KISTLER

measure. analyze. innovate.

Load Washers

for Forces of 7,5 ... 1 200 kN

Type 9001A ... 9071A
9081B, 9091B

1-component force sensor for measuring dynamic and quasi-static forces in z direction.

- Calibrated measuring range 100 % and 10 %
- Linearity incl. hysteresis ≤±0,5 %
- Extremely high rigidity
- Very compact
- Threshold <0,01 N, independent of measuring range
- Degree of protection IP67
- Operating temperature range –196 ... 200 °C
- No aging, unlimited lifetime

F_z

Type 9001A ... 9071A

Type 9081B, 9091B

Description

The force to be measured acts through the cover and base of the tightly welded steel housing on the quartz sensing elements. Quartz yields an electric charge proportional to the mechanical load.

The sensitivity (a material constant of quartz) and therefore the threshold, too, are practically the same for all load washers.
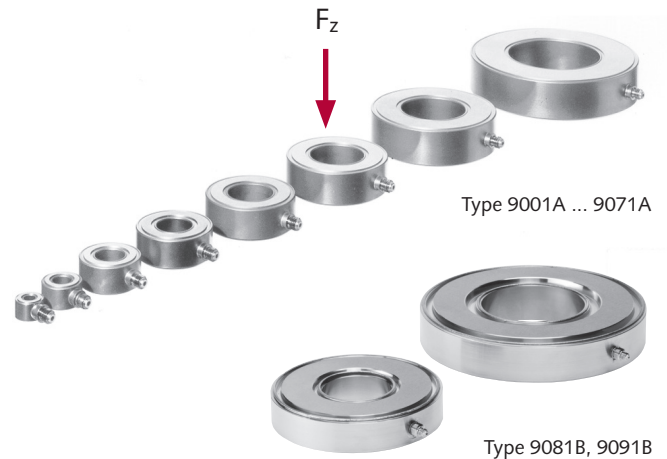
This has three unique advantages:

- Even very small forces can be measured with a sensor having a large range, which assures a high safety against overload
- Similarly a sensor with a large range can be chosen when the highest possible rigidity (small deformation) is required
- Several sensors can be connected electrically in parallel to a single charge amplifier whose output signal corresponds to the sum of all forces acting

Applications

The load washers are very rigid and suitable above all for measuring highly dynamic forces. Their extreme rigidity changes the dynamic behavior of the measuring object into which they are built in very little.

Depending on the magnitude of the force it is possible to measure quasistatically over several minutes or even hours. Zero point stability is substantially determined by charge amplifiers connected downstream. However, genuine static measurements over an infinitely long time are not possible.

Yet a sensor that has been loaded (e. g. inserted in a screwed connection) can, after any period of time, be connected again to a charge amplifier and the disappearance of the force can be measured again precisely.

Dynamic measurements, however (AC-mode, peak-to-peak) can be done for an unlimited period of time. The load washers have a virtually unlimited lifetime.

Application Examples

- Forces in assembly technology
- Forces in spot welding
- Forces in presses
- Force variations in bolted connections under high static pretension
- Shock and fatigue resistance
- Cutting and forming forces
- Forces in railroad brakes
- Impact forces

KISTLER

measure. analyze. innovate.

Technical Data

Type			9001A	9011A	9021A	9031A	9041A	9051A	9061A	9071A
Measuring range	F_z [1]	kN	0 … 7,5	0 … 15	0 … 35	0 … 60	0 … 90	0 … 120	0 … 200	0 … 400
Calibrated ranges	F_z [2]									
100 %		kN	0 … 6	0 … 12	0 … 28	0 … 48	0 … 72	0 … 96	0 … 160	0 … 320
10 %		kN	0 … 0,6	0 … 1,2	0 … 2,8	0 … 4,8	0 … 7,2	0 … 9,6	0 … 16	0 … 32
Overload	F_z [1]	kN	9	18	42	72	108	144	240	480
Max. bending moment	$M_{x,y}$ [3]	N·m	5	15	60	130	240	390	800	2 400
Rigidity	c_z	kN/µm	≈1,1	≈1,6	≈3,4	≈5,4	≈6,9	≈9,8	≈15	≈29
Capacity	C	pF	≈8	≈23	≈37	≈54	≈65	≈64	≈148	≈203
Dimensions										
Internal diameter	d	mm	4,1	6,5	10,5	13	17	21	26,5	40,5
External diameter	D	mm	10,3	14,5	22,5	28,5	34,5	40,5	52,5	75,5
Height	H	mm	6,5	8	10	11	12	13	15	17
Weight		g	3	7	20	36	70	80	157	370

General Data

Sensitivity [1]	pC/N	≈–4				≈–4,3				
Threshold	N					≤0,01				
Operating temperature range	°C					–196 … 200				
Linearity incl. hysteresis [2]	%FSO	≤±1				≤±0,5				
Insulation resistance	Ω					≥1·10^{14}				
Temperature coefficient of sensitivity	%/°C	–0,02								
Natural frequency [4]	kHz	180	150	100	80	65	55	45	30	
Degree of protection EN60529										
with connected cable						IP65				
with cable Type 1983AD… and welded sensor						IP67				

[1]	Without pretension
[2]	With a preload of 20 % of the measuring range
[3]	Pretension F_v = 0,5 · measuring range; F_z = 0
[4]	in a dismounted condition (without pretension) the natural frequency will be reduced due to the installation conditions
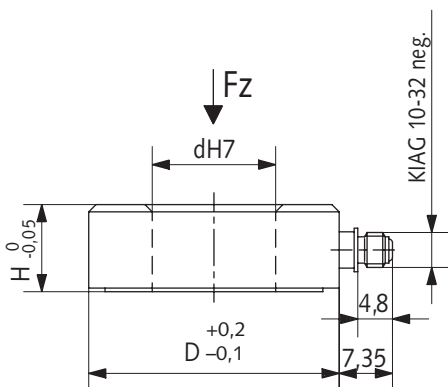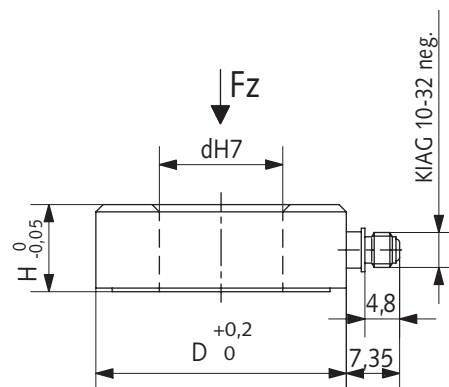

Fig. 1:	Dimensions load washer, Type 9001A ... 9031A

Fig. 2:	Dimensions load washer, Type 9041A ... 9071A

Type			9081B
Measuring range	F_z [1]	kN	0 ... 650
Calibrated ranges	F_z		
100 %		kN	0 ... 650
10 % [5]		kN	0 ... 52
Overload		kN	715
Max. bending moment	$M_{x,y}$ [2]	N·m	4 430
Rigidity	c_z	kN/µm	30
Capacity	C	pF	≈750
Dimensions			
Internal diameter	d	mm	40,5
External diameter	D	mm	100
Height	H	mm	22
Weight		g	910

General Data

Sensitivity [1]	pC/N		≈−2,2
Threshold	N		≤0,02
Operating temperature range	°C	−40 ...200	−40 ...120
Linearity incl. Hysteresis [1] [4]	%FSO		≤±1
Insulation resistance	Ω	≥1·10^13	≥1·10^12
Temperature coefficient of sensitivity	%/°C		−0,02
Natural frequency [3]	kHz	>18	>11
Degree of protection EN60529			IP65
with connected cable			
with cable Type 1983AD…			IP67
and welded sensor			

[1] Without pretension

[2] Pretension $F_v = 0,5 \cdot$ measuring range; $F_z = 0$

[3] in a dismounted condition (without pretension) the natural frequency will be reduced due to the installation conditions

[4] Type 9091B (calibrated range 100 %): linearity only
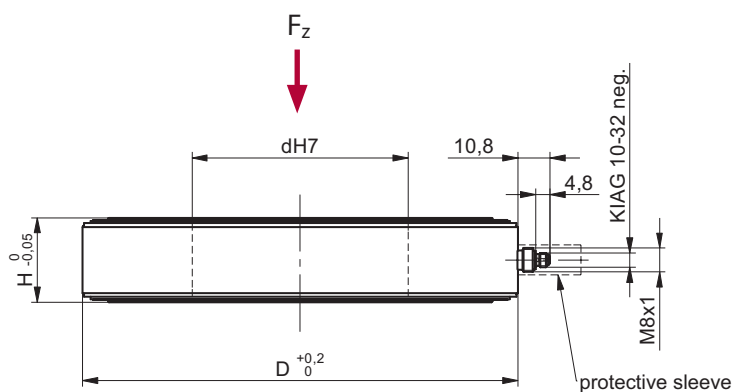
[5] With a preload of 20 % of the measuring range

F_z

Fig. 3: Dimensions load washer, Type 9081B and 9091B

KISTLER

measure. analyze. innovate.

Mounting

The load washers must be installed between two plane-parallel, rigid and fine-machined (preferably ground) faces. This is necessary to achieve a good load distribution on one hand and a wide frequency response on the other hand.
The load washers are always installed under pretension.

The reasons are:
- the sensor is fixed in this way
- measuring compression and tension
- the faces are pressed together which allows to benefit fully of the rigidity of the sensor

Simple Mounting with Mounting Set Type 9422A...
(Included Accessories)

This mounting set is supplied with each sensor of Types 9001A ... 9051A. The sensor can be pretensioned with the pretensioning screw up to 30 % of its range. The centering clip also serve to center the sensor with the screw (Fig. 4 and table).
The pretensioning screw shunts part of the force. Its sensitivity will be about 7 ... 9 % lower.

Important

For pretensioning, the force must always be measured with the sensor itself, using the sensitivity indicated in the technical data. The pretensioning screw always shunts part of the force and therefore the sensor must be calibrated again after installation to determine the final sensitivity of the completed measuring setup.
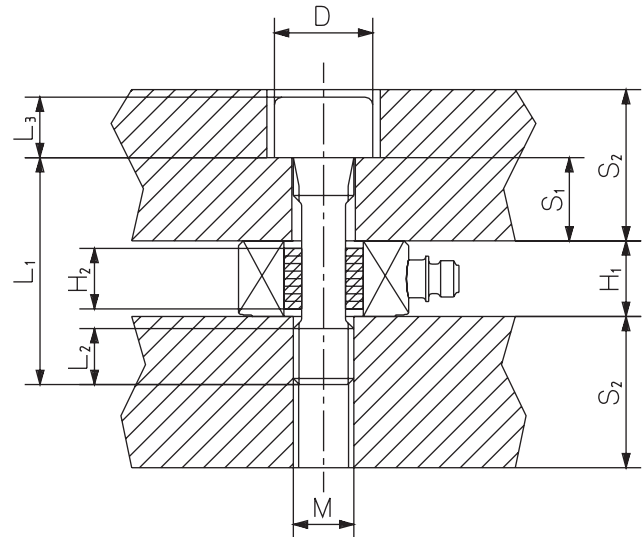

Fig. 4:   Mounting with Type 9422A... (Included Accessories)

Sensor	Mounting Set		Dimensions								Pretension	Force Shunt
Type	Type	M	D	L_1	L_2	L_3	H_1	H_2	S_1	S_2	F_v [kN]	%
9001A	9422A01	M3x0,5	5,5	16	4,2	3,5	6,5	6	3,5	7	≤2,5	≈7
9011A	9422A11	M5x0,8	8,5	20	6,5	6	8	6	4	10	≤5	≈8
9021A	9422A21	M8x1,25	13	30	10	9	10	8	7	16	≤10	≈9
9031A	9422A31	M10x1,5	16	35	12	11	11	8	9	20	≤20	≈9
9041A	9422A41	M12x1,75	18	40	14,3	13	12	8	12	25	≤30	≈9
9051A	9422A51	M14x2	21	45	16,6	15	13	9	15	30	≤40	≈9

9001A_000-105e-05.18

KISTLER

measure. analyze. innovate.

Mounting with Pretensioning Elements Type 9420A…

Sets of special pretensioning elements for sensors Types 9001A ... 9071A are available (Fig. 5). With these pretensioning stud bolts made of high-strength steel, the sensor can be pretensioned up to 50 % of its range. At the same time they assure an optimal force introduction.
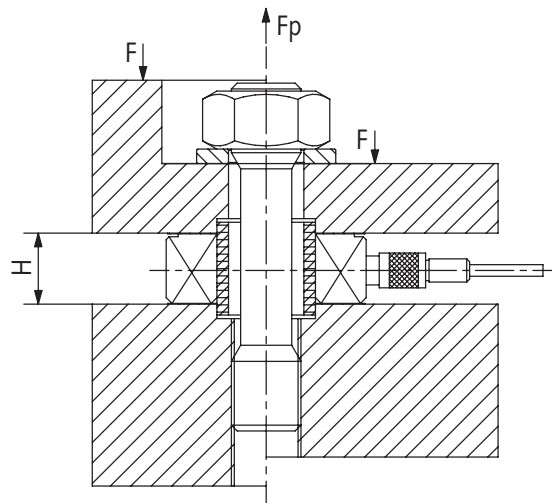
Fig. 5:   Load washer pretensioned with the pretension set Type 9420A01 … 9420A71 (available as accessories, see data sheet set of pretensioning elements for load washers 9420A_000-192)

Mounting with Pretensioning Elements Type 9455/56

With the pretensioning elements Types 9455 and 9456 (available as accessories) sensor Types 9081B and 9091B can pretensioned with a force of up to 400 kN/600 kN. The high pretension forces can only be applied hydraulically. The pretensioning as well as the calibration of the whole force link can be done at the Kistler headquarter in Winterthur, Switzerland if necessary.
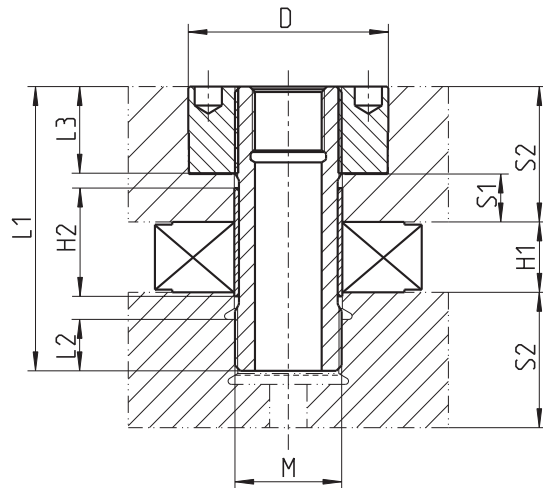
Fig. 6:   Load washer pretensioned with the pretension set Type 9455/56 (available as accessories, see data sheet set of pretensioning elements for load washers 9451A_000-869)

Sensor Type	Mounting Set Type	M	Dimensions								Pretension F_v [kN]	Force Shunt %
			D	L_1	L_2	L_3	H_1	H_2	S_1	S_2		
9081B	9455	M40x2	75	105	20	33	22	40	19	50	≤250	≈9

Force Distributing Ring

Bearing surfaces must be flat and rigid. If they can not be fine machined, local overloads and damage to the sensor surfaces must be prevented by using a force distributing ring (Fig. 7).
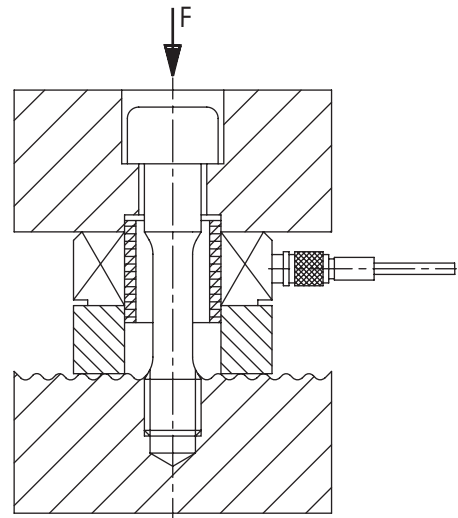

Fig. 7: Mounting with use of a force distributing ring Type 9505 … 9575 (see data sheet mounting accessories for load washers Type 9505_000-193)

Bending Moment

Bending moments may not only have a negative influence on the measurement, but may even lead to destruction of the sensor. However, when the sensor is mounted in a thrust rod or a press punch, it is often impossible to avoid bending moments entirely.

The permissible value for the bending moment M_b is dependent on the sum of the pretensioning force F_v and the current process force F_z applied, in which the maximum possible bending moment $M_{b,max}$ is reached at $F_v + F_z = B/2$.

$$\text{(1a)} \quad M_{b,perm.} \leq \frac{2 \cdot M_{b,max}}{B} \cdot (F_v + F_z) \qquad F_v + F_z \leq B/2$$

$$\text{(1b)} \quad M_{b,perm.} \leq \frac{2 \cdot M_{b,max}}{B} \cdot (B - F_v - F_z) \qquad F_v + F_z \geq B/2$$

In the bending moment graph, the equations (1) limit the range of the permissible bending moment as a function of F_v and F_z.

Maximum Possible Bending Moment

Type	Range limit value B	Max. possible bending moment $M_{b,max.}$
	[kN]	[N·m]
9001A	7,5	5
9011A	15	15
9021A	35	60
9031A	60	130
9041A	90	240
9051A	120	390
9061A	200	800
9071A	400	2 400
9081B	650	4 430
9091B	1 200	13 260

With the table values for B and $M_{b,max}$, the permissible pure bending moment as a function of the pretension force F_v and the process force F_z can be estimated as follows:
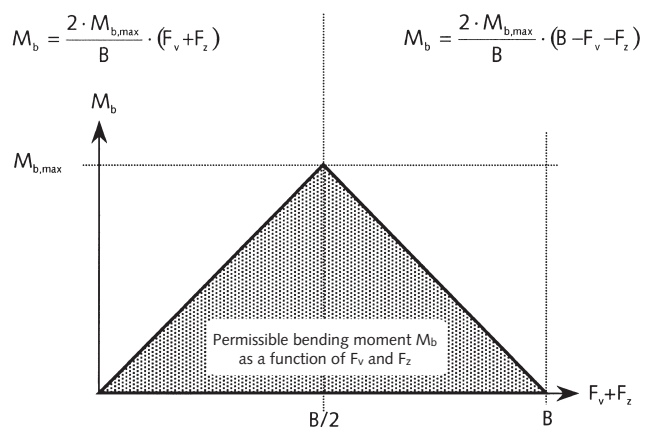
Bending Moment Graph

$$M_b = \frac{2 \cdot M_{b,max}}{B} \cdot (F_v + F_z) \qquad\qquad M_b = \frac{2 \cdot M_{b,max}}{B} \cdot (B - F_v - F_z)$$

Fig. 8: Bending moment graph (pure bending moment)

KISTLER

measure. analyze. innovate.

Attention

If a bending moment $M_b = F_{x,y} \cdot h$ is produced by a lateral force $F_{x,y}$ at a distance h from the reference plane, this will lead to a shear force $F_{x,y}$ in the sensor plane. In this case, the maximum permissible bending moment is lower than the permissible value for a pure bending moment determined using the equations (1).

Example 1

A SlimLine sensor Type 9031A is pretensioned with 18 kN. What bending moment is acceptable for process forces in the range of 0 … 40 kN?

$F_v + F_{z,min} = 18 + 0 = 18$ kN $\leq B/2 \rightarrow$ (1a) $\rightarrow M_b \leq 78$ N·m
$F_v + F_{z,max} = 18 + 40 = 58$ kN $\geq B/2 \rightarrow$ (1b) $\rightarrow M_b \leq 8{,}67$ N·m
The bending moment must not be greater than 8,67 N·m.

Example 2

A SlimLine sensor Type 9051A is pretensioned with 30 kN. How wide is the measuring range with a bending moment of 35 N·m? By resolving (1) according to F_z, we get the equations (2) with which the permissible measuring range for the process force F_z can be calculated as a function of a bending moment.

$$(2a) \quad F_{z,min} \geq \frac{B \cdot M_b}{2 \cdot M_{b,max}} - F_v$$

$$(2b) \quad F_{z,max} \leq B \cdot \left(1 - \frac{M_b}{2 \cdot M_{b,max}}\right) - F_v$$

Inserting the values for B, $M_{b,max}$ and F_v produces the permissible measuring range for F_z

from (2a) –24,6 kN $\leq F_z \leq$ 84,62 kN from (2b).

Attention

Lateral forces $F_{x,y}$ and/or a torque M_z further reduce the measuring range.

When the equations (2a) and (2b) are resolved according to F_v, the minimum pretension force required or the maximum permissible pretension force can be calculated as a function of the other parameters.

Mounting in Force Shunt Mode

The widest variety of measuring problems can be solved with the load washer mounted in force shunt mode. The mounting surface must be flat and be ground as finely as possible. The sensor can be center aligned at both the inner and outer sheaths. For mounting as in Fig. 6, the measuring surface of the sensor and the separation surface of the machine structure must be machined together. In all cases, the sensor must be machined only on one side to a maximum of 0,10 mm. Depending on applications, the sensor is pretensioned from 10 % to 20 % of the measuring range. This is done by placing a steel foil (a few µm thick) on the measuring surface of the sensor (Fig. 6) or by pretensioning with a special nut (Fig. 7).
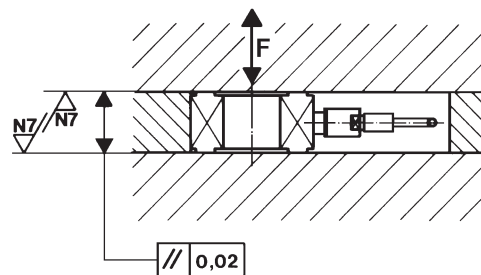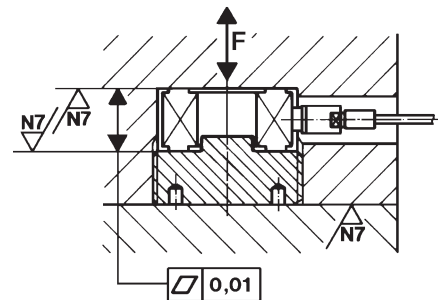

Fig. 9: Mounting for force shunt measuring

Fig. 10: Mounting in force shunt mode

Connection

Only high-insulation coaxial cables with low capacitance producing only very low triboelectricity during movement must be used for connecting piezoelectric sensors. For industrial environments, we recommend using the types listed in the Accessories. For more stringent requirements in a harsh environment, the industrial, integrated cable connector KIAG 10-32 with O-ring is used. If required, the connector can be seal welded to the sensor case.
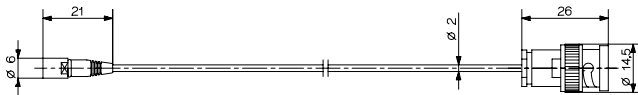
9001A_000-105e-05.18

KISTLER

measure. analyze. innovate.

Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1631C…
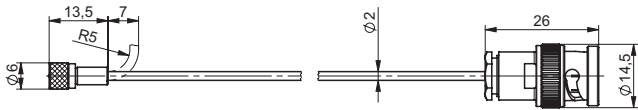
Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1941A…

Connecting Cable for Sensors with KIAG 10-32 neg. Connector Type 1983AD…

Please refer to data sheet 1631C_000-346 for further information on the cables.

Force Links

The load washers Types 9001A ... 9071A are available already mounted and calibrated in the form of force links (see data sheet force links 9301B_000-107). They are ideal for measuring compression and tensile forces (Fig. 11).

Fig. 11:   Force links Type 9301B … 9371B

Connecting Quartz Sensors in Parallel

As all load washers have the same nominal sensitivity, several of them can be connected in parallel to a single charge amplifier. The output signal then corresponds to the sum of all forces acting on the connected sensors.

Sensor Type 90x1B	Connecting Cable Type 1631C…	maXYmos TL Type 5877A...

Sensor Type 90x1B	Connecting Cable Type 1631C…	Charge Amplifier Type 5015A...

Sensor Type 90x1B	Connecting Cable Type 1983AD	Charge Amplifier Type 5073A111

KISTLER

measure. analyze. innovate.

Included Accessories	Type/Art. No.
• Special grease	1063
• Mounting set	9422A…
(metric thread for	
Types 9001A ... 9051A)	
• Connector protection	3.414.366
(Type 9081B/9091B)	

Optional Accessories

• Set of pretensioning elements	9420A...
for load washers (see data sheet	
9420A_000-192) and	
(data sheet 9451A_000-869)	9455...
	9456...

Mounting Accessories

• Force measurement with load washers	
(see data sheet 9001A_000-182)	
• Force distribution ring for load washers	95x5
(see data sheet 9505_000-193)	
• Spherical washer for load washers	95x3
(see data sheet 9505_000-193)	
• Insulating washer for load washers	95x7
(see data sheet 9505_000-193)	
• Force distribution cap for load washers	95x9
(see data sheet 9505_000-193)	

Cables

• Connecting and extension cables:
Data sheet cables for force, torque and
strain sensors (1631C_000-346)

Ordering Key

Type 90 ☐ A

Load Washer

Range 0 … 7,5 kN	01
Range 0 … 15 kN	11
Range 0 … 35 kN	21
Range 0 … 60 kN	31
Range 0 … 90 kN	41
Range 0 … 120 kN	51
Range 0 … 200 kN	61
Range 0 … 400 kN	71

Type 90 ☐ B

Load Washer

Range 0 … 650 kN	81
Range 0 … 1 200 kN	91*

---
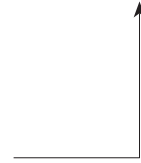
* temporarily not available