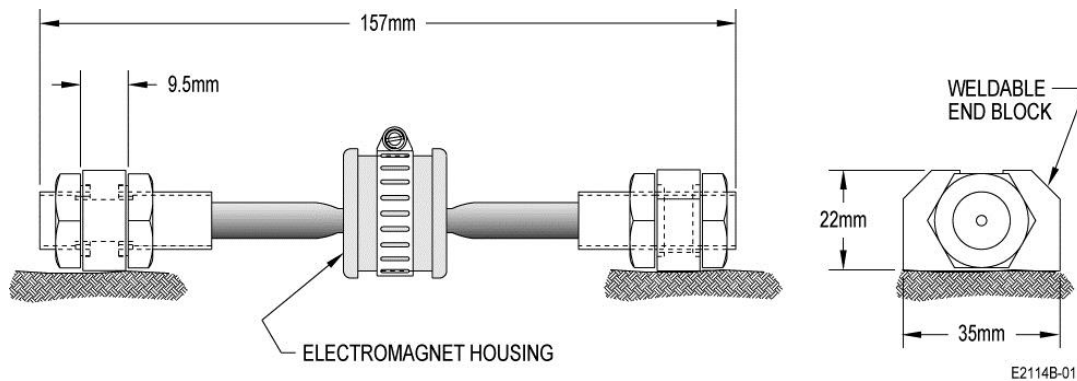


Figure 1: SM-5B vibrating wire strain gauge description and dimensions

To mount the gauge on steel structures, the anchor blocks are set onto the spacer bar (described below), to provide the required spacing before they are welded to the structure. After welding, the spacer bar is removed and replaced by an actual gauge with a separate coil/magnet assembly mounted over the gauge to excite the gauge and measure the response. The wire is tensioned to the required level using the nuts mounted on the threaded end pieces. The mounting blocks can also be bolted to the steel structure or, in rock or concrete structures, grouted into shallow holes.

1.1 STRAIN GAUGE

The nominal strain range of the SM-5B strain gauge is 3,000 microstrains. The wire is attached to the threaded end pieces of the gauge by hydraulic crimping.

Figure 2 is a plot showing a typical strain range of the SM-5B gauge with the NORMAL reading shown plotted against the LINEAR reading.

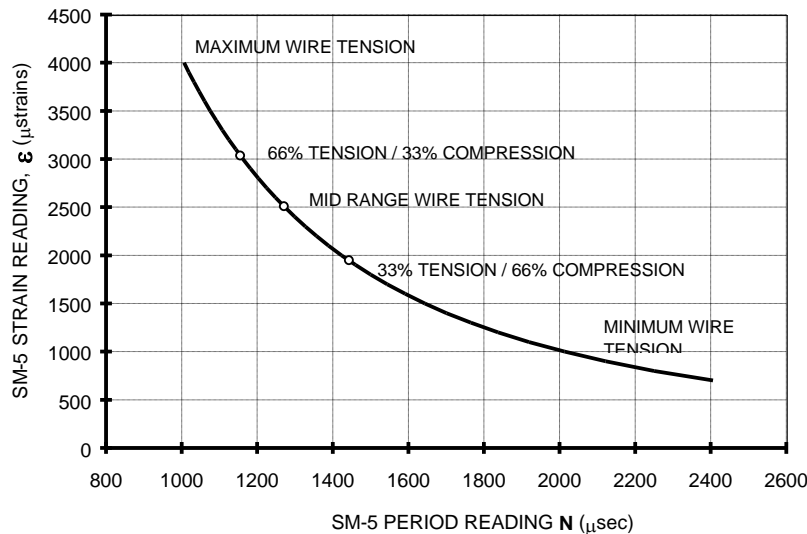


Figure 2: SM-5B strain range vs period

1.2 READINGS

The SM-5B vibrating wire strain gauge can be read with the MB-6T or MB-6TL portable readout units or with the SENSLOG Data Acquisition System.

2 INSTALLATION PROCEDURE

SM-5B gauges are supplied fully sealed with the coil/magnet assembly separate, and with the wire pretensioned. The SM-5B coil/magnet assembly also contains a thermistor which

is read using the MB-6T readout. It is suggested that a preliminary check of both the vibrating wire and the thermistor be carried out to verify the gauge lead cable and readout. Connect the wire leads to the readout box as follows:

IRC-41A Cable	MB-6T Leads
Red	Wire HI
Black	Wire LO
Green	Thermistor HI
White	Thermistor LO
Shield	Shield

A complete description of the readout procedure is contained in the MB-6T or MB-6TL instruction manuals.

In all cases, the gauge should not be operated or checked at values lying outside the range shown in Figure 2.

The initial uninstalled **N** reading of the pretensioned gauges should lie within 1,200 to 1,300 microseconds, which corresponds approximately to the mid-range of the gauge. At the time of installation, the initial setting can be changed to suit the magnitude and direction of the expected change in strain (see Figure 2).

The correct resistance readings between the conductors in the lead cable are:

Leads	Resistance
Black	140 \pm 10 Ω
Red	
Green	3000 Ω at 25°C (77°F) (varies with temperature)
White	

If the correct resistance is not obtained, check for faulty connections or possible damage to the cable. If required, consult Roctest for repair or replacement.

2.1 GAUGE LENGTH ADJUSTMENT

Before fastening the anchor blocks to the structure they must be mounted onto the spacer bar to ensure correct spacing. The two blocks are mounted over the ends of the spacer bar and the locking nuts are set handtight, while holding the anchor blocks against a flat surface to maintain proper alignment as shown in Figure 3.

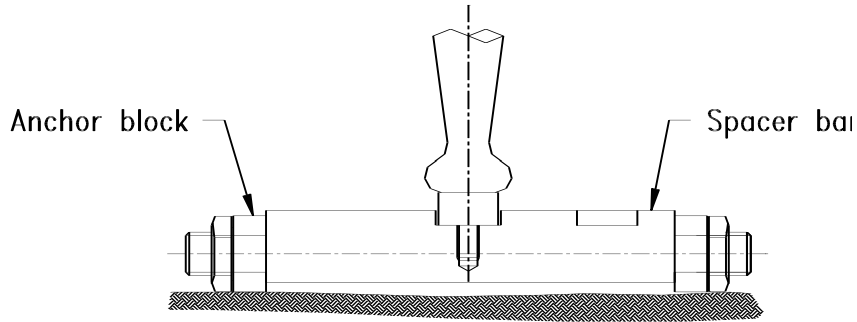


Figure 3: Use of the spacer bar for correct anchor block spacing

2.2 ATTACHMENT OF ANCHOR BLOCKS

The SM-5B gauge is attached to anchor blocks which can be fastened to the surface to be studied by a variety of methods.

2.2.1 WELDING ONTO METAL SURFACE

Welding is the standard technique for mounting the SM-5B gauges. First, install the anchor blocks on the spacer bar as described before. The spacer bar with anchor blocks is then firmly held against the surface to which the blocks are to be welded. First, tack all four (4) edges, avoiding excessive heat. Then, firmly weld in place as in the sequence shown in Figure 4. Tap each block lightly after they are welded in place.

NOTE

Weld only the end block surfaces parallel to the gauge axis. Do not weld the end surfaces of the anchor blocks, as this could prevent the spacer bar from being removed.

Allow the anchor blocks and spacer bar to cool. Then loosen the nuts and lift out the spacer bar.

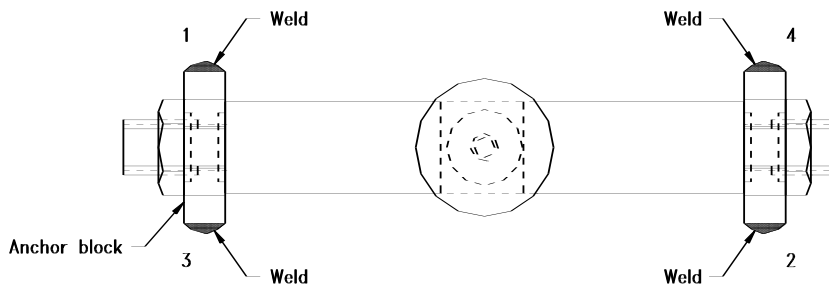


Figure 4: Welding sequence for anchor blocks

2.2.2 BOLTING TO STEELWORKS

Special mounting blocks can be bolted to structural steelworks by single bolts welded onto the mounting blocks and tightened from the underside of the steelworks. Special jigs are supplied to ensure correct hole spacing.

2.2.3 FASTENING TO ROCK OR CONCRETE SURFACES

It is best to place the mounting blocks in the concrete before it sets. Mounting blocks for placement in concrete are equipped with short lengths of reinforcing steel bars. Where this is not possible, such as in rock, shallow holes can be drilled into the rock and the rebar mounting blocks, grouted in the holes using cement or cold setting epoxy resin. To ensure correct spacing, the same jig as described for the welding sequence is used to set the anchors on the spacer bar.

2.2.4 EPOXY BONDING

Under certain circumstances, it may not be feasible to use any of the above mentioned techniques to attach the anchor blocks, in which case bonding may be considered. The gauge puts a maximum 3.2 kg force on the anchors, so bonding using cold setting epoxy resins is a practical technique.

Weldable mounting blocks may be epoxied to any type of surfaces (metallic, concrete, rock, etc.) using the positioning jigs described above to set the mounting blocks correctly. A good bond will be attained only if the surfaces are clean, dry and sound (free of flakes). The anchor blocks must be degreased using acetone (or an equivalent), and sanded to remove the cadmium plating on the lower surface. Weights or clamps may be used to hold the anchor blocks in place until the epoxy has set.

2.3 GAUGE INSTALLATION

The coil/magnet assembly is supplied in two halves that snap into place about the crimped section of the gauge body. The thinner section goes on the underside of the gauge body up against the structure. The thin section must be set under the gauge body before the gauge is slid into final position in the second end block.

1. Clip the 2 parts assembly over the strain gauge. Clamp the two halves together with the hose clamp, and connect it to the readout.
2. After the anchor blocks are mounted in place, the strain gauge is positioned in them by backing off the four threaded end piece nuts to provide the necessary clearance. Flats are cut in the threaded end pieces to prevent them from rotating in the anchor blocks. Tighten one of the threaded end pieces in its anchor block by tightening the two nuts, one on each side of the anchor block. Use Loctite cement to prevent the nuts from loosening.
3. Referring to Figure 5, turn nut 1 to tension the wire to the pre-determined value. In the NORMAL mode, the reading should be between 1,000 and 2,000 μ seconds. The actual initial reading will depend upon whether or not tensile or compressive strains are

to be measured; refer to Figure 2. When in doubt, set the initial reading to mid-range.

- Once the reading has been selected, tighten nut 2 against the mounting bracket. The reading may shift ± 50 units during tightening. The reading can be re-adjusted by re-tightening or slackening nut 2. When both nuts are tight, apply Loctite to prevent loosening.

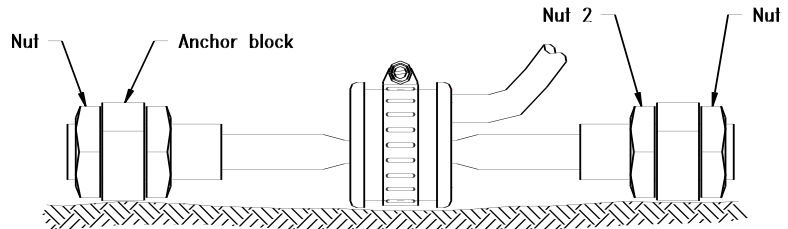


Figure 5: SM-5B installation procedure

2.4 GAUGE AND LEAD WIRE PROTECTION

The amount of protection depends on the type of installation and the environmental conditions. ROCTEST TELEMATICS supplies a variety of accessories for this purpose.

Gauges may be protected by cover plates bolted over the top of the gauge. Studs may be tapped directly into the work surface, or they may be glued, grouted or welded to the surface. The studs go through holes in the cover plate, which is then retained in place by nuts. Studs should not be positioned within 6 inches of the strain gauge, nor should the cover plates be tightened down hard, as this may induce non-uniform strains.

It is usual to run the leads from different gauges to a central measurement station such as the SENSLOG Data Acquisition System, and to connect them to terminal boxes for easy reading. Where required, a conduit should be provided to protect the lead wires, particularly if shotcreting is to be used.

3 MB-6T READINGS

The vibrating wire strain gauge is set to an initial tension during its installation. This initial value must be subtracted from subsequent readings to determine strain change in the surface under study. To read the SM-5B gauge, follow the instructions given in the MB-6T or MB-6TL instruction manuals. The readout displays two readings: the NORMAL mode reading (N value) and the LINEAR mode reading (L value).

3.1 NORMAL READINGS (N)

The change in strain in the surface under study on which the SM-5B is mounted is given by the following formula:

$$\Delta\varepsilon = \varepsilon_1 - \varepsilon_0 = K \times 10^9 \left[\frac{1}{N_1^2} - \frac{1}{N_0^2} \right]$$

where:

$\Delta\varepsilon$	=	strain change in μ strains in the surface under study
K	=	gauge constant = 4.0624
N_0	=	initial reading in NORMAL mode (in μ seconds)
N_1	=	current reading in NORMAL mode (in μ seconds)
ε_1	=	current strain corresponding to N_1
ε_0	=	current strain corresponding to N_0 .

3.2 MB-6T LINEAR READINGS (N)

To determine the strain change in the instrumented structure from **LINEAR** readings, the following equation is applied:

$$\Delta\varepsilon = (L_1 - L_0)$$

where:

$\Delta\varepsilon$	=	strain change in μ strains in the structure
L_0	=	initial reading in LINEAR units
L_1	=	current reading in LINEAR units.

Decreasing L values correspond to a negative $\Delta\varepsilon$ and are equivalent to a contraction of the structure.

4 SPECIFICATIONS

STRAIN RANGE:	3000 μ strain
RESOLUTION:	- Wire: 0.01 μ sec (MB-6T(L)) 0.1 μ strain (MB-6T(L)) 0.1 Hz (PALMETO WW) - Temperature: 0.1°C
OPERATING TEMPERATURE RANGE:	-20°C to +80°C
GAUGE FACTOR:	4.0624
THERMISTOR:	- Type: 3 k Ω (2k Ω optional) - Accuracy: \pm 0.5% F.S.
ELECTRICAL CABLE:	- IRC-41A (standard): 2 twisted shielded pairs 22 AWG, 6.2 mm O.D., PVC jacket - IRC-41AP (optional): identical to IRC-41A except that jacket is polyethylene
ACCESSORIES:	<ul style="list-style-type: none"> • Portable readout units (MB-6T(L), PALMETO VW) • Data acquisition system (SENSLOG) • Setting tools • Terminal and junction boxes • Lightning protection box • Protective cover • Splicing kit

5 MISCELLANEOUS

5.1 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns	Inches	3.94E-05
	Millimeters	Inches	0.0394
	Meters	Feet	3.2808
AREA	Square millimeters	Square inches	0.0016
	Square meters	Square feet	10.7643
VOLUME	Cubic centimeters	Cubic inches	0.06101
	Cubic meters	Cubic feet	35.3357
	Liters	U.S. gallon	0.26420
	Liters	Can-Br gallon	0.21997
MASS	Kilograms	Pounds	2.20459
	Kilograms	Short tons	0.00110
	Kilograms	Long tons	0.00098
FORCE	Newtons	Pounds-force	0.22482
	Newtons	Kilograms-force	0.10197
	Newtons	Kips	0.00023
PRESSURE AND STRESS	Kilopascals	Psi	0.14503
	Bars	Psi	14.4928
	Inches head of water*	Psi	0.03606
	Inches head of Hg	Psi	0.49116
	Pascal	Newton / square meter	1
	Kilopascals	Atmospheres	0.00987
	Kilopascals	Bars	0.01
Kilopascals	Meters head of water*	0.10199	
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32		
	Temp. in °C = (Temp. in °F - 32) / 1.8		

* at 4 °C

E6TabConv-990505

Conversion Factors

5.2 THERMISTOR: TEMPERATURE READING

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
-50		201100	670500	1	6208	9310	31030
-49		187300	670500	2	5900	8851	29500
-48		174500	624300	3	5612	8417	28060
-47		162700	581700	4	5336	8006	26690
-46		151700	542200	5	5080	7618	25400
-45		141600	440800	6	4836	7252	24170
-44		132200	472000	7	4604	6905	23020
-43		123500	411700	8	4384	6576	21920
-42		115400	384800	9	4176	6265	20880
-41		107900	359800	10	3980	5971	19900
-40	67320	101000	336500	11	3794	5692	18970
-39	63000	94480	315000	12	3618	5427	18090
-38	59000	88460	294900	13	3452	5177	17260
-37	55280	82870	276200	14	3292	4939	16470
-36	51800	77660	258900	15	3142	4714	15710
-35	48560	72810	242700	16	3000	4500	15000
-34	45560	68300	227700	17	2864	4297	14330
-33	42760	64090	213600	18	2736	4105	13680
-32	40120	60170	200600	19	2614	3922	13070
-31	37680	56510	188400	20	2498	3748	12500
-30	35400	53100	177000	21	2388	3583	11940
-29	33280	49910	166400	22	2284	3426	11420
-28	31300	46940	156500	23	2184	3277	10920
-27	29440	44160	147200	24	2090	3135	10450
-26	27700	41560	138500	25	2000	3000	10000
-25	26080	39130	130500	26	1915	2872	9574
-24	24580	36860	122900	27	1833	2750	9165
-23	23160	34730	115800	28	1756	2633	8779
-22	21820	32740	109100	29	1682	2523	8410
-21	20580	30870	102900	30	1612	2417	8060
-20	19424	29130	97110	31	1544	2317	7722
-19	18332	27490	91650	32	1481	2221	7402
-18	17308	25950	86500	33	1420	2130	7100
-17	16344	24510	81710	34	1362	2042	6807
-16	15444	23160	77220	35	1306	1959	6532
-15	14596	21890	72960	36	1254	1880	6270
-14	13800	20700	69010	37	1203	1805	6017
-13	13052	19580	65280	38	1155	1733	5777
-12	12352	18520	61770	39	1109	1664	5546
-11	11692	17530	58440	40	1065	1598	5329
-10	11068	16600	55330	41	1024	1535	5116
-9	10484	15720	52440	42	984	1475	4916
-8	9932	14900	49690	43	945	1418	4725
-7	9416	14120	47070	44	909	1363	4543
-6	8928	13390	44630	45	874	1310	4369
-5	8468	12700	42340	46	840	1260	4202
-4	8032	12050	40170	47	808	1212	4042
-3	7624	11440	38130	48	778	1167	3889
-2	7240	10860	36190	49	748	1123	3743
-1	6876	10310	34370	50	720	1081	3603
0	6532	9796	32660	51	694	1040	3469

Temperature reading (Continued)

Temp. °C	Reading in Ohms			Temp. °C	Reading in Ohms		
	With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor		With a 2K Thermistor	With a 3K Thermistor	With a 10K Thermistor
52	668	1002	3340	102	128	192.2	640.3
53	643	965.0	3217	103	125	186.8	622.1
54	620	929.6	3099	104	121	181.5	604.4
55	597	895.8	2986	105	118	176.4	587.5
56	576	863.3	2878	106	114	171.4	571.0
57	555	832.2	2774	107	111	166.7	555.1
58	535	802.3	2675	108	108	162.0	540.0
59	516	773.7	2580	109	105	157.6	524.9
60	498	746.3	2488	110	102	153.2	510.7
61	480	719.9	2400	111	99	149.0	496.4
62	463	694.7	2316	112	97	145.0	483.1
63	447	670.4	2235	113	94	141.1	469.8
64	432	647.1	2157	114	91	137.2	457.4
65	416	624.7	2083	115	89	133.6	444.9
66	402	603.3	2011	116	87	130.0	433.4
67	388	582.6	1942	117	84	126.5	421.8
68	375	562.8	1876	118	82	123.2	410.7
69	363	543.7	1813	119	80	119.9	399.6
70	350	525.4	1752	120	78	116.8	389.4
71	339	507.8	1693	121	76	113.8	379.2
72	327	490.9	1636	122	74	110.8	369.4
73	316	474.7	1582	123	72	107.9	360.1
74	306	459.0	1530	124	70	105.2	350.8
75	296	444.0	1479	125	68	102.5	341.9
76	286	429.5	1431	126	67	99.9	333.0
77	277	415.6	1385	127	65	97.3	324.6
78	268	402.2	1340	128	63	94.9	316.6
79	260	389.3	1297	129	62	92.5	308.6
80	251	376.9	1255	130	60	90.2	301.1
81	243	364.9	1215	131	59	87.9	293.5
82	236	353.4	1177	132	57	85.7	286.0
83	228	342.2	1140	133	56	83.6	279.3
84	221	331.5	1104	134	54	81.6	272.2
85	214	321.2	1070	135	53	79.6	265.5
86	208	311.3	1036	136	52	77.6	259.3
87	201	301.7	1004	137	51	75.8	253.1
88	195	292.4	973.8	138	49	73.9	246.9
89	189	283.5	944.1	139	48	72.2	241.1
90	183	274.9	915.2	140	47	70.4	235.3
91	178	266.6	887.7	141	46	68.8	229.6
92	172	258.6	861.0	142	45	67.1	224.2
93	167	250.9	835.3	143	44	65.5	218.9
94	162	243.4	810.4	144	43	64.0	214.0
95	157	236.2	786.4	145	42	62.5	208.7
96	153	229.3	763.3	146	41	61.1	203.8
97	148	222.6	741.1	147	40	59.6	199.4
98	144	216.1	719.4	148	39	58.3	194.5
99	140	209.8	698.5	149	38	56.8	190.1
100	136	203.8	678.5	150	37	55.6	185.9
101	132	197.9	659.0				

Temperature reading