INSTRUCTION MANUAL

VANE BORER

Model M-1000

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This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.
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1. DESCRIPTION

The M-1000 vane borer is an instrument for carrying out in-situ shear tests in cohesive soils. The test results appear graphically on a waxed paper disk that constitutes a permanent record. It is simple to use and has a very small relative vane volume displacement.

The instrument is normally mounted on a boring rig for testing at various depths without a drilled hole, or is mounted on the casing of a borehole using an adapter.

2. OPERATING INSTRUCTIONS WHEN USED WITH THE BORING RIG

1. The base-frame of the boring is fastened to the ground with the earth augers. These are screwed down with one of the crank handles of the boring rig, or with a power drill. Note that the base-frame must be sufficiently level to permit subsequent rod plumbing within the adjustment tolerances of the vertical frame.

2. Plumb the vertical frame and tighten the securing bolts.

3. Bolt the base clamp that accepts the torque-recording head to the top of the frame (2 bolts). Insert the instrument head and turn it so that the crank handle is in an unobstructed position. Lock the instrument head in the base clamp.

4. Place a paper disk in the instrument and turn it counter-clockwise once only, to scribe a zero line for visual reference during the testing. Make sure that the instrument's clutch is disengaged and is not gripping a rod, if any is passing through the head.

5. Assemble the vane and the slip coupling on the 80 cm starting rod. Tighten adequately. Hold the assembly under the instrument, thread a 100-cm rod through the head and tighten the 2 rods together. Add another rod to the top of the rod string just assembled.

6. It is important to start the tip sounding with proper rod alignment. Put the vane point against the ground surface so that the axis of the rod is vertical and parallel with the chain when the driving yoke is in its lowest position. If required, a shallow hole may first be dug for the vane. The torque instrument itself, with clutch disengaged, serves as an upper rod guide. After checking for rod plumbness, verify that all rod connections are tightly screwed.

   Note: The vane can sustain quite a heavy load but it is fairly brittle because of the hardening treatment. It must therefore not be subjected to excessive side pressure or crushing pressure. These forces can occur in stony fills, crushed brick layers and similar materials. In such cases a pilot hole should be bored prior to testing.

7. Insert the rod fork in the flats machined-on rods. The rod fork, for convenience, should be placed as high as possible along the rod. Press down the vane carefully until the desired test depth is attained.

   Note: The mobile part of the clutch shall be in its lowest position when driving the rod. When ready to test, push the clutch in its uppermost position and turn it counterclockwise to firmly lock it on the rods.

8. With the vane in position, apply the torque to the vane at a rate that should not exceed 0.1°/s. This generally requires a time to failure of from 2 to 5 min., except in very soft clays where the time to failure may be as much as 10 to 15 min. In stiffer materials, which reach failure at small deformations, it may be desirable to
reduce the rate of angular displacement so that a reasonable determination of the stress-strain property is obtained. Record the maximum torque.

The vane is rotated by using one of the two axles that protrude on the side of the torque instrument. The axle located in the center of the hexagonal brass nut provides a high ratio of vane rotation to crank handle rotation. The other axle mounted at 90 degrees to the high gear ratio provides a low ratio of vane rotation to crank handle rotation. The gear ratio chosen is a matter of convenience. For the most uniform vane rotation, the high gear ratio is used. To engage the high gear ratio, the small gear ratio axle must be pulled outward (about 1 cm). To engage the small gear ratio, push the small gear ratio axle inward.

The charts below shows the rates of crank handle rotation in the high gear ratio vs "a" (radial distance in cm) required to rotate the vane at a rate of .1°/second (6°/minute).

The plots are shown for different rod lengths and take into account the rod twist. To remain within the ASTM D2573 specification, the rate of rotation of the crank handle in the high gear ratio should not exceed those shown.

As a general rule, the following table may serve as a guide for crank handle rotation.

<table>
<thead>
<tr>
<th>Vane Test Depth Meters</th>
<th>High Gear Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ft)</td>
</tr>
<tr>
<td>0 - 10 (32.8)</td>
<td></td>
</tr>
<tr>
<td>11 - 20 (65.6)</td>
<td></td>
</tr>
<tr>
<td>21 - 30 (98.4)</td>
<td></td>
</tr>
</tbody>
</table>

For rates exceeding approximately 3 RPM, it may be convenient to use the low gear with a 30: 1 high: low ratio.

9. After the test, the torque instrument is slowly loosened from the base clamp and the rod-gripping clutch is released. Do not release tension on the rods by cranking the handle counterclockwise. This will damage the equipment. A wrench is then used to rotate the rods and vane clockwise up to twenty times to insure
complete remolding. Immediately afterwards, the rods must be turned counterclockwise about 90 degrees to re-establish the free slip in the coupling. Care must be used not to turn too far counterclockwise to avoid loosening the rod joints. Ordinarily, the slip can be felt; just a few degrees may be sufficient. The end of the slip is usually noted by an abrupt increase in torque.

10. The remolded vane shear test should follow immediately (to avoid thixotropic effects). First, press in the small ratio axle to free the high ratio. Using the small ratio, the crank handle is then rotated with 1 to 2 rpm until the curve gets radial.

**Note:** If the clay's shear strength during this test is so small that the vane cannot provide the reaction for the torque required to turn the slip coupling, corresponding to a torque of approximately 5 kg/cm, one does not obtain the free slip part of the test curve. The remolded strength then corresponds to a torque of less than 5 kg/cm (4.3 in. lb. (0.49 N/m).

11. The axle for the small gear ratio must be pulled out so that the high ratio can be used later, if desired.

12. Screw on the next rod and continue boring. Be sure joint tightness exceeds the torque to be applied later, to avoid joint slipping during a test. If tests have been made in the dry crust, you should pull up the vane and scrape it clean of clay from the dry crust before the vane is pushed down further into softer layers. Otherwise, if you happen to test just at the boundary between a very stiff dry clay crust and very soft underlying clay, the softer clay cannot scrape the vane clean of the much stiffer dry clay.

While pressing the vane down to a greater depth for the next test, one re-establishes the slip angle between the rods and the vane because there is a slight pitch on the vane. The pitch of the vane blades is such that it develops approximately 15° of free slip during a 1-m depth increase. When testing at depth intervals less than 1 m, one should rotate the rod counterclockwise, before pressing from one testing depth to the next, to assure some free slip for the next test. Do not overturn, to avoid loosening rod and vane connections. This procedure can also be followed for test depth intervals of 1 m, thereby obtaining a larger and more certain free slip. The rod fork is used when pushing the vane to greater depth so that the rod does not undergo any rotation, which can remove or reduce the amount of free slip.

13. When the last vane test is finished and the rods and vane are to be withdrawn, the rod-cleaning equipment is fixed to the bottom of the rig. The wheel for depth recording (if in use) is removed first. Then the rubber wiper and its holder are passed over the rod and are held in place on the bottom beam of the rig with the forked end of the holder fastened to the 2 studs on the beam.

14. The rods are then pulled up and uncoupled. For convenience, use a 2-m rod-length by disconnecting each second rod. While pulling up, it is best to hold the rod with a clamp (lifting iron or ball cone clamp) which is fixed above the rig so that the rod does not sink each time one changes grip.

15. The vane and the slip coupling must be cleaned immediately. Make sure that the rubber around the connection has not been damaged. If damaged, it must be replaced (see instructions further on).

16. Oil the connection and the vane and make sure that the vane surfaces are smooth and not warped.

**Note 1:** If a pause is taken while vane sounding, this must be done after a test and not after the vane has been pushed down to the next test depth. During a longer pause, i.e. a night, the rod must be pulled up a few meters before the pause. When the sounding is started again after a pause, the rod must be turned again approximately 10 revolutions and the rod pulled up and down so that the clay around the rod is properly disturbed. A pause taken while boring must be noted in the record. However, it is sometimes desirable to perform tests at the same depth after various rest-time intervals following remolding, in
order to measure strength regain with time (thixotropic) effects. The free-slip feature also permits to take proper account of thixotropic effects along the rods.

**Note 2:** The condition of the slip coupling must occasionally be checked. This is done by fixing the vane in the ground surface and verifying the instrument to measure how great a torque is required to turn the slip coupling. This torque should not be greater than approximately 3 to 5 kg/cm (2.5 to 4.5 in. lbs.).

**Note 3:** When the recording pointer just reaches the cylindrical washer at the center, the vane-boring instrument must not be loaded further. If yielding does not occur in the clay at this load with the smallest vane, an undisturbed test cannot be made using the instrument. Instead, continue to the next test depth. With this sounding equipment, two men can press with a force of approximately 1500 to 2000 kg. The chain's breaking load is 4000 kg. The crank handles of the rig bend at a load corresponding to approximately 1000-kg penetration force per crank handle.

### 3. OPERATING INSTRUCTIONS IN A CASED HOLE

The vane borer can also be used in a drilled hole. The instructions pertaining to its use with the boring rig are slightly different. A casing adapter is used to mount the instrument head.

The vane, the slip coupling and the string of rods are assembled at the collar and lowered to the bottom of the hole. In casing depths greater than about 5 m, guide bushings are placed on the rods to center them inside the casing. They are placed at intervals of 5 - 10 m.

Once the vane and rod assembly reaches the bottom of the hole, the adapter is clamped onto the casing. The length of rod protruding above the casing must be about .6 meters greater than the proposed depth of shear testing below the bottom of the borehole. The chuck on the instrument head is unlocked and the instrument is then threaded over the rod and clamped on the adapter.

The rods are then pushed down with the fork, to the desired position of the vane below the casing bit. The clutch is locked on the rods. The test can be carried out as described in the previous section. In very soft clays, a swivel or rod clamp is used to support the vane-rod assembly during the test.

### 4. INTERPRETATION OF THE VANE BORING CURVE

The waxed paper chart record of a typical undisturbed and subsequent remolded vane shear test is shown below. The distance "a" to a point on the curve from the zero line, in the radial direction, is linearly proportional to the torque M applied to the aboveground end of the vane rod. The linear relationship between radial distance and torque is expressed by a calibration constant K for each instrument, or

\[ M = K \times a \]

Where:
- \( M = \text{torque in kg \cdot m} \)
- \( a = \text{distance from zero torque reference line in cm} \)
- \( K = \text{calibration constant for the torque recording head in kg \cdot m / cm} \)
Results of a vane shear test scribed on the waxed paper chart.

On the curve in the above figure, the torque required to rotate the rods plus the slip coupling corresponds to the torque $M_f$. The torque required to rotate the rods and the vane at yielding corresponds to the maximum moment $M_s$. The difference between $M_s$ and $M_f$ is equal to the torque $M_v$ needed to turn only the vane at yielding. Note that the small torque required to perform the slip is thus conservatively neglected.

The torque $M_f$ must be measured just before the breaking point of the curve, as shown on the figure. This is because the torque required to overcome rod friction sometimes decreases with continued remolding during the free slip angle, and its value at the break point is most representative of the desired value (at $M_s$). Any further decrease, after the break point, is neglected. The importance of such neglect can be checked by another slip-torque test immediately after yielding.

With the remolded test, one does not in certain cases get a distinct difference between $M_f$ and $M_s$. The explanation is that the reaction torque from the remolded clay along the vane is so small that it is not sufficient to move the slip coupling. In other words, this means that the torque required to turn the vane is smaller than the torque needed to turn the slip coupling (3 to 5 kg/cm, 2.5 to 4.5 in. lb.).

The torque required to turn only the vane, $M_v$, is obtained as described. It is then converted to undrained shear strength $s_u$, in kg/cm$^2$ using the following relationships:

\[
M_v = K (a_s - a_f)
\]
\[
S_u = M_v \times C
\]
\[
S_u = K (a_s - a_f) \times C
\]

where

- $M_v =$ the torque required to rotate the vane only in kg $\cdot$ m
- $a_s =$ distance in cm between the zero torque reference line to the peak of the curve
- $a_f =$ distance in cm between the zero torque reference line and the circular arc scribed during the first 15 degrees of rotation (corresponds to rod friction)
- $S_u =$ the undrained shear strength in kg/cm$^2$
- $C =$ vane form constant in $10^{-2} \times cm^3$
- $K =$ calibration constant for the torque recording head in kg $\cdot$m / cm (close to 1 typ.)

The vane constants for the "type 3" vanes are as follows:
The vane constants can be determined from the formulae below.

In the above manner, one can obtain both the undisturbed and remolded shear strengths. Furthermore, the curve shows the strength of the soil immediately after yielding, which is of great importance when evaluating the effects of progressive strain. Also, the shape of the curve after yielding will show the character of the soil.

<table>
<thead>
<tr>
<th>Vane dimensions (cm)</th>
<th>C (10^2 x cm^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 x 11</td>
<td>0.2</td>
</tr>
<tr>
<td>6.5 x 13</td>
<td>0.1</td>
</tr>
<tr>
<td>8 x 17.2</td>
<td>0.05</td>
</tr>
<tr>
<td>10 x 20</td>
<td>0.026</td>
</tr>
</tbody>
</table>

In pure clays, the post-yielding part of the curve will be very smooth but, if there is silt or sand in the clay, this part of the curve will appear rugged.

**Example**

\[
C = 0.05 \times 10^2 \times \text{cm}^3 \quad (8 \times 17.2 \text{ cm vane})
\]

\[
K = 1.1 \text{ kg / m / cm}
\]

\[
a_s - a_f = 5 \text{ cm}
\]

Then:

\[
S_u = K (a_s - a_f) \times C
\]

\[
S_u = 110 \text{ kg / cm / cm (5 cm)} \times (0.05 \times 0.01 \times \text{cm}^3)
\]

\[
S_u = 0.275 \text{ kg / cm}^2 = 27 \text{ kPa}
\]
The slip coupling

Shown on Figure below is a section through the slip coupling.

It is important to keep the rods and vane tightly connected. Otherwise, there will be slippage in these joints and this unwanted behavior will remain undetected.

Cross-sectional view of the slip coupling

When loosening and fastening the vane, the slip coupling must not be gripped so as to damage the needle bearings. The coupling can be gripped as shown in the figure, either above the needle bearing or at the lower part of the coupling. To avoid damaging the surface of the coupling, use a pad with pipe wrenches or similar tools. Any damage should be smoothed with a file. To avoid excess rod torque and help assure that its value is nearly constant with slip, the surface of the coupling must always be kept free from rust and unevenness.

5. INSPECTION AND SERVICE

1. The M-1000 vane borer should be brought in annually for checking and calibration.
2. It is very important to occasionally check the condition of the slip coupling.
3. If the slip coupling is damaged or if too large, a torque (greater than 5 kg.cm or 4.5 in.lb) is required to turn the coupling; it should be sent for repair to the factory.

   In emergency, the repair can be done on site as follows:
   a) The rubber nose must be loosened and the pin approximately in the middle of the slip coupling should be knocked out with a punch.
   b) The connection is taken apart and the needle bearings taken out.
   c) The connection and the needle bearings must be thoroughly cleaned, in kerosene.
   d) The needle bearings must be embedded with waterproof grease and placed in position on the shaft of the coupling. The assembly is then pushed into the cylinder and the pin carefully driven in.
e) If possible, the pin and the coupling are to be sealed with solder. See to it that the temperature during soldering does not get too high.

f) The rubber hose is then cut to length approximately 1/2 inches. Slip the rubber over the tapered end of the coupling. Fasten the upper edge of the rubber sleeve using a double strand of wire to hold it in place. Rotate the free end of the rubber sleeve clockwise and fasten it using the wire. The twist in the rubber sleeve should provide sufficient torque to maintain the lower part of the coupling in a set position and allow 15 degrees of clockwise rotation between the upper and lower sections of the coupling.

![Diagram of rubber sleeve mounting](image)

**Mounting of the rubber sleeve**

### 6. ADDITIONAL NOTES ON THE OPERATION OF THE M-1000 VANE BORER SYSTEM

1. Check that the angle of play of the slip coupling is in the right direction before pressing down the rod for the final half-meter of depth.

2. Check that the rods are securely screwed together. Keep the threads clean.

3. Check that the rod chuck grips. Do not put any grease on the rods.

4. A **Quick Recording Head Diagnostic** can be done as follows:
a) Secure the recording head tightly. If possible use the casing clamp and attach the head to some kind of bench or table.

b) Put a sheath and a rod in the head. Engage the clutch.

c) Apply some torque on the rod and make sure the needle responds.

d) Clamp vice grip pliers on the rod but with little compression. Hold the vice grip tightly and turn the handle on the head. The rod will slide in the vice grip.

e) Increase compression on the vice grip and make sure the needle responds properly.

5. Check the slip coupling before starting in a new hole.

6. If the dry crust is tough, one should at first dig a hole with a spade in order that clay does not stick to the vane. If the vane is not clean, one will normally not get a clear break in the curve. It may sometimes suffice to run the vane up and down a few times in the dry crust.

7. The rod chuck is located at the base of the instrument head. Its purpose is to lock the instrument unto the rods. The following points are important:

f) To lock the rods, turn the chuck slightly, from left to right, while pushing upward. Then turn in the opposite direction until the rods are squeezed tight.

g) To unlock the rods, pull downward on the chuck while turning it from left to right.

h) It is important not to unduly strain the spring.

7. The vane borer is mounted either on a boring rig or on the casing top of a drillhole.

8. For protection, the recording head is delivered with a little piece of cardboard underneath the needle. Keep this cardboard in place when carrying the equipment.

7. VANE BORER EQUIPMENT

**Torque Recorder**
- 1 - instrument head with clutch for rod and guide bushing
- 1 - crank handle
- 1 - Allen key type M4
- 1 - steel transport case

**Torque Recorder Accessories**
- 50 registration charts (waxed paper disc)
- 1 - base clamp

**Standard vanes and slip coupling**
- 1 - 5 x 11 cm
- 1 - 6.5 x 13 cm
- 1 - 8 x 17.2 cm
- 1 - slip coupling

**Boring rig**
- 1 - M-71 standard boring rig (2 ton capacity) or M-70 (1 ton capacity)
- 2 - crank handles
- 4 - earth anchors (extensions for deep anchoring optional)
- 4 - anchor lock plates
- 1 - /rod fork
- Nec. 20.6 mm x 1 meter length rods
- 1 - 20.6 mm x .75 meter length starting rod
- Nec. galvanized steel case for rods
- 2 - rod wrenches
8. PARTS LIST

**M-100 Torque Recorder**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Qty</th>
<th>Part No.</th>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-101</td>
<td>Instrument housing</td>
<td>1</td>
<td>M-138</td>
<td>Screw F6S</td>
<td>4</td>
</tr>
<tr>
<td>M-102</td>
<td>Cover, complete</td>
<td>1</td>
<td>M-139</td>
<td>Indicator</td>
<td>1</td>
</tr>
<tr>
<td>M-103</td>
<td>Glass for cover</td>
<td>1</td>
<td>M-140</td>
<td>Ballbearing</td>
<td>1</td>
</tr>
<tr>
<td>M-104</td>
<td>Fastening screw for cover</td>
<td>2</td>
<td>M-141</td>
<td>Pressure center</td>
<td>1</td>
</tr>
<tr>
<td>M-105</td>
<td>Stainless clutch</td>
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<td>M-142</td>
<td>Instrument crank, compl.</td>
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<td>M-106</td>
<td>Center house</td>
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<td>M-143</td>
<td>Handle for instrument crank</td>
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<tr>
<td>M-107</td>
<td>Center axle</td>
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<td></td>
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<tr>
<td>M-108</td>
<td>Spring activator</td>
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<td>M-144</td>
<td>Instrument case</td>
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<tr>
<td>M-109</td>
<td>Outer distance shim</td>
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<td>M-145</td>
<td>Chuck for instrument, compl.</td>
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<td>M-111</td>
<td>Fastening plate</td>
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<td>M-146</td>
<td>Outer section to chuck</td>
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<tr>
<td></td>
<td>(base clamp)</td>
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<tr>
<td>M-112</td>
<td>Measuring spring</td>
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<td>M-147</td>
<td>Inner section to chuck</td>
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<tr>
<td>M-113</td>
<td>Spring fastening</td>
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<td>Cylinder</td>
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<td>M-114</td>
<td>Spring pin</td>
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<td>M-149</td>
<td>Spring</td>
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<td>M-115</td>
<td>Axle</td>
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<td>M-150</td>
<td>Screw, M4 x 15</td>
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<td>M-116</td>
<td>Wedge</td>
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<td>M-117</td>
<td>Needle bearing</td>
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<td>Registration paper</td>
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<td>M-118</td>
<td>Screw, worm, large</td>
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<td>M-153</td>
<td>Angular slip coupling</td>
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<td>M-119</td>
<td>Worm gear, large</td>
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<td>M-154</td>
<td>Outer section for part 153</td>
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<td>M-120</td>
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<td>Lash wire</td>
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<td>Locking pin</td>
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<td>Sprocket, large</td>
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<td>M-130</td>
<td>Screw</td>
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<td>M-163</td>
<td>Vane, 13 x 6,5 cm</td>
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<td>M-131</td>
<td>Screw</td>
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<td>M-164</td>
<td>Vane, 17,2 x 8 cm</td>
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<td>M-132</td>
<td>Indicator plate</td>
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<td>M-165</td>
<td>Screw, EC6S, M4 x 15</td>
<td>1</td>
</tr>
<tr>
<td>M-133</td>
<td>Screw</td>
<td>3</td>
<td>M-166</td>
<td>Screw, EC6S, M6 x 10</td>
<td>2</td>
</tr>
<tr>
<td>M-134</td>
<td>Ballbearing small</td>
<td>2</td>
<td>M-167</td>
<td>Screw, B6S, M6 x 15</td>
<td>3</td>
</tr>
<tr>
<td>M-135</td>
<td>Indicator axle</td>
<td>1</td>
<td>M-168</td>
<td>Screw, B6S, M6 x 12</td>
<td>3</td>
</tr>
<tr>
<td>M-136</td>
<td>Spring</td>
<td>1</td>
<td>M-169</td>
<td>Locking screw, M3 x 10</td>
<td></td>
</tr>
<tr>
<td>M-137</td>
<td>Support plate for registration</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
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