THE CLOCK BOOK

The Mechanica M3
Precision pendulum clock
Construction and Technology

MECHANICA
by Erwin Sattler

Build your own personal piece of history

Mechanica
by Erwin Sattler
M3

Walnut

Black Laquer
with upgrades

Cherry
with upgrades

Foreword

Dear fellow clockmakers!

I congratulate you on obtaining this outstanding clock kit. I am confident that when you assemble your Mechanica M1 precision pendulum clock you will experience the fascination of a classic technology – clockmaking.

In today's hectic times, which are dominated by computers and electronic technology, more and more people love mechanical clocks. The steady tick and the calming swing of the pendulum give every room a relaxing atmosphere. The fascination of the visible mechanism made me think of the Latin name »Mechanica«.

In recent times, more and more clocklovers have asked Erwin Sattler of Munich for gears, pendulums or cases from its range of clocks. The company has always had to refuse because it will never sell an Erwin Sattler clock as a kit. But I couldn't get the idea of a »doityourself« clock for enthusiasts out of my mind. The famous company Strasser and Rhode, which produced precision clocks at the end of the 19th century, made components available to individual clockmakers.

Erwin Sattler has more than 59 years experience in building precision clocks and in that time has manufactured more than 10.000 clock-movements. The company wants to foster the skills and values of classic clockmaking. In addition, it wants to further develop traditional craftsmanship making use of the new technology available today.

Company »know how«, modern CNC machinery, totally new methodology, and the use of uptodate materials have made this project possible.

The movement of the M1 has of 87 parts and although it has the same technical quality as a Sattler Precison clock, it is designed so that even inexperienced clock enthusiasts can assemble it without difficulty.

Those who want to read more about the principles of pendulum clocks may refer to the second chapter of this book.

Precious clocks can enhance any room and be the pride of every owner; especially, in this case, when he has assembled the clock by himself.

I wish you an enjoyable experience as you assemble and regulate the clock to perform with precision.

A clock of this quality will last hundreds of years and will be passed with pride from generation to generation.

Herzlichst Ihr

Richard Müller

MECHANICA
BY ERWIN SATTLER

M3

Acknowledgments

Many, many, thanks to all who made this project possible:

Production of the entire movement:
Clockmakers, Master Clockmakers, Engineers and Mechanics of Erwin Sattler GmbH & Co.KG

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Responsible for the concept and achievement of the project:

Richard Müller and Stephanie Sattler-Rick

Müller & Sattler Uhrenbausatz GmbH

Price: Euro 25,–

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CHAPTER I

INSTRUCTIONS FOR THE MECHANICA M3

Before you start assembling your Mechanica M1, please read the following information carefully.

Your M3 is a precision pendulum clock. All the parts were produced very accurately to extremely close tolerances. It is necessary therefore to be careful when unpacking, handling and assembling the components to avoid damage. Some of the parts are delicate.

Carrying out the procedures in the order described will save unnecessary work and ensure success.

Upgrade Kits:

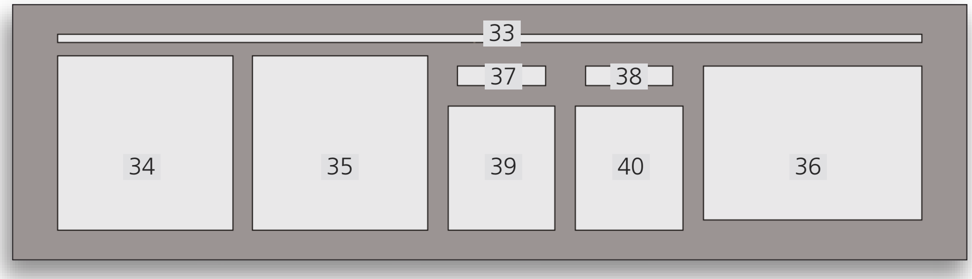
The assembly instructions for the numerous options available are added as variants to the relevant steps and highlighted to make them distinguishable.

You will find a clear list of the accessories currently available for the technical and visual enhancement of your Mechanica M3 at the end of this book on page 124, together with a short description of each one.

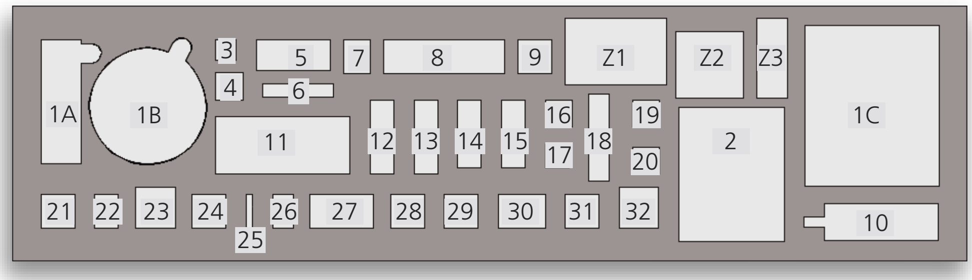
We have tried to avoid using technical terms in this manual. When the use of special terms was unavoidable, we explain them in a glossary at the end of the book. They are marked in the text with an asterisk* .

Your Mechanica M3 assembly kit is clearly divided into three levels and organised using numbered compartments. The corresponding compartment numbers are listed next to the relevant components, tools and aids for clarity. An overview of the compartment numbers in the levels is provided on the pack list and in the figures that follow.

Upper level



Middle level



Lower level

- ☐ case back
- ☐ bottom plate
- ☐ cornice (upper) plate
- ☐ side piece left with magnet
- ☐ side piece right
- ☐ top frieze
- ☐ shelf cover with bottom frieze
- ☐ door complete
- ☐ felt inlay
- ☐ 2 side glasses
- ☐ block for pendulum scale

verified date: ....

Important information before starting

Let's start with the case. The versions which are to have a natural wood finish are first treated with woodcare oil. Make sure the room used has good ventilation. Between uses store the oil-soaked cloth firmly closed in the jar provided. This will prevent potential combustion due to the volatile gases. The treated case takes some time to dry, so you have plenty of time to continue with the next steps.

When assembling the case, handle the glass with care to avoid possible injury.

Choose and prepare your work place carefully before continuing with the assembly of the pendulum and movement. It must be clean at all times and should have good illumination.

We clean and pack the components carefully before despatch. To avoid contamination unpack parts just before assembly. Check for damage in transit.

The ball bearings* are made of stainless steel*. To ensure very low friction they are not sealed bearings and must be kept away from dust and dirt.

For maximum durability the arbors* are made of hardened steel and can corrode. If held with the fingers, the gears, which are gold-plated, should be touched only at the ends of the teeth. Alternatively they can be held with tweezers.

If you drop a wheel, check for damage using the loupe (magnifying glass). Even slight damage to a tooth could stop the gear train from running smoothly. A damaged part must be replaced.

The needle of the oil syringe can cause injury. Keep away from children.

Note also that the sharp tip of the pendulum rod, protected in transport by a brass supply, could also cause injury. The dial and the pendulum scale can be scratched easily so please be particularly careful when handling these parts.

The dial is the face of your M3.

Should you have any problems regarding your precision clock M3 call us from 9am to **4**pm (weekdays) at

Phone +49 (0)89 / 8955 806-20.

Use of the tools

Only the simple tools provided are needed. You will gain confidence by learning to use the tools correctly and there will be less chance of damaging the components.

Note how clockmakers use a screwdriver. The screw is held vertically with tweezers, the end of the screwdriver is placed in the slot or socket, held in position with the index finger and rotated with the thumb and second finger. Be very gentle. Pressure may cause the tool to slip, damaging the surface. Tighten firmly but remember that small screws require little force.

The syringe is used to lubricate the pallets*, the pulley and the pallet arbor pivots*. Avoid over oiling. The gear train* has ball bearings which do not need oil.

For correct lubrication, push the syringe piston carefully until a drop of oil appears at the tip of the needle. Now touch the drop on the place were the oil is required. You will find that there is no need for the needle itself to actually touch. Note that your hand can be rested on something to steady it.

Enjoy the project
and
much success.

If you have chosen the black lacquer case you can begin the assembly immediately.

Tools:

For the natural wood finishes, where surface treatment is required, the following equipment is provided:

• Natural oil	Middle level, compartment 11
• cloth	Middle level, compartment 11
• Steel wool	Middle level, compartment 11

The case parts are in the bottom section of the pack. Locate the following parts for surface treatment:

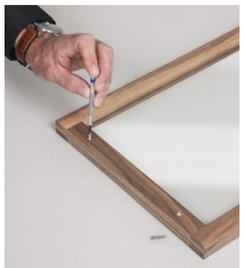
Parts:

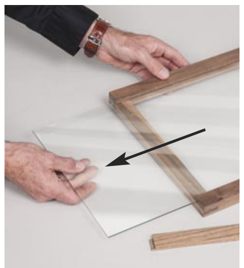
• case-back	Bottom level
• bottom plate	Bottom level
• cornice (upper) plate	Bottom level
• two side pieces	Bottom level
• top frieze	Bottom level
• shelf cover with bottom frieze	Bottom level
• door	Bottom level
• block for the pendulum scale	Bottom level

Saftey note:

When handling the case glasses be aware of the danger of injury.

Before treating the wood the door must be dismantled. The glass fits in a groove and is secured with a screwed fillet. Unlock both screws with a crosstip screwdriver (not included) at the inner side of the upper door fillet and remove it. Pull the glass carefully from the groove and store it safely in the packaging provided. Take care when handling the glass.





The oil provided is a natural product but you should carry out the following steps in a room with good ventilation.

Providing the natural wood finish

The case of your Mechanica M3 is made from of solid wood, except the case back which is laminated and veneered for greater stability.

All cases except the black lacquer version must be treated with the wood care oil provided.

This method of surface treatment protects the wood from moisture, highlights the natural grain of the wood and enables any subsequent scratches to be repaired.

The Auro oil is linseed oil with the addition of tree resin and natural wax. It is not damaging to the environment.

Safety information:

Oil your case in a wellventilated room. Store the oil-soaked cloth in the jar provided and close it firmly to prevent the combustion of the gases produced by the linseed oil.

Let´s start:

How to oil the case correctly

Because spills or drips can be difficult to clear up after the oil has dried, protect your workplace with cardboard or paper. The parts are pre-sanded and ready to treat. The oil must be shaken before first use.

Apply the oil with the cloth provided. Treat all case parts with the oil. The wood will absorb the oil in about 20 minutes. Any oil which remains on the surface should be wiped off.

The treated parts should then be allowed to dry 12-24 hours.

When the surface feels dry you should sand it very lightly because the treatment raises the wood grain a little.
The smoother the surface before the second oiling, the better the result.

To remove any stray wood fibres, simply rub the surfaces gently with wire wool during the interim polish.

Hint:

Give the case plenty of time to dry and keep it in a warm dry and ventilated place.

For the second oiling, follow exactly the same procedure as the first. Since the wood is no longer as absorbent, pay attention to areas where the oil is not fully absorbed. Oil your case in well-ventilated rooms only.

Good lighting will help you identify these areas particularly well.

After this the case should dry at least 24 hours before assembling.

The surface should feel dry, not sticky. If you think the wood can absorb more oil, you may treat it a third time.

Assemble the case first so that you will have a safe place to put the movement when you have finished it.

Tools:

Locate the following tools:

• allen wrench 4 mm	Compartment 8
• allen wrench 5 mm	Compartment 8
• allen wrench 6 mm	Compartment 8
• oil syringe	Compartment 8

In addition to the oiled wooden parts the complete case consists of the following:

Parts:

• door glass	Lower level
• 2x felt inlay	Lower level
• 2x side glasses	Lower level
• sealing strip	Compartment 2
• 2x hinge pins	Compartment 15
• 8x corpus screws M6 x 30 with washers	Compartment 15
• Pendulum scale	Compartment 5
• 2x instrument screws 2,5 x 10	Compartment 5
• 4x case adjusting screws	Compartment 19 + 20
• Pendulum cock	Compartment 16
• Counter sunk allen screw M6 x 30 with washer	Compartment 16
• 2x case pillars*	Compartment 12 + 13
• 2x allen screws M8 x 30 with washer	Compartment 17
• Cable pillar	Compartment 14
• ICounter sunk allen screw M6 x 24 with washer	Compartment 14

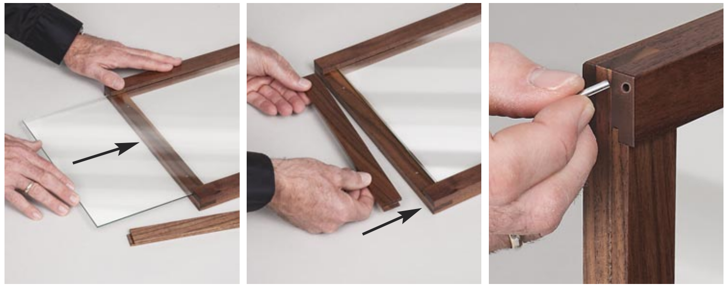
Bevelled panes of mineral glass *Upgrade*

To enhance the aesthetic appearance of your case, we offer an alternative set with bevelled* panes of mineral glass.

These are used in place of the standard panes. Care should be taken when fitting the panes to ensure that the bevelled edges are always on the outside. The bevelled panes are somewhat thinner at the edges, which may result in a little play in the grooves of the case. To avoid this play and the noise it can cause, velvet tape is glued to the edge of the glass at regular intervals.

Assemble the door first

Slide the door glass back into the groove it came from with the rubber damping strip in the bottom groove. Place the end fillet back into the notch. The top of the door should be aligned. Attach the fillet from behind using the two instrument screws 2.5 x 10 mm. Push the hinge pins into the holes at the top and bottom of the door.



Prepare top and bottom plates

Place a drop of oil in the bushings using the syringe.

Recall the information about handling the syringe (page 17).

The adhesive felt is applied to the bottom of the hidden shelf. Remove the protective backing, carefully position the felt, and press it down firmly.

Sealing the case

Fitting the seal to protect the movement from dust.The seal consists of a selfadhesive velvet, which is glued into the corresponding slots.

Hint:

Note the door trim, which is fitted with magnets, as this will be fitted to the lefthand side of the case later on.

Attaching the bottom plate

Lay the case back on your table; push the bottom plate onto the wooden plugs in the case back. Attach the bottom plate with two corpus screws M6x30mm and the matching washers.

Installing the side glasses, the side pieces and bottom plate

Place the side glasses into the grooves in the case back and bottom plate. Fit the side pieces, groove down, on the side glasses and push them along so that the wooden plugs fit into the holes in the bottom plate.

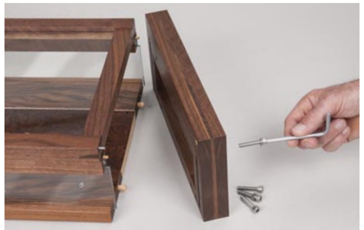
Please ensure that the side trim is fitted with the magnets on the left-hand side (from the front) of the case. The magnets are set symmetrically in the case trim, so it does not matter which way round the part is fitted.

Attach the side pieces and bottom plate using the corpus screws, M6x30 mm, and washers.

Attaching the top plate and the case door

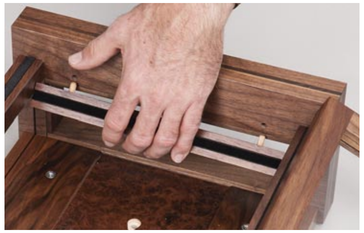
Put the door in position on the case. The lower hinge pin of the door must fit into the hinge bushing in the bottom plate. When positioning the top plate make sure that the upper hinge pin also fits into the bushing of the top plate.

Attach the top plate using the 4 corpus screws, M6 x 30 mm, and washers.



Now open the door and check that it moves freely.

The top frieze must now be pushed into the top plate.



Hint:

To prevent any damage to the door trim in the following step, use a suitable object, such as the upright movement assembly base provided, to support the open case door on the workbench.

Installing the pendulum cock, case pillars and cable pillar

Assemble the pendulum cock, the case pillars* and the cable pillar by using the enclosed counter-sunk Allen screws in the corresponding recesses of the case back side. The different shapes avoid confusion.

Screw the case retaining screws into the pre-assembled threaded sleeves on the case back panel until the tips of the screws are flush with the case back panel. This will allow you to align the case precisely on the wall later.

To ensure that the pendulum spring* hangs truly vertically in the assembled case, before finally fixing the pendulum cock in position, place the tweezers included in the assembly kit in the slot of the pendulum cock and move them left or right to determine the correct position. The tip of the tweezers must then point exactly at the central stepped drill hole below the pendulum cock. Tighten the screw of the pendulum cock only once you have aligned it.

Installing the pendulum scale

Attach the scale to the scale block with the two instrument screws, 2,5 x 10 mm. Push the block, with its wooden plugs, into position at the back of the case.

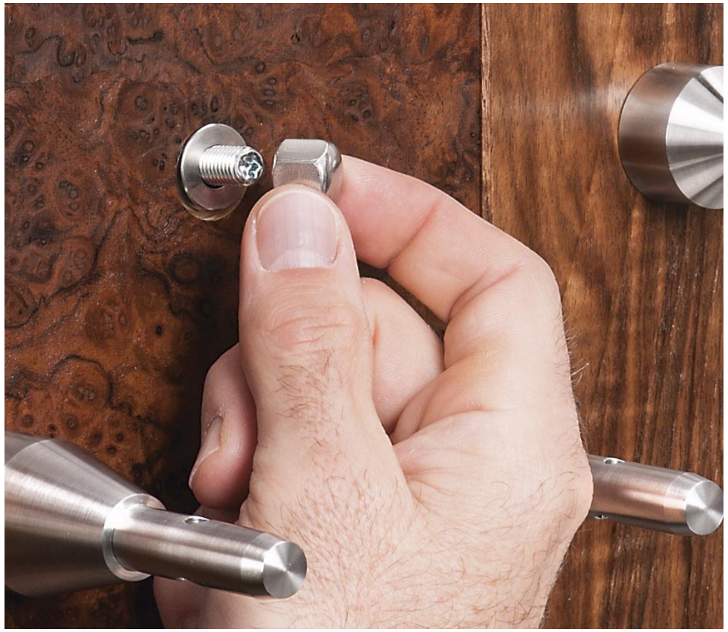
How to hang the case

Choose a solid wall which can support the weight of your clock. Follow the instructions carefully to avoid damaging your case.

Put the bolt-screw (compartment 18) into the wall with a suitable plug. This screw is placed at the height you want the centre of the dial to be. The thread should protrude 35 mm (1.4 inches) from the wall. For the second bolt-screw (compartment18) a second hole must be drilled exactly 114,5 cm (30.7 inches) below the first. Hold the case on the wall with the upper case hole over the first boltscrew, fit the two washers (compartment18) and tighten the cap nut.

Hint:

Levelling the case is described on page 39.



Before you level your case with the lower bolt screw we recommend assembling the pendulum so it can be used to establish the perpendicular.

In the hidden shelf you will find space to store the tools for operating your M3: Tweezers, winding key, curb pin, pendulum spring, fine regulation weights, etc.

A clean working place should be available

Tools:

For assembling the pendulum have the following tools available:

• Allen wrench 0.9 mm	Compartment 8
• Allen wrench 1.5 mm	Compartment 8

Parts:

Have the pendulum parts at hand:

• Invar pendulum rod* with protective cap	Compartment 33
• Table for fine regulation * with two grub screws M2 x 2 mm	Compartment 4
• Beat adjustment lever	Compartment 5
• Bushing	Compartment 5
• Allen screw M2x12 mm	Compartment 5
• Knurled screw	Compartment 5
• Coil spring *	Compartment 5
• Pendulum bob*	Compartment 1A
• Compensation tube*	Compartment 6
• Grub screw M3 x 8 mm	Compartment 5
• Regulation nut*	Compartment 7
• Lock nut*	Compartment 7
• 2 Suspension springs* (one is spare part)	Compartment 3

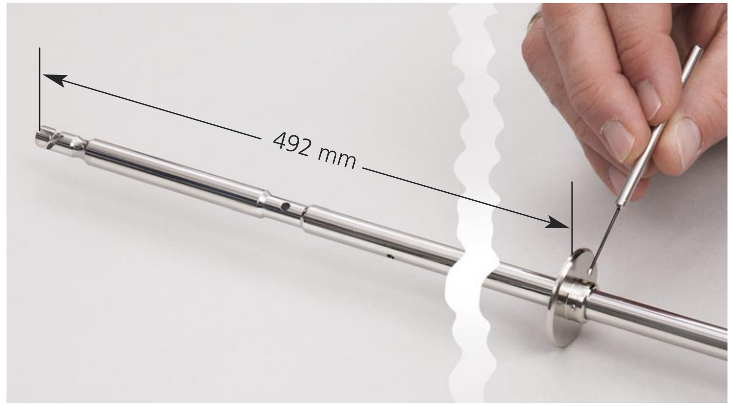
Assembling the fine regulation table*

Fit the fine regulation table with the grub screw M2x2 mm. (The screw is already in the regulation table). The screw should face the same side as the opening of the pendulum hook (towards the back of the clock). The table should be positioned 492 mm (19.4 inches) from the top end of the rod.

To avoid injury, never hold the pendulum by the regulation table*.

The grub screw only clamps the table to the rod, it cannot support the full weight of the pendulum.

Safety information: *When handling the pendulum rod be aware of the danger of injury from the pointed tip.*



Accessories:

Assembling the barometric instrument

Parts:

• Barometric instrument Compartment Z2

To compensate for brief changes in rate caused by fluctuations in pressure and to further improve the accuracy of your Mechanica M3, we offer an optional barometric instrument.

The changes in rate shift by approximately a tenth of a second per day and can, in favourable conditions, balance out within a month.

A detailed description of how the barometric instrument works can be found in Section II – »Technology and workings of the Mechanica M3«.

Pay attention to the position of the fin regulation table* and barometric instrument, which differ depending on the pendulum design. The relevant dimensions are shown in the figures on page 35 and also summarised in a table. Note that different designs for air-pressure compensation are used for pendulum bodies that differ in weight and size.

Now carefully remove the shrink wrap from the aneroid capsules* and securely fit the barometric instrument using the two M2 x 2 grub screws, either 215 mm or 235 mm away from the top end of the pendulum, depending on the pendulum model.

In cylindrical and lenticular pendulums, the barometric instruments are not in the same position. To measure where they should be, the top edge of the screwed-on flange acts as a point of reference (see figures).

The screw connection should be located on the side of the pendulum hook opening, facing the back panel of the case.

In all pendulums with barometric instruments, the fine regulation table* should have a clearance of 492 mm from the top end of the pendulum to the contact face.

Versions of the pendulum bob

As already shown when assembling the barometric instrument, in addition to the standard cylindrical pendulum bob, we also offer another optional design:

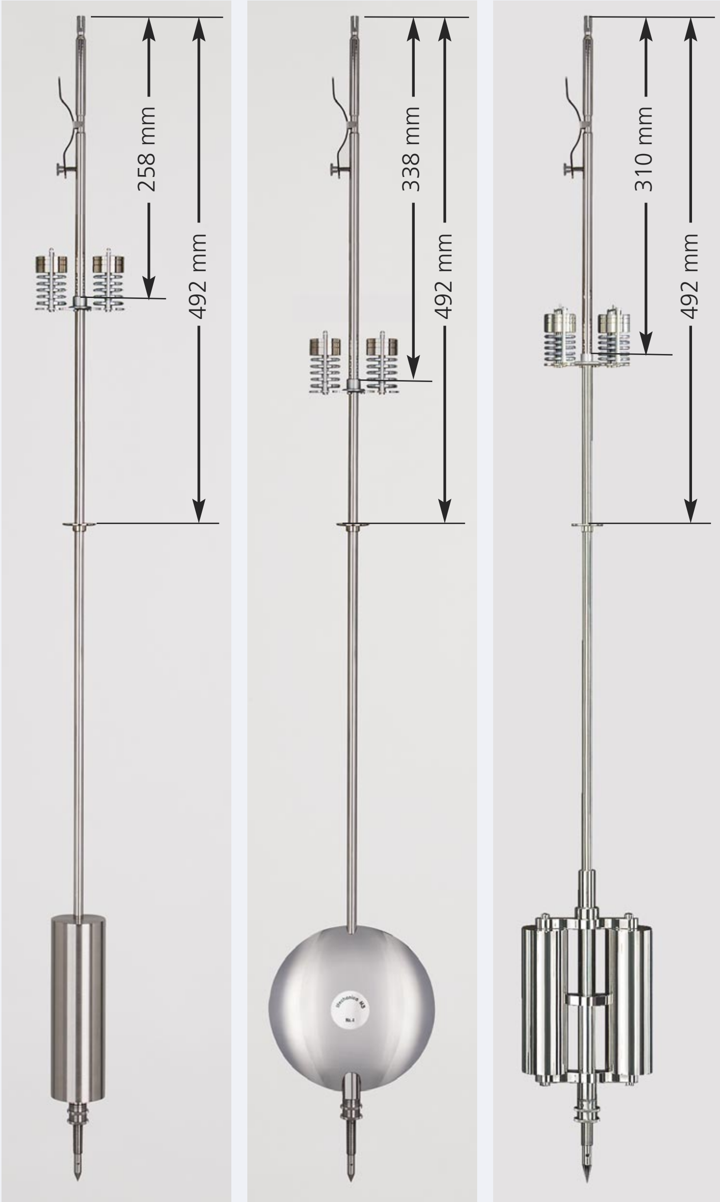
- **lenticular pendulums** Compartment 1B

The lenticular pendulum has a special position amongst pendulum variants because it has the best rate results. Its aerodynamically optimised shape creates less air resistance and makes the lenticular pendulum run more steadily. This results in a greater amplitude of oscillation and a smaller deviation between oscillations. Fluctuations in air pressure also have a reduced impact.

The pendulum bob is finely turned from solid bronze* and polished. A nickel-plated version is also available on request. The consecutive numbering milled into it is of particular interest to collectors.

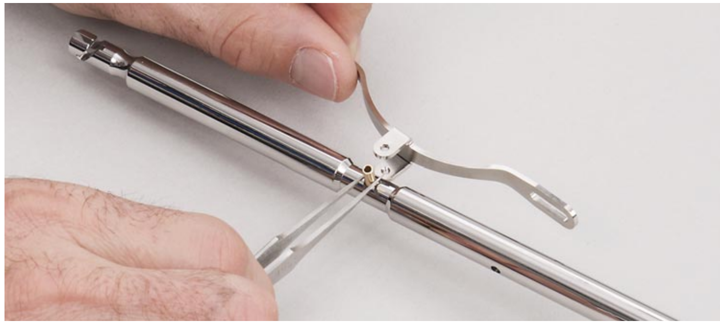
- **Double cylinder pendulum body** Compartment 1C

Only available as nickel-plated

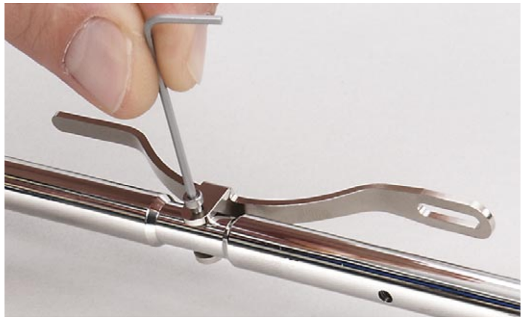


Installing the beat adjuster*.

1. Put the bushing into the cross hole in the upper quarter of the pendulum rod , where the pendulum rod tapers in and out.



2. Position the beat adjuster ...



3. ... and attach it with the Allen screw M2 x 12 mm inserted through the bush. With the opening of the pendulum hook facing away from you, the beat adjusting lever must be on the left of the rod. The beat adjusting lever must be free to move, but not too free. Position the coil spring* and the knurled screw. The screw is used to adjust the beat.

Assembling the pendulum bob and compensation tube

Remove the protective cap. Insert the tip of the pendulum into the smaller drilling of the pendulum bob*.

Push the compensation tube* onto the pendulum rod and secure it by inserting the M3 x 8 grub screw through the slot on the compensation tube and into the threaded hole for the pendulum rod. When assembled, the index engraved on the compensation tube must project downwards out of the pendulum body.

Screw the regulation nut* with the scale graduation towards the compensation tube and unscrew the lock nut*. Slide the pendulum body over the compensation tube.

Precise regulation is described in the section »Setting your Mechanica M3 in motion« starting on page 70.

Note:

During the first weeks of operation, the pendulum must be regulated in the relevant installation location.

Installing the pendulum

Put the suspension spring* with its thin cross pin into the pendulum hook. Hang the pendulum by the suspension spring in the pendulum cock with the beat adjuster facing left. Take care not to bend the suspension spring.

If the pendulum spring is damaged, the pendulum could fall, which may in turn damage the case. It is therefore important that you replace damaged pendulum springs immediately.

Levelling the case

When the pendulum is hanging in the case you can use it as a perpendicular line. Move the base of the case side ways so that the pendulum tip points to the »0« on the pendulum scale.

To fix the case in this position, remove the scale block and tighten the cap nut on the lower case screw.

Replace the scale block to hide the screw. Use the four case adjusting screws to allow for unevenness in the wall. Turn the screws clockwise so that the case has a little clearance from the wall and does not rock when pressed at any corner.

Hint:

Make sure the case back remains vertical and the pendulum does not touch the case back.

Take your time and assemble the movement with concentration and care. Your working area should be clean and well illuminated.

All the components are manufactured with care. Each group of parts is packed separately. To avoid loss, dirt or damage, the bags should only be opened immediately prior to the assembly stage at which they are required.

Tools:

Have the following tools available:

• Allen key 0.9 mm	Compartment 8
• Allen key 1.5 mm	Compartment 8
• Allen key 2.5 mm	Compartment 8
• Allen key 4 mm	Compartment 8
• Tweezers	Compartment 8
• Clockmaker's screwdriver	Compartment 8
• Magnifying glass (loupe)	Compartment 8
• Assembly block	Compartment 2

Hint:

Note that the assembly steps should be carried out in the order they aregiven.

The delicate parts should be stored in the compartments of the foam packaging to avoid damage and dirt.

The use of the assembly block is illustrated. To allow the assembly to proceed smoothly the instructions which follow do not include descriptions of function.

The function of the components and the way precision clocks work is described on page 79.

Assembling the back plate

Parts:

• back plate	Compartment 39
• 4 x movement pillars*	Compartment 25
• 4 x washers	Compartment 24
• 4 x Counter sunk allen head screws M4 x 10 mm	Compartment 24
• 2 x banking pins	Compartment 24
• 5 x ball bearings* for the back plate	Compartment 22

Accessories:

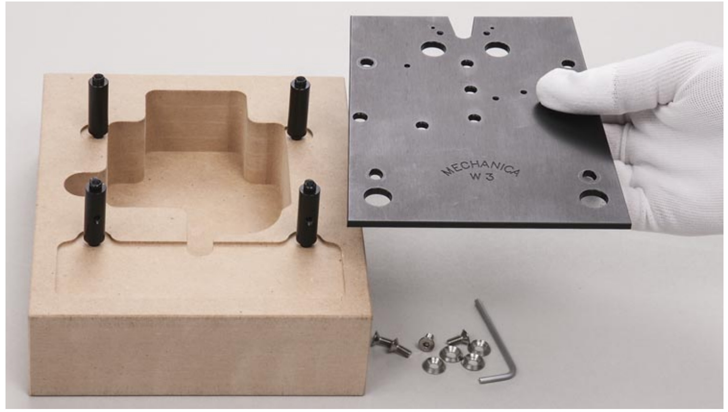
Fine polished set of screws

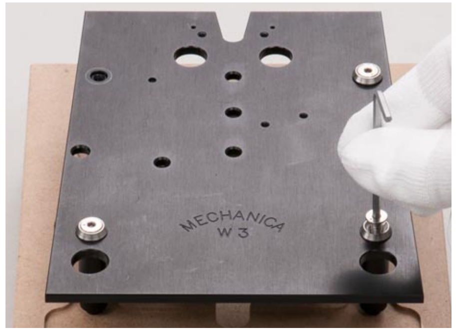
Parts:

A finely polished set of screws is available as an accessory for your Mechanica M3. These 29 finely polished and finely turned stainless steel screws*, four gold-plated washers and two banking pins considerably enhance the aesthetic appearance of the movement and replace the corresponding standard parts for the movement assembly.

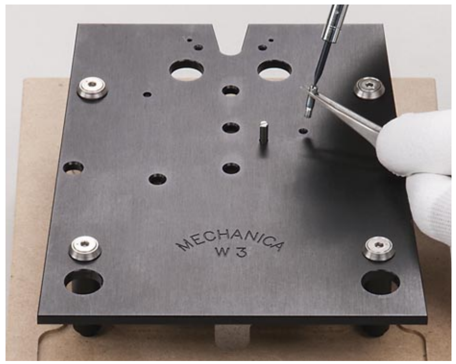
• 4 x screws M4 x 6 mm and 4 brass washers to connect the back plate with the movement pillars*	Compartment Z1
• 11x screws M2 x 4 mm for the changing wheel pinion, both escapement lever bearings and the dial	Compartment Z1
• 4 x knurled nuts for the front plate	Compartment Z1
• 2 x allen screws M3 x 10 mm connecting the escapemant bridge*	Compartment Z1
• 2 x allen screws M4 x 20 mm connecting the movement with the movement holding pillars	Compartment Z1
• 2 x banking pins Screw in the back plate to limit the swing of the crutch*	Compartment Z1

Insert the 4 movement pillars in the holes of the assembly block. Put the plate* on the shoulders of the movement pillars*. The engraving »Mechanica W3« on the rear of the plate should be facing upwards. Note the differently shaped pillar shoulders to avoid confusion.





Put on the 4 washers in place over the pillar* ends and attach with the 4 counter sunk allen screws M4 x 10 mm.



Screw in the two banking pins which limit the swing of the crutch*.

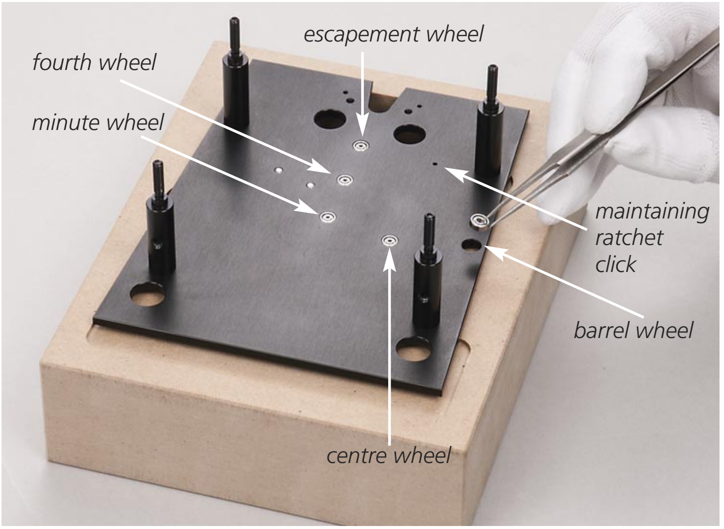
Assembling the movement

Turn the plate over.

Turn the plate over. Using tweezers put the 5 inox ball bearings in the milled recesses. Place the bearings with the balls visible to the outside (down, at this point). Because of their different diameters the bearings will only fit into the right place.

Hint:

Do not add any oil to the bearings



Assembling the gear train

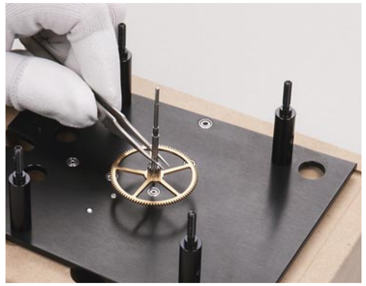
The hardened steel arbors* have not had a protective surface treatment. Touching them with your fingers may cause corrosion. Please use tweezers. Take care not to scratch the gilded surface of the wheels.

Parts:

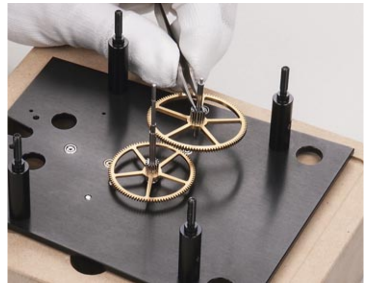
Insert the shoulders of the preassembled geartrain components into the ball bearings.

• minute wheel*	Compartment 30
• centre wheel*	Compartment 31
• barrel wheel* with steel cable	Compartment 32
• escapemant wheel*	Compartment 28
• fourth wheel*	Compartment 29
• maintaining ratchet click*	FachCompartment 21

How to put the pre assembled parts in place:



1. minute wheel*



2. centre wheel*

3. barrel wheel* with steel cable

4. escapement wheel*

5. fourth wheel*

6. maintaining ratchet click*

Note that the winding ratchet* must engage the teeth of the maintaining ratchet wheel on the barrel assembly.

Preparing and installing the front plate

Parts:

Following parts are needed:

• front plate	Compartment 40
• Pallet arbor bearing	Compartment 24
• 2 x screws M2 x 4 mm	Compartment 24
• intermediate wheel stud (stainless steel)	Compartment 24
• screw M2 x 4 mm	Compartment 24
• hour wheel stud (gold-plated brass)	Compartment 24
• screw M2 x 4 mm	Compartment 24
• 5 x ball bearings* for the front plate	Compartment 24
• 4 x washers	Compartment 24
• 4 x knurled nuts	Compartment 24

Put the assembly block with the partially assembled movement on one side to work on the front plate:

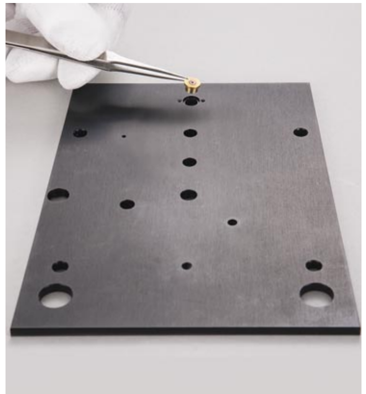
Installing the pallet lever bearing

Hint:

For the next steps place a sheet of pager underneath the plate to avoid scratches.

As with its great predecessors, the longevity of your Mechanica M3 has been significantly increased by using jewels for the pallet lever bearings.

Insert the chaton* with the pallet lever bearing into the milled recess of the front plate and position it with the two screws M2 x 4 mm.



Installing the intermediate wheel stud and the hour wheel stud

Install the intermediate wheel stud (stainless steel) and the hour wheel stud (goldplated brass) on the opposite side of the plate (dial side), attach it with the screw M2 x 4 mm.

Putting the ball bearings into the front plate

Insert the ball bearings in the milled recesses in the front plate. As with the backplate place the bearing so that the balls are visible to the outside of the plate. They have different diameters so cannot be put in the wrong place.

Hint:

Do not add any oil to the bearings.

Adding the front plate to the movement frame

Insert the ball bearings in the milled recesses in the front plate. As with the backplate place the bearing so that the balls are visible to the outside of the plate. They have different diameters so cannot be put in the wrong place.

Attach the front plate using the 4 washers and the 4 knurled nuts.

After you tightened the nuts, make sure all the arbors have end play and there is no jamming. Using your tweezers, grip each wheel and move up and down to insure easy movement.

Assembling the motion work

Parts:

For the next step you need:

- intermediate wheel* Compartment 23
- screw M2 x 4 mm Compartment 23
- canon pinion* with counter weight* Compartment 23
- grub screw M2 x 2 mm Compartment 23
- minute hand Compartment 37

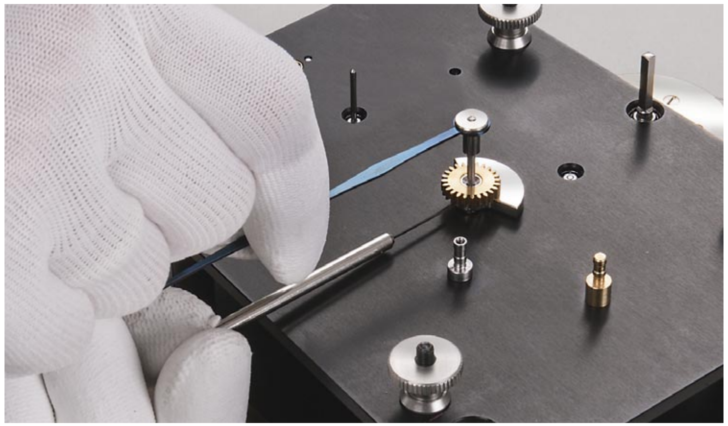
To avoid an imbalance at the minute wheel shaft, the quarter-hour wheel* is compressed with a counterweight suitable for the minute hand.

Installing canon pinion with counter weight

Put the canon pinion with counter weight on the arbor of the minute wheel.

Adjusting the minute hand with respect to the counter weight

Place the minute hand on the square of the minute wheel arbor and align it so that it points directly away from the counter weight. Then fix this alignment by tightening the grub screw M2 x 2 mm.



The 0.9 mm wide Allen wrench can be useful if you want to fit this into the M2 x 2 Allen grub screw that is only loosely screwed into the thread. This must now be placed directly beneath the hand. The minute hand can be removed again and put to one side.

Fit and screw the intermediate wheel

Put the intermediate wheel on the intermediate wheel stud. Tighten the screw M2 x 2 mm which holds the intermediate wheel in position.

Hint:

Check for free play and end shake in the intermediate wheel!!*

Testing the free action of the gear train

After setting the relationship between the motion work and the gear train by tightening the grub screw M2 x 2 mm, remove the minute hand and place the movement in an upright position. By turning the barrel wheel, check the complete gear train for smooth running. Alternatively use the winding crank, turning it clockwise on the winding square of the barrel arbor. The gears should continue to turn for a while after applying a little force to the barrel or crank.

Hint:

By turning the barrel wheel, check that the motion work is freemoving.*

Check list: Gear train

End Shake of the arbors*

All arbors need to be able to move back and forth a little between the plates. You should be able to see it and feel it.

☐ OK

Motion work

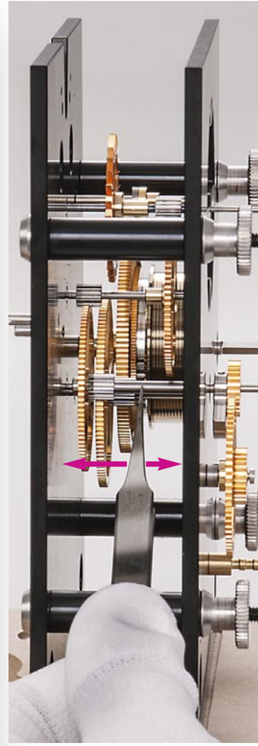
The wheels of the motion work should turn easily when the canon pinion is not locked.

☐ OK

The maintaining ratchet click

The maintaining ratchet click must engage the teeth of the maintaining ratchet wheel. It must not touch the teeth of the barrel wheel. If the maintaining ratchet is engaged, the gears should run smoothly and slow down steadily.

☐ OK



If anything is not working properly, please give us a call. You reach us on weekdays from 9am-4pm

Phone +49 (0)89 / 8955 806-20.

Hint:

All parts are checked carefully before despatch.

Fitting the escapement

When you assembled and tested the gear train, identify the escapement components:

Parts:

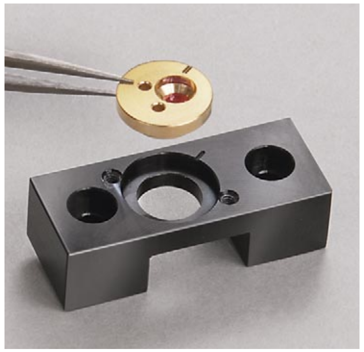
Parts you need:

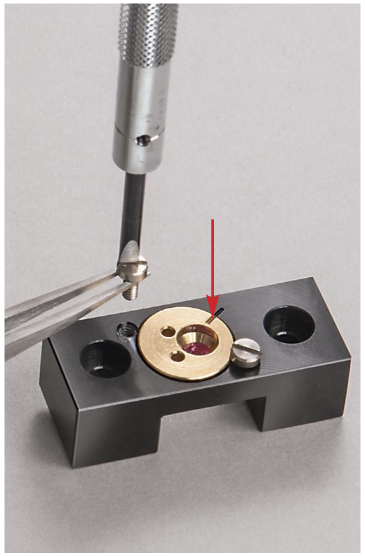
• pallet arbor bridge*	Compartment 26
• eccentric bearing*	Compartment 26
• 2 x screws M2 x 4 mm	Compartment 26
• pallet arbor with crutch*	Compartment 26
• crutch pin	Compartment 26
• counter sunk screw M2 x 6 mm	Compartment 26
• 2 x allen screw M3 x 10 mm	Compartment 26

Put the movement and assembly block aside. Insert the eccentric bearing* into the milled recess of the pallet arbor bridge*. The eccentric bush must be installed so that the index markers on the bush and the bridge are aligned (this is a factory setting). The eccentric bush is clamped with 2 screws M2x4 mm.

Hint:

The function of the escapement is explained in the chapter »Escapemant« on page 90.*

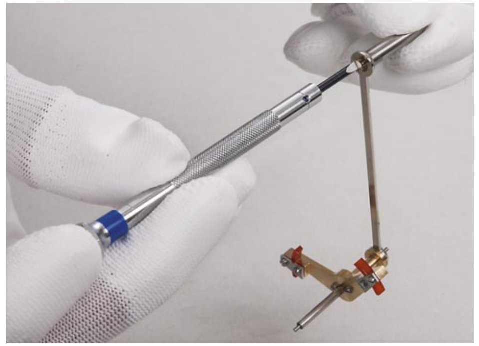




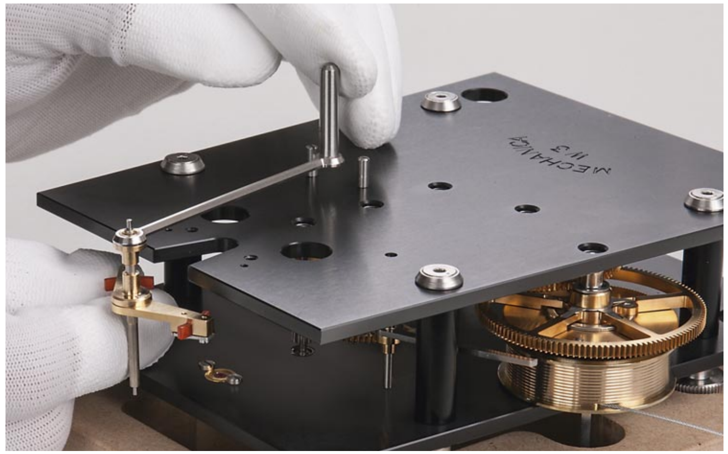
Escapement lever with agate pallets

Your Mechanica M3 is equipped with an anchor body with agate jewel pallets. As is the case with classical premium-quality precision pendulum clocks*, the agate pallets* used here also prevent friction and thereby ensure that your Mechanica M3 runs with minimal wear. In addition, the bright red pallets are a decorative feature for every movement.

Attach the crutch pin to the crutch with the countersunk screw M2 x 6 mm. Now the pallet arbor is ready for installation.



Put the movement on the assembly block with the engraving »Mechanica W3« facing upward. Insert the pallet arbor pivot into the jewelled bearing fitted on the front plate

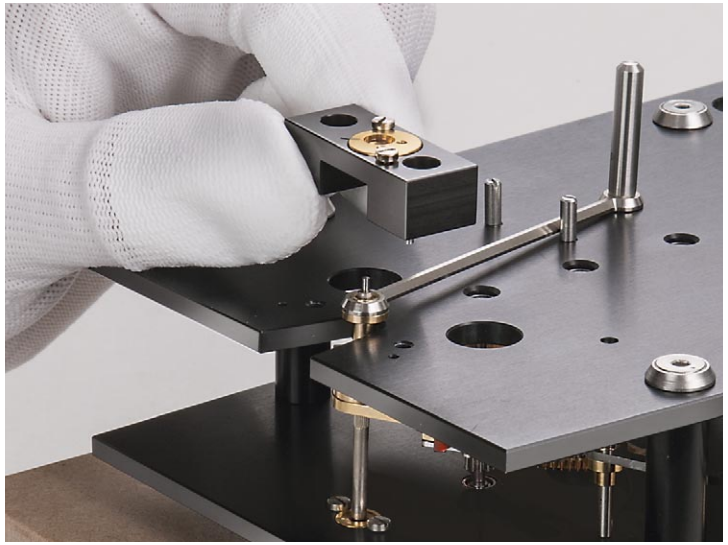


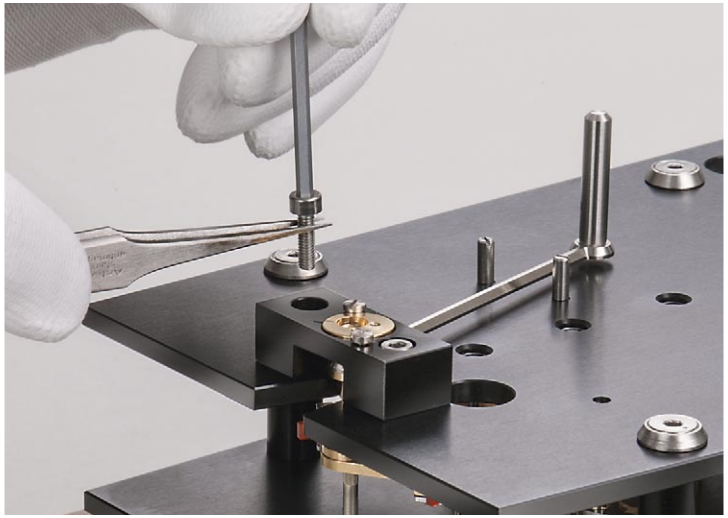
Hint:

Please take care to assemble these components correctly!

The crutch* must lie between the two banking pins on the back plate. The pallets of the pallet arbor must fit into spaces between teeth of the escapement wheel.

Insert the rear pivot of the pallet arbor into the eccentric bush of the pallet arbor bridge and position the bridge over the matching holes in the back plate.





When you are sure both pivots are inserted in the bearings, fix the bridge in place with the allen screws M3 x 10 mm

Check list escapemant

Axial freedom of the pallet and escapement wheel arbors*

You must be able to see and feel the endshake in these arbors.

☐ OK

The action of the pallet arbor

Hold the crutch centered between the banking pins. The pallets* must be equidistant from the escape wheel.

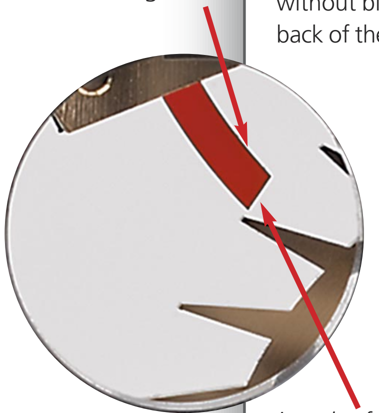
Move the crutch carefully back and forth between the banking pins. Neither pallet must touch the base of the gap between the teeth of the escape wheel. It is easier to observe the action of the escapement if viewed through the holes in the back plate against a white background. A suitable piece of card is provided as a bookmark at the end of this book.

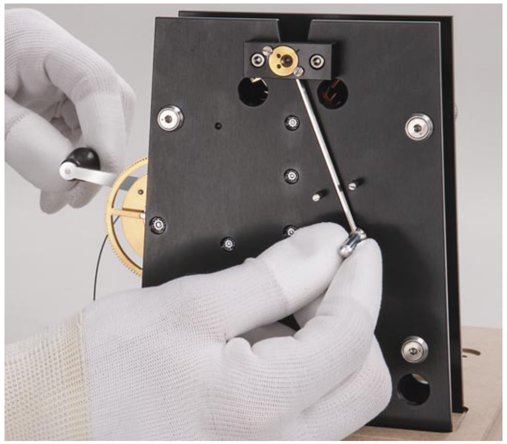
☐ OK

Check list escapement

Supply a little pressure against the winding direction to the gear train with the winding crank:

Move the crutch slowly and carefully back and forth. With each movement one tooth of the escapement wheel must pass a pallet without blocking the action of the pallet arbor. Viewed from the back of the clock the escapement wheel is turning anti-clockwise.





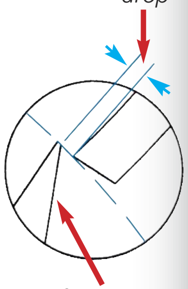
Checking the drop*

The drop is the free motion of the escapement wheel after one of its teeth has passed the impulse plane of the pallet and the locking plane of the second pallet stops another tooth.

The size of the drop can be noted when you check the gap between the tooth tip and the pallet after the tooth has left the impulse plane.

This distance should be equal at all the teeth of the escapement wheel at both the entry and exit pallets.

☐ OK

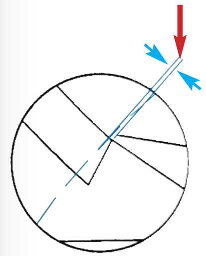


Check list escapement

Checking the lock

When the drop is equal on both pallets, every tooth must rest safely on the locking* plane of both pallets. Guide the crutch carefully back and forth when the gear train has power and observe each tooth of the escapement wheel with your loupe.

☐ OK



The escapement components have been carefully adjusted in the factory.

If, never the less, you have any problems, call us. We will be able to help you quickly and easily. Call us any week day from 9am to 4pm.

Phone +49 (0)89 / 8955 806-20.

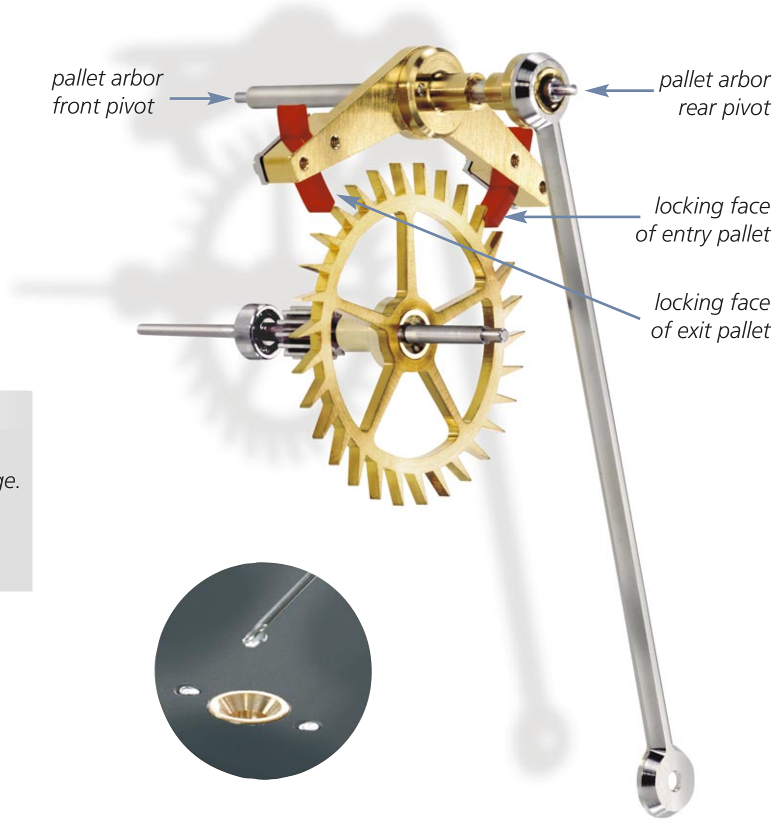
Lubricating the escapemant

The gear train of your Mechanica M1 has ball bearings which need no oil.

The escapement however does need lubrication. Give a little oil into the oil sinks* of the pallet arbor bushes as well as the locking face of the pallets.
Caution: Too much oil is as bad as no oil.

Use only the special clock oil supplied, Möbius Microgliss D5.

Oil only as indicated



Saftey note:

Be careful with the needle of the syringe. Keep away from children.

Fitting the regulator dial

The design of the regulator dial* is based on the classic precision pendulum clocks* of the previous century and therefore visually resembles the great clock on which it is modelled, the Classica Secunda 1985, from clock manufacturer Erwin Sattler.

Parts:

Parts you need:

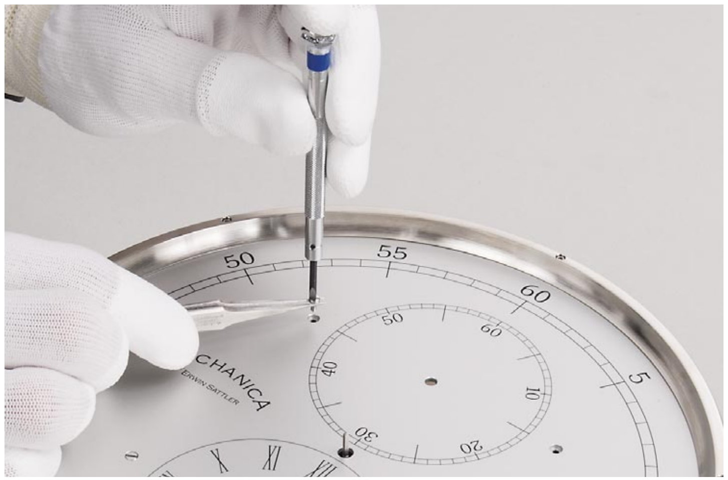
•	hour wheel* with pipe	Compartment 23
•	regulator dial*	Compartment 34
•	bezel*	Compartment 35
• 6 x	allen screws M1,6 x 8	Compartment 24
• 4 x	screws M2 x 4	Compartment 24
•	Regulator hands	Compartment 37 + 38

Before attaching dial be sure to replace the hour wheel onto the minute pinion.

Check for free play and end shake in the intermediate wheel!

Start by preparing the regulator dial* (with optional recess) for installation by placing the bezel* on the dial and screwing it in place from the front using six M1.6 x 8 Allen cylinder-head screws.

Carefully lower the dial onto the movement pillars* and tighten the screws M2 x 4 mm



Fitting the hands

Now fit the hands to their respective arbors* in the following sequence:

1. Regulator second hand (make sure that the hand is not touching the dial)
2. Regulator hour hand (push onto the arbor as far as possible)
3. Regulator minute hand (push onto the arbor as far as possible; make sure that the hand is parallel to the dial)

Hint:

Make sure the minute hand is oriented correctly in relation to the counter weight, see illustration page 50.

Hand-finished set of hands for the M3

Accessories:

A set of hands that have been painstakingly domed*, polished and blued* by hand is available for the M3 as an accessory.

Please ensure that hand-finished hands are treated with a special wax spray to protect them against corrosion.

To bring out the full gloss of the finish and the doming, carefully rub the wax layer using a soft cotton or leather cloth.

Aligning the hands

One of the joys of a precision clock is the correct alignment of the hands in relation to the escapement, the dial and each other. Move the crutch against one banking pin back and position the second hand so that it is aligned with a division on the seconds scale.
When turning it, hold the hand as close as possible to the shaft to avoid bending it.

Apply some power to the gear train by turning the winding crank and move the crutch from side to side. Check that the second hand jumps precisely from one index to the next and does not touch the dial.

Gently move the minute hand to exactly 12 o'clock.

Hold the minute hand and turn the hour hand carefully to the nearest hour marker.

Hint:

The minute hand should not project axially beyond the dial.

Turn the minute hand through a full rotation and check that the hands don't touch or rub the dial.

Parts you need:

• 2x	movement fitting allen screws M4 x 20	Compartment 24	*Parts:*
•	Allen key 3mm	Compartment 8	*Tools:*

Hold the finished movement by the bezel* and place it on the two case pillars*.

Make sure the crutch pin is on the left side of the beat adjusting lever and that the steel cable hangs freely out of the right-hand side of the movement.

Hint:

When fitting the movement into the case, please protect the case bottom with a strip of foam material. Then, if you drop parts or tools, they will not damage the case

Insert both case screws into the vertical holes of the case pillars and tighten gently.

Assembling the pulley and weight

Parts:

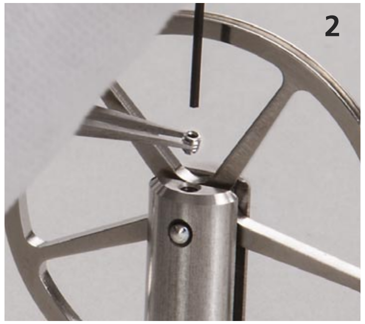
To drive the movement you need to install the weight. You need:

- pulley stirrup — Compartment 9
- pulley — Compartment 9
- pin — Compartment 9
- grub screw M2 x 2 mm — Compartment 9
- tungsten driving weight — Compartment 10

The pulley rotates with its bush on a hardened pin. The bush needs a drop of oil.

Place the pulley in the slot of the pulley stirrup. Push the pin through the holes in the pulley stirrup and the pulley bush. Clamp the pin by tightening the grub screw M2 x2 mm in one arm of the stirrup. (Figure1+2)

1



2

3

Now screw the rope pulley bracket onto the threaded piece protruding from the top of the winding weight. (Figure 3)

Ball-bearing rope pulley Accessories

Accessories:

The ball-bearing rope pulley, which is available as an accessory, is not only visually appealing but also has two technical advantages.

- Ball bearings* are particularly wear-resistant
- Frictional losses are kept to a minimum, which improves the accuracy of the clock.

The following are required for assembly:

Parts:

- Ball-bearing rope pulley — Compartment 9
- Driving weight with weight hooks — Compartment10

Tools:

- winding crank Compartment 8

Hanging the weight

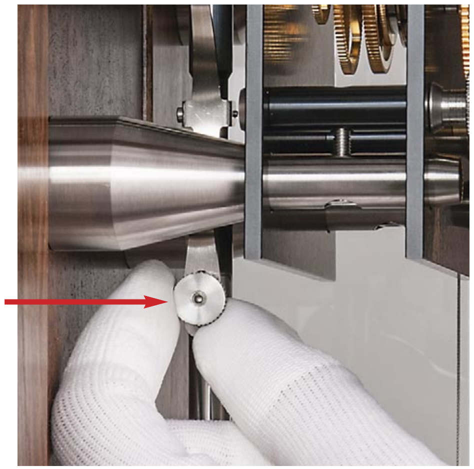
Unwind the cable and pass the end loop through the pulley stirrup. Hold the weight and attach the loop to the notch in the cable pillar. Never bend or kink the cable. As you lower the weight make sure the cable runs in the groove of the pulley.

Adjusting the beat

Place the winding crank on the winding square. Always wind the clock counter clockwise.

First, wind only one turn. Watching the tip of the pendulum and the pendulum scale, move the pendulum to one side until you hear a »tick«. Note the position of the pendulum at this point. Next, move pendulum to the other side until you again hear another »tick«. Read the indication on the pendulum scale again. If the beat is perfect, the pendulum tip should have moved the same amount to each side.

If it is not you can adjust the beat by turning the knurled screw on the beat adjustment lever. If a turn in one direction does not even the beat, turn the other way.



Winding the clock

When the beat is adjusted, you can wind the clock completely. Stop winding before the weight disappears behind the dial.

Hint:

Allways wind up counter-clockwise

Setting the time and starting the clock

Set the clock to the correct time (guided by a radio-controlled clock or time signals). The minute hand can be turned forward and backward as required. Don’t touch the second hand. To synchronise your clock with a reference time, stop pendulum when the second hand points to the 60, hold the pendulum to one side until the reference clock has reached the 60 (or the time signal has given its last 'pip') and let it swing back during the 1st second of the next minute.

Enjoy now
your Mechanica M3!

Regulating your Mechanica M3

Tools:

- Regulation pin* Compartment 8

When your Mechanica is set in motion and you set the correct time, put a regulating weight on the regulation table on the pendulum rod. Check the time after 24h (using the same standard as before).

Now the clock has to be regulated by adjusting the centre of gravity of the pendulum so that it will keep time precisely.

After a 24-hour observation period, compare the time displayed by your Mechanica

M3 with that shown by a different clock (such as a radio clock) and check for what clockmakers call »drift*«. You can use this comparison to determine the daily rate* of the clock, in other words whether your Mechanica M3 drifts ahead or behind official time.

It is extremely likely that your Mechanica M3 will deviate considerably from official time at the start of regulation*. This is not a cause for concern as the regulation nut* on the tip of the pendulum can be used to adjust the clock with ease.

- Stop the pendulum. Insert the regulation pin* into the whole near the bottom of the pendulum rod.
- Hold the pin firmly so that the delicate suspension spring will not be twisted
- Loosen the lower nut, the so-called lock nut*, and turn the upper nut, the regulation nut; to the left one index to correct a gain of one second per day, or to the right by one index mark to correct a of one second per day.
- When this basic regulation has been achieved, tighten the lock nut gently against the timing nut

Hint:

At the end of this book there is a table on which you can record the performance of your clock and the effect of the changes you made. This will allow you to make adjustments systematically.

Observe the rate of your clock over several days.
As a basis for the subsequent fineregulation*, your clock should loose about 1 second per day.

Hint:

Please always use the curb pin to regulate the clock, otherwise the pendulum spring may be damaged and the pendulum itself may fall.

Fine regulation of your Mechanica M3

Parts:

- Stainless steel wheights Compartment 8

Manipulating the regulation nut gives a rough adjustm ent. But the pendulum of the Mechanica M3 can be regulated in extremely small steps without stopping the clock.

In the centre of the pendulum rod you find the fine regulation table. When you add the small stainless steel weights supplied to this table the clock will gain.

Hint:

For adding and removing weights use the tweezers, they can be kept on the hidden shelf.

The heavier the weight added the greater the acceleration of the pendulum and the faster is the clock. Adding weight to the table raises the centre of gravity of the pendulum.

When you remove a weight the period of oscillation increases and the clock runs slower.

Accessories:

A 12-part set of fine adjustment weights is also available as an accessory for your Mechanica M3 and is described in detail in the section that follows.

Correcting the rate

You can correct daily rates of 1-2 seconds using the weights provided. For this fine adjustment there is no need to stop the clock. When fine regulation has been achieved there should still be some weights on the table so there is something to remove should the clock start to gain.

If the clock is one second slow, add a second weight until the clock catches up and then remove it. Any deviation of more than a second can be corrected by temporarily decreasing the weight on the fine regulation table.

Accessories: **precision fine adjustment weightst**

- precision fine adjustment weights Compartment Z3

This set of 12 certified weights makes it possible to adjust the timepiece even more finely. This set includes a pair of tweezers and 12 precision weights in the following increments:

Aluminium	Nickel silver*
1 mg	10 mg
2 mg (twice) 5 mg	20 mg (twice)
5 mg	50 mg
	100 mg
	200 mg (twice)
	500 mg

The hidden shelf of your Mechanica M3 has a small recess specially designed for the box containing the set of precision weights.

Certified precison weights

Our weights are certified and comply with weight tolerance level M1. The metrological properties of each weight are determined in a German Calibration Service (DKD)-accredited laboratory and certified. This certification originates from the ISO 9000 quality assurance standard and has international validity (unlike official verification exclusively recognised in Germany). Recalibration is not necessary as the weights are not subject to mechanical wear.

Now nothing stands between you and finely regulating your timepiece.

Having completed the assembly and regulation you have now made yourself a precision timekeeper.

Like any other precision instrument, your Mechanica M1 needs care and a certain amount of maintenance. The case door should be kept closed to protect the movement from dust.

Hint:

Never leave the case open unnecessarily.

Its design, and the use of ball bearings, makes your M3 an extremely low maintenance movement. Nevertheless some parts need lubrication, the escapement for example. Oil ages and looses its lubricating properties over the years. It is not simply a matter of adding more oil. After 5 to 7 years dismantling and special cleaning is required to remove the oxidized oil.

We can look after the maintenance of your clock in our workshop and refurbish or replace worn or damaged parts.

Maintenance:

Maintenance can always be carried out in our workshop.

With care like this your M3 will run for centuries without problems and can be passed with pride from one generation to the next.

The movement must be removed in order to retrofit the majority of accessory parts. Make sure that you have enough time to modify your Mechanica M3 as intended. This will allow you to carry out the work described without having to rush.

Whenever you are carrying out work on the movement, the instructions from the section »Important information before beginning work« at the beginning of this book apply. The series of work steps to be carried out, which is specified in these modification instructions, should save you from exerting unnecessary effort and enable you to achieve a successful outcome in a safe manner.

Please prepare your workstation carefully before beginning to remove the movement. The workstation must be kept clean and should be well lit.

Tools:

The following tools are required to remove the movement:

- Allen wrench 3 mm — Compartment 8
- Allen wrench 0.9 mm — Compartment 8
- Tweezers (pincers) — Compartment 8
- Assembly base — Compartment 2

We recommend removing the movement once it has run down, i.e. when the driving weight is at the bottom of the case.

Note:

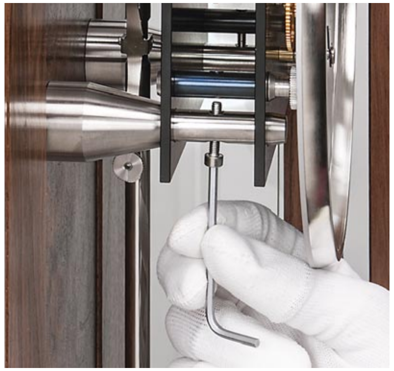
The steel cable must remain taut under all circumstances after unhooking the weight.

Release the rope pulley bracket by turning it away from the weight. When doing so, keep a firm hold on the weight and ensure that the steel cable is never slackened because if this happens, its own spring force would cause it to become caught in the movement. Put the weight aside and thread the steel cable (before unhooking the loop from the cable post) through the rope pulley bracket, which can now also be put aside.

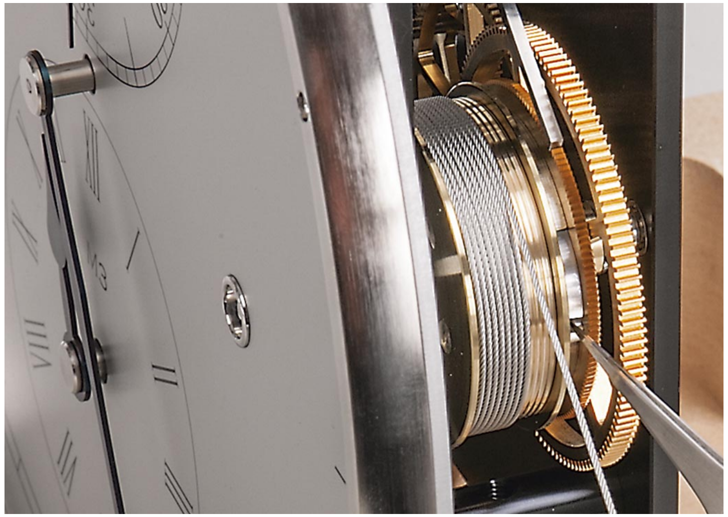
For the ball-bearing rope pulley, only the weight must be unhooked and, after detaching the loop, the rope pulley must be removed. Put the driving weight and rope pulley aside safely.

You must keep the steel cable taught at all times – both prior to this point and throughout the following steps.

Loosen the two movement-holding screws using the Allen wrench (3 mm width across flats). Remove the movement from the case carefully and slowly towards the front and safely place the movement on the assembly base. You should now wind down the movement if the clock was removed before it had not fully run down.



To do so, proceed as follows: Press on the notch in the ratchet on the barrel wheel* with the tip of the tweezers (see figure) and, while doing so, pull on the steel cable until this is fully unwound from the cable roller*. When the clock is running, the barrel wheel turns once every two and a half days. This means that the notch in the ratchet may unfortunately be located at a point that is difficult to access. In this case, the steel cable must be unthreaded twist by twist.



Chapter II

TECHNICAL INFORMATION AND FUNCTION OF THE MECHANICA M3

This chapter will introduce you to the operation and special design of your precision clock.

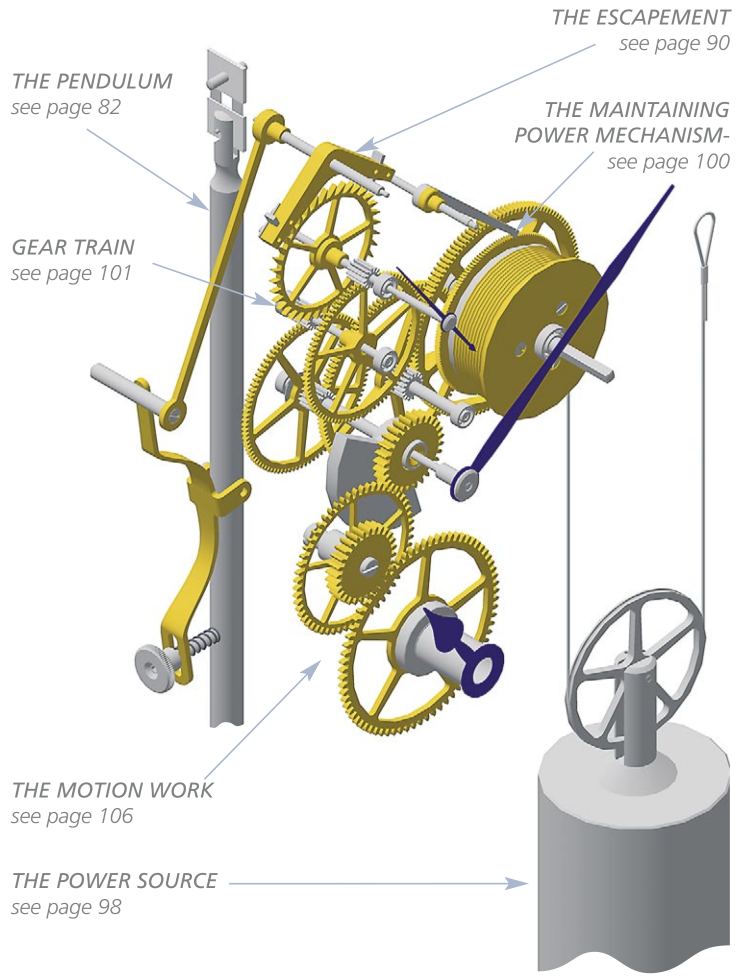
To explain the complex function of pendulum, escapement and gear train in a short and readily understandable text is no easy task. Clockmakers have a three year apprenticeship to learn the basics of clockmaking.

With this manual we not only want to enable you to assemble a precision clock, we also want to share with you our fascination of this special type of clock. It is the interaction of natural laws with what at first glance appears to be a simple mechanism that enables us to measure time with such remarkable precision. Clockmakers made a great effort over hundreds of years to enhance the accuracy of precision clocks.

Continuing this tradition we also try to improve clockmaking by using new material, new technologies and new design.

The fascination of a precision clock lies not only in its accuracy; when you take a closer look it is also in the simple and straightforward design. You can observe and follow the results of basic principles. A mechanical clock is something you can understand and, in the case of your M3, something you can touch.

When you take the time to understand the processes in your M3, you can share our enthusiasm with clockmaking and see your clock in a different light.



MECHANICA BY ERWIN SATTLER

M3

The pendulum

The pendulum* is still today's most accurate mechanical oscillation device. It divides time into precisely defined units. These are defined by the length of the pendulum and the force of gravity. This time-keeping breakthrough was discovered by Galileo Galilei in 1585. According to his observations, a pendulum has always the same oscillation time (period) regardless of its amplitude. This principle is called 'isochronism'*. Strictly speaking it only holds at very small amplitudes.

In conclusion one can say that the accuracy of a clock pendulum is determined by constant length, constant small amplitude and a constant force of gravity.

But the length of a pendulum is dependent on external influences like temperature. An increase in temperature results in the expansion of almost all solid materials. This means the pendulum rod becomes longer. When temperature falls the effect is reversed. The result is a longer period at higher temperatures and a shorter period at lower temperatures. In order to keep the oscillation angle or amplitude* of the pendulum constant, it is necessary to supply the energy, that is lost with every swing due to the resistance of the air and in the suspension spring*.

How did clockmakers over the last 400 years manage to overcome these difficulties and make an accurate clock possible? If we take a closer look at our pendulum, it consists of a pendulum rod, a compensation tube* on which the pendulum bob sits, a regulation nut* and a lock nut.

In the middle of the pendulum rod you see the table for fine regulation and at the upper end, the beat adjuster*.

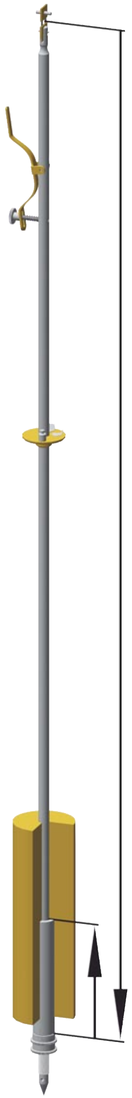
Accessories:

A barometer instrument for compensating for accuracy changes caused by air-pressure fluctuations is available as an accessory and is described in detail in the following section.

As we know, when the pendulum rod expands with rising temperature, our clock is slow.

Therefore the use of a material with very low thermal expansion is important. At the end of the 19th century the French scientist Charles Edouard Guillaume discovered a Iron-Nickel alloy whose expansion is 10 times less than normal steel and 5 times less than wood. It is called Invar*.

Clocks with wooden pendulum rods were accurate to only a few seconds per week. To improve the accuracy to a few seconds per month, it is not enough to simply use a Invar rod, it is necessary to compensate for the remaining thermal expansion.



This is why the so called 'compensation tube' sits on top of the regulation nut supporting the pendulum bob. This short tube is made of normal steel and has a precisely calculated length, so that its expansion is the same as the complete pendulum rod and suspension spring. Any change in the length of the rod is balanced by a similar change in the tube and the pendulum bob.This method of temperature compensation was invented by Siegmund Riefler in1896 and is used in a number of precision clocks.

Next we have to consider the force of gravity. This, together with pendulum length determines the period. The force of gravity at a given location is virtually constant. It changes when you move from North to South or when you change the altitude.

Therefore a pendulum clock must be adjusted to the place where it is located. When we use the regulation nuts we change the length of the pendulum. In this way we can adjust the clock to a deviation of 1 to 2 seconds a day. But to reach an accuracy of 2 to 3 seconds a month we need to adjust the length of the pendulum (or more correctly its centre of gravity) with the fine regulation weights.

When we add weights to the fine regulation table in the middle of the pendulum rod, the centre of gravity of the pendulum is raised and the pendulum is accelerated, reducing its period. We can do this without stopping the clock.

When we remove a weight, the oscillation time is longer and the clock runs slow. In conclusion one can say that the pendulum of the M3 has all attributes that make a first class precision pendulum clock*.

The last unanswered requirement is the provision of a constant pendulum amplitude. This is not provided by the pendulum but is due to the power that is supplied to the pendulum to keep it oscillating. This is delivered by the escapement which is the connection between the gear train and the oscillation system.

The design and function of the escapement is explained in the next chapter.

We know already that it keeps the pendulum going. Since the friction of air and suspension system is almost constant (although that of the air varies with barometric pressure and humidity), the power supplied to the pendulum must also be as constant as possible.

Power is supplied to the gear train by a weight and because the force of gravity is constant it is constant.

This is explained in the section »driving force and gear train« on page 99.

Air-pressure compensation using a barometer instrument

In addition to temperature changes, the effects of which are counteracted by temperature compensation, air-pressure fluctuations also cause accuracy changes. This accuracy deviation, also known as the pendulum's air-pressure constant, equates to approximately one to two hundredths of a second per mbar (millibar) per day, depending on the shape of the pendulum body and its specific weight. This error is caused by a change in air resistance and the pendulum's buoyancy. The mean air pressure at sea level

(NN) is 1013 mbar and fluctuates between 930 and 1070 mbar (hPa, hectopascals). As a result, in the event of extreme pressure changes of 100 mbar, the accuracy* of your clock may change by around one to two seconds per day, as shown by measurements on our own pendulum test stand.

To counteract these deviations, Riefler has developed the concept of air-pressure compensation using aneroid capsules*, as can already be seen in aneroid barometers and barometric altimeters. Air-pressure fluctuations are generally short lived. These fluctuations may balance out, which means that if the accuracy is monitored over an extended period of around a month, they have very little impact. Using air-pressure compensation is nevertheless worthwhile.

We cannot assume that the air pressure has remained exactly level between the points at which the state of the clock* is checked. However, a good precision pendulum clock* features a steady motion and is not affected by outside interferences.

The barometer instrument available as an accessory for your Mechanica M3 compensates for accuracy fluctuations that are caused by changes in air pressure. To be more precise, we are referring to changes in air density or air weight that are proportional to the air pressure. Accuracy fluctuations caused by increasing air density arise from the pendulum's increased buoyancy. Together with other influential factors, such as increased air resistance, this causes the pendulum to swing more slowly.

The impact this error has on the pendulum depends on the shape of the pendulum and its specific weight. This impact cannot be calculated with sufficient accuracy and must be determined using very time-consuming measurements on a pendulum test stand housed in a sealed glass tank and isolated from environmental influences.

These measurements have been carried out for each component of your Mechanica M3 over months of test runs in the in-house laboratory of the clock manufacturer Erwin Sattler OHG.

Compensation works by changing the pendulum's moment of inertia by moving a mass on the pendulum rod and thus causing the period of oscillation to change. When using this kind of compensation, movement of the mass is brought about by the weight of the five aneroid capsules* or barometer capsules. Each of these capsules consists of two thin metal membranes that are soldered together in a vacuum. If the air pressure outside these capsules increases, they are pushed together and the counterweight lowers. This results in a total movement of 1.5 mm in the event of a pressure change of 100 mbar. Thanks to the capsule design, temperature influences do not affect the total stroke. The instrument is fitted between the pendulum pivot (pendulum spring*) and the centre of the pendulum rod. The position specified in the installation instructions must be followed exactly, as this is crucial for ensuring the precision of the compensation effect.

Accessories:

How barometer compensation works:

When the air pressure increases, the buoyancy of the pendulum increases and the air resistance rises. Without compensation, the pendulum would swing more slowly and the clock would lose time. The aneroid capsules* for the air-pressure compensation are pushed together.

This causes the counterweight to move downwards and the speed at which the pendulum swings to increase. Attentive clock construction kit customers may ask themselves whether we have made an error here. After all, by doing this we are changing the pendulum's physical centre of gravity, which must surely result in the oscillation slowing down. Did you not do exactly the same thing when setting your Mechanica M3? Moving the pendulum bob* downwards causes the clock to slow down. The same can be achieved by removing a fine adjustment weight from the support plate. To explain this slightly confusing fact, let's imagine a mathematical (ideal) pendulum, which consists of a massless pendulum rod and a point-shaped pendulum weight of any mass.

Increasing the mass of the pendulum weight on this pendulum has no effect on the period of oscillation. The same would happen if we were to add a mass to the fulcrum point of the pendulum (suspension). Neither effects the pendulum's moment of inertia or, therefore, the period of oscillation. Adding a mass at any other point on the pendulum rod between the fulcrum point and the pendulum weight accelerates the period of oscillation. This effect is most noticeable in the centre between these two points. You use this very concept when precisely adjusting* your Mechanica M3. If we consider the extent of the effects in relation to the position on the pendulum rod, we see the effect line illustrated by the parabola shown in the adjacent figure. This intersects with the pendulum rod at the fulcrum point on the pendulum spring and at the centre of gravity (centre of oscillation) at the level of the pendulum body. The vertex (maximum acceleration) is in the middle of the pendulum rod.

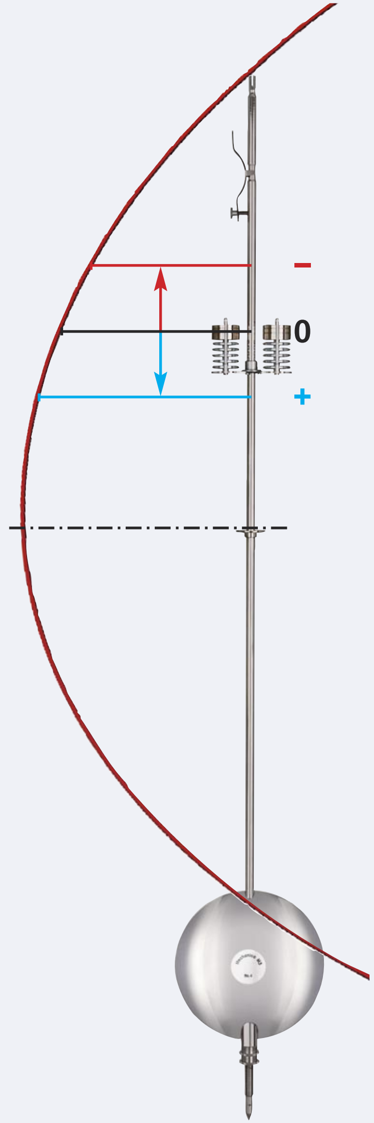
As shown in the schematic figure, this results in a mass above the middle that is being moved downwards, causing the period of oscillation to accelerate. Your compensation system works in accordance with this principle. This also highlights the importance of the instrument's position. Fitting it further up causes the gradient of the parabola to be more slight and increases the effect of

the displacement of the counterweight on the period of oscillation. This means that the compensation effect can be changed by moving the instrument

or changing its counterweight. You can reproduce this effect on your

Mechanica M3 as well, for instance by moving the regulation table on the pendulum rod downwards or upwards based on the vertex in the middle of the parabola. This will cause the period of oscillation to be reduced in each case.

The position of the barometer instrument on the various pendulum designs is shown in the figures on page 35.



The escapement

The escapement has two important tasks.

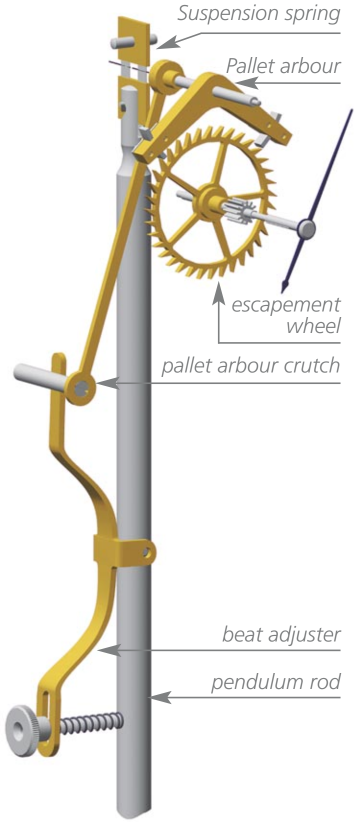
- It is the connection between gear train and oscillation system. It replaces the energy that the pendulum loses through friction.
- In addition to this it controls the gear train.

The action of the escapement is controlled by the pendulum, making it possible to 'count' the oscillations of the pendulum with the gear train and display them with the hands.

Since the discovery of the pendulum as an oscillation device for clocks, different escapement systems were developed which worked more or less satisfactorily.

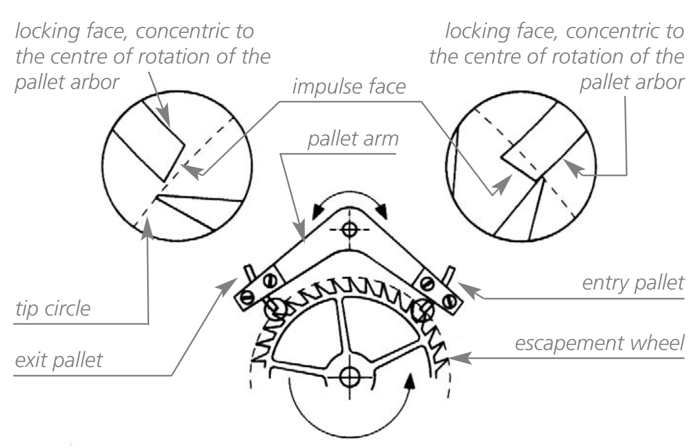
In our M1 we use the so-called 'dead beat' escapement invented by George Graham in 1720. This is why it is also called Graham escape-ment*. This escapement evolved from the earlier escapements and its simplicity and reliability is unmatched. In some cases escapements were invented that work more precisely but they are much more complicated and difficult to set up.

To understand the genius of this escapement, we have to take a closer look at its design and the physical basis.



The escapement and its parts are sho on figure 1.

Figure 1



The escapement consists of the sharp tips of the escapement wheel and the escape arbor with its two paletts. The escape wheel, like all other wheels, is mounted between the two plates.

The pallet arm and the crutch are attached to the pallet arbor mounted, between the front plate and the pallet arbor bridge*.

The crutch reaches behind the movement and is the connection to the pendulum. The crutch is rigid and moves with the pendulum. The centre of rotation of the crutch and the pendulum should lie on the same line, horizontally and vertically.

We can see that the action of the crutch as the pendulum swings causes the entry and exit pallets to engage with the tip circle of the escapement wheel.

The pallets are made of achat. They have a curved shape and are positioned so as to have the same centre of rotation as the pallet arbor. The ends of the pallets which engage with the tip circle of the escapement wheel are bevelled and polished. They are the impulse faces*.

The outer radius of the entry pallet and the inner radius of the exit pallet are the locking faces*. The escapement gives a regular supply of energy to the pendulum.

It is an advantage if the impulse takes place when the pendulum has its highest oscillation speed and its highest kinetic energy. This is the case when it moves through the zero position. At this time interference with the pendulum (giving it a push) will have the least effect on timekeeping.

Hint:

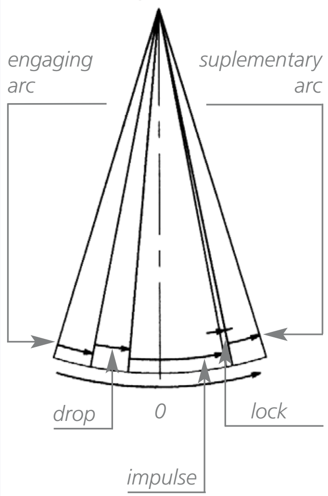
The escapement function you find at the end of the book table 3A-G

One half of an oscillation is divided into five steps that are shown in figure 2 as angular stages. Thecomplete escapement function and the positions of the pendulum are shown on table 3A-G during one half oscillation of the pendulum.

To explain the single steps, it is important that you understand the sequence of the function.

Figure 2

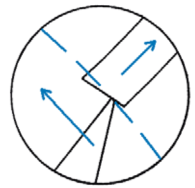
One half oscillation of the pendulum from the left to the right extremes, divided into 5 angular steps



Explanation of each part of the swing

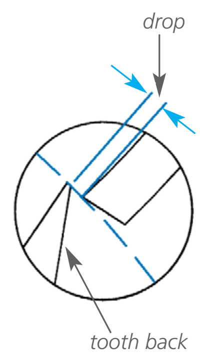
Impulse

The impulse* is one of the two important functions of the escapement. During the impulse the pendulum receives the necessary energy that is needed to keep it swinging. One tip of the escapement wheel slides along the impulse face and gives a partial turn to the pallet arbor. In the Graham escapement the impulse takes place as the pendulum moves through the zero position.



The Drop

The drop* is the free movement of the escapement wheel, after the escapement wheel tooth has left the impulse face. The drop is necessary so that the pallet can engage with the tip circle without hitting the back of the escapement wheel tooth at the next half oscillation. In addition a bigger drop ensures that the escapement works correctly even if the escapement wheel has small pitch errors. For a reliable escapement function it is necessary that the drop is equal on both pallets.

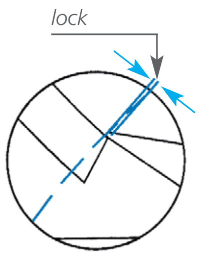


The escapement wheel tooth has dropped from the impulse face o the entry pallet, another tooth drops on the locking face of the exit pallet and the pendulum moves on to the end of its swing. During this time the escapement wheel is locked and the motion of the gear train is arrested.

This is the second important function of the escapement and because of this it is called dead beat escapement.

This is possible because the pallets are positioned concentrically* and has the advantage that the friction on the locking faces is constant.

The path of the pendulum from the end of the impulse and drop to the inversion point is called supplementary arc*. The engaging arc is from inversion point to the locking. The engaging arc plus locking should be as big as the arc between the zero position and the end of the impulse. This ensures proper function, even when the clock is not levelled perfectly and the drop is not symmetrical to the zero position of the pendulum. This problem is called 'beat error'. The beat error can be corrected by manipulating the beat adjuster on the pendulum rod. The beat error is heard when the ticking of the clock is not balanced. It sounds as if the clock is limping. By turning the knurled screw on the beat adjuster* the relationship of the pendulum to the pallet arbor can be changed so that the tick is even.



Finally locking has to be explained:

The lock is the small distance between the edge of the impulse face and the point on the locking face where the escapement wheel tooth lands after the drop. It's only a fraction of a millimetre but prevents the escapement wheel tooth dropping onto the impulse face and stopping the oscillation of the pendulum.

In conclusion one can say that the lock provides a safety margin when the escapement wheel has a small concentricity error.

We make the escapement wheel so precisely that we can guarantee a concentricity error* of less than 0.02mm. The amount of lock can be adjusted by shifting one pallet in the pallet arm.

The lock of your clock is slightly bigger to ensure a proper function in serial production.

As you can see on figure 2, the lock moves the impulse a little out of the zero position. Theoretically it is useful to adjust the lock to be as small as possible and then to check that each escapement wheel tooth drops onto the locking face.

This is not necessary and you should only move the pallets if you are able to adjust them very precisely.

The same caution is necessary when making fine adjustments to the drop.

The drop must be equal on both pallets. To check the drop and lock of the preadjusted escapement, you should apply power to the gear train by pushing the crank against the winding direction. Now you can move the lever back and forth and watch with the eyeglass through the holes in the back plate how the escapement works (as described on page 57). At first check the drop.

The drop is the free movement of the escapement wheel, after a tooth leaves one pallet and another tooth is stopped by the other pallet.

We can see this by observing at the distance between the end of the impulse face and the tip of the tooth which has stopped after leaving it. This distance is the drop, and can be seen on the entry and exit pallet while moving the lever fork back and forth.

We admit that it is difficult to see any small differences and that it takes a little patience and practice. If you notice an unequal drop, it can be adjusted by turning the eccentric bushing* in the lever bridge. When the drop on the exit pallet is too big turn the bushing a little clockwise. If it is too small turn counter clockwise.

When the drop is equal, check the lock. Check if every tooth drops safely on the locking face on both pallets.

If one tooth drops on the impulse face, one of the two pallets has to be pushed deeper into the tip circle of the escapement wheel.

When adjusting the escapement it is very important to work in the right order. First adjust the drop then the lock, because turning the eccentric bushing also changes the engaging distance of the pallets to the escapement wheel.

To get an idea of the incredible precision provided by the pendulum and escapement of your Mechanica M3, we can put together a small calculation:

60 seconds in a minute

60 minutes in an hour and

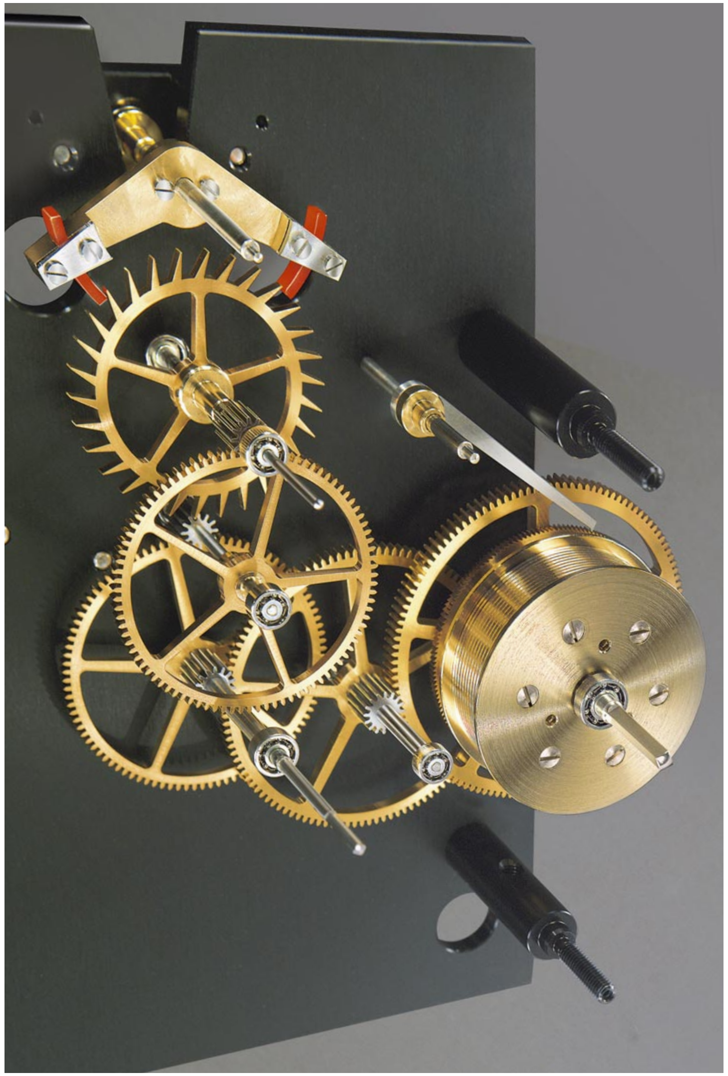
24 hours in a day, multiplied together, result in:
86,400 seconds in a day,
or multiplying this by
7 days in a week results in: 604,800 seconds in a week.

If your Mechanica M3 were to drift by one second a day, this would correspond to an incredible accuracy of 99.9989%.

A very realistic drift of one second per week would mean an accuracy of 99.9998%.

Driving mechanisn and gear train

The driving mechanism together with the gear train has to supply the escapement and the pendulum with energy. It also drives the hands.



The driving mechanism

As mentioned in the chapter about the pendulum, we know that we have to drive the pendulum with a constant force to produce consistent oscillations of the pendulum.

This force we get from a weight, which puts, because of gravity, a constant force to the barrel wheel.

Therefore the gear train receives a constant force which transmits constant force to the pendulum.

The height of fall*, determined by the case and the diameter of the cable drum, result in 12 revolutions of the barrel wheel per month. The second hand fixed on the escapement wheel turns 43000 times during this time.

The gear train has to transmit the slow turns of the great to the rapid motion of the escapement wheel. The force transmitted must be as constant as possible to ensure a steady impulse to the pendulum. The force is reduced in the same ratio as the gearing.

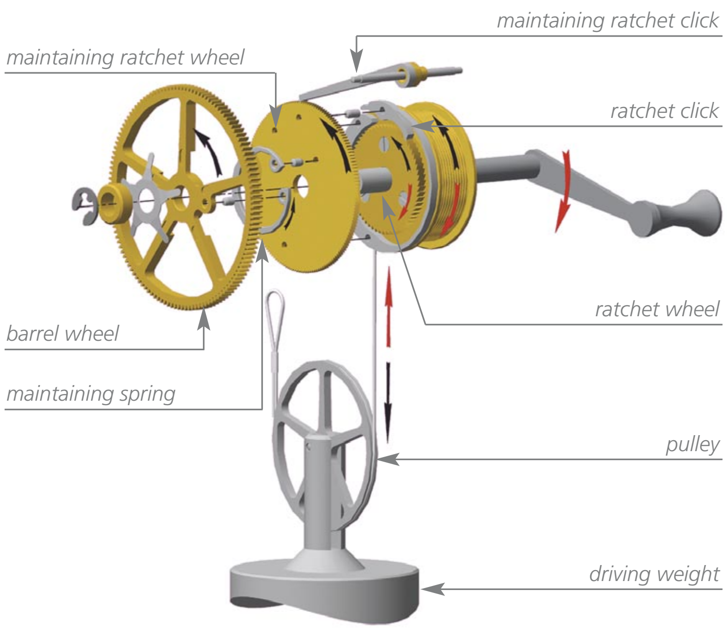
The weight doesn't hang directly on the cable drum, it works via a pulley. The driving force is halved by the pulley and so is the fall, doubling winding period.

Maintaining power mechanism

When you wind your M3, the steel cable winds on the drum and the weight moves upwards. During this time the weight cannot put force on the gear train and the clock stops. To avoid this your M3 is equipped with a maintaining power mechanism*.

It has following parts:
- Maintaining wheel
- maintaining click
- maintaining spring

The circular maintaining spring is positioned between maintaining ratchet wheel and barrel wheel and connects both parts. The maintaining ratchet wheel and barrel wheel can rotate freely on the barrel-wheel arbor. The winding ratchet, pivoted on a separate shaft between the plates, engages with the teeth of the maintaining ratchet wheel.



The function of the maintaining power is very simple: Under normal working conditions the driving weight puts force on the barrel (black direction arrow). This, transmitted via the ratchet wheel and the click on the maintaining ratchet wheel, puts tension on the maintaining ratchet spring and drives the movement. When the clock runs down the maintaining ratchet wheel rotates freely underneath the maintaining ratchet click. When winding (red direction arrow), the weight moves upwards and cannot drive the movement, the maintaining spring wants to expand and the maintaining ratchet wheel ensures that the force is transmitted to the barrel wheel which drives the movement during winding.

Gear train

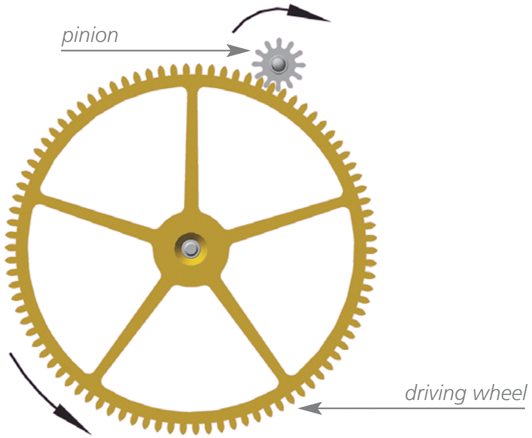
The weight is 3000g, because of the pulley the movement receives half of that, 1500g.

The transmission ratio from barrel wheel to escapement wheel is 1 to 3840. If we divide 1500g by this huge transmission ratio we get only 0.39g on the escapement wheel.

This is only a rough calculation, but it demonstrates what remarkably little force is required to operate a precision clock movement. If we were to make an exact calculation of the torque the result would be even lower without taking the friction into account.

This shows what a good gear train achieves. The gear train must transmit power evenly to the escapement with only small losses. In addition to this it should work for a long time without wear.

The gear train of your M3 is a completely new development. We put our more than 30 years experience building precision clocks into fulfilling the most demanding criteria for a perfect gear train.



In a gear train clockmakers call the bigger driving gear a »wheel« and the smaller driven gear a »pinion«*. Wear is a result of friction. It takes place in bearings and the engaging surfaces of wheels and pinions. Engagement is the mating of the teeth of a wheel with teeth of another wheel.

Friction

Most of the friction occurs in the bearings of the wheels. In common clocks the thin pivots* turn directly in holes of the front and back plate (most made of brass) and are lubricated with some oil. This form of bearing serves well for ordinary clocks, but has the disadvantage that because of abrasion, dirt, and evaporation, the oil looses its lubricating abilities. This increases the wear, the holes enlarge and there is a loss of driving force; the clock keeps stopping. As the bearing holes get larger the engagement distance changes producing a further loss of driving force.

For this reason some precision clocks have jewelled bearings. Even after decades these bearings show hardly any wear. To avoid friction however these bearings need oil. But every oil ages and the bearings must be cleaned and relubricated regularly to avoid damage.

The friction of these bearings is called sliding friction, because the pivot slides with its circumference along the wall of the bearing hole.

Ball bearings can interfere with how our gear train runs, for example due to dust. However, our movement is adequately protected against this interference thanks to the specially sealed case.

This bearing is excellent for clocks and enables us to work with less driving force, as the ball bearings produce less friction, resulting in reduced loss of power. Less driving force also means less strain on the teeth, which in turn increases the longevity of the gear train.

Next we focus on the friction in individual wheel-pinion engagements.

A number of factors determine the amount of friction:

- The material, especially the combination of materials
- The shape of the wheel teeth
- The number of teeth
- The transmission ratio

Materials:

Your Mechanica is equipped with hardened steel pinions and brass wheels.

This is for two reasons:

- First the higher rotation speed of the pinions puts more load on the teeth, therefore the material must be harder.
- The friction between two different materials is less than between identical materials. In clockmaking the combination of brass and steel serves well.

The shape of teeth:

Compared to other technical devices, clocks have a very high transmission ratio. This makes a special shape of the teeth necessary for a smooth power transmission. The theoretically perfect shape for this purpose was developed centuries ago, but it cannot be produced, not in the past nor in the present.

We use a tooth shape that comes as close to the ideal as possible, where the teeth almost roll in the engagement and don’t slide. It’s called involute gearing and comes close to the ideal cycloidal* gearing.

The number of teeth, and the transmission ratio, have a close relationship.

Experience shows that it is an advantage when as many teeth as possible engage with the other wheel at the same time. The transmission of power is then very smooth, with little friction. This is achieved by using pinions with a high number of teeth. More than 10 is ideal. Experience also shows that a high transmission ratio produces more friction, and a ratio of less than 1 to 10 is ideal.

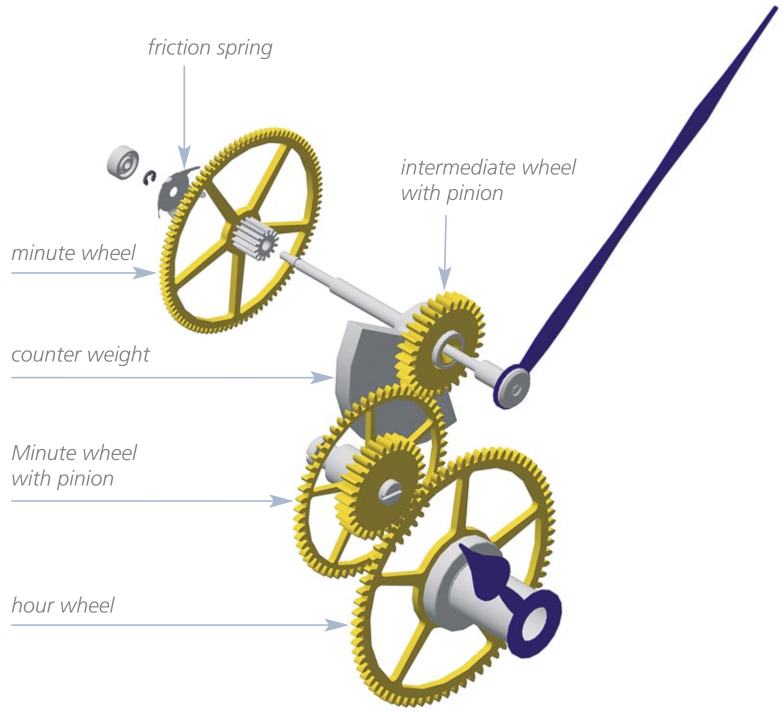
Your Mechanica has pinions with 12, 14 and 16 teeth. The transmission ratio is between any wheel/pinion pair is between 1 to 8 and 1 to 7.5.

The motion work

The The last part to be explained is the motion work*.

The centre arbor carrying the minute hand goes around once an hour. It has to be geared down by a ratio 12 to 1 for the hour hand. Because both hands must turn in the same direction two steps must be used. The ratios are 2 to 1 and 6 to 1. The minute hand sits directly on the minute wheel arbor. To be able to set the hands, it is necessary to be able to disconnect the minute wheel arbor from the rest of the gear train. This is done by the use of a friction* spring between the minute wheel and its pinion.

We use a preloaded friction spring with 5 arms that works like a slipping clutch. A simple minute hand is very unbalanced. In the first half of an hour it supplies power to the gear train, in the second half it absorbs power producing an uneven load. It is therefore balanced with a counter weight* out of sight behind the dial.



All of these points combine to form a robust gear train that satisfies all possible requirements for a precision pendulum clock*.

A

Amplitude:
The angle through which a pendulum moves from is central position to one extreme. On the pendulum scale you can read the amplitude in minutes of arc.

Aneroid barometer compensation:
Device to compensate for the influence of the changing air pressure on the accuracy of a clock. It will be available for the M3 in the future.

Anodise:
Electro-chemical treatment of aluminium. Surface is treated in acid-bath. The result is a very durable oxidation layer. The M3 has a few anodised parts like plates, crutch and barrel.

Arbor:
Shaft in a movement.

B

Ball bearing:
A bearing in which balls roll in a groove between the inner and outer ring. The rolling friction is very low. This is why ball bearings have very low friction and almost no wear. In the M3 the ball bearings have a very low load and need no oil.

Barre:
Cylinder on the barrel arbor. When winding the weight the cable is wound around the circumference of the barrel. The barrel has grooves like a thread to prevent the cable from scratching.

Barrel wheel:
First wheel in the gear train. Mounted on the barrel arbor together with the barrel, the ratchet and the maintaining power device.

Beat:
The tick of the clock. Said to be in 'in beat' when the tick is even and occurs in the same position when the pendulum is approaching either extreme. The supplementary arcs are equal.

Beat adjuster:
Device to adjust the beat. With a screw you can adjust the relationship between the pallets and the pendulum by tilting the crutch.

Bezel:
Dial ring

Blueing:
Heat treatment of carbon steel. If polished or ground steel is heated to ca. 300°C an oxide builds up on the surface which appears blue.

Brass:
Alloy of copper and zinc. The gears of your M3 are made of brass. As protection against corrosion they are gold plated.

C

Calibre:
Type of movement.

Cannon pinion:
Part of the motion work. Attached to the minute wheel arbor. Drives the intermediate wheel.

Centre wheel:
Part of the gear train. Transmits power from the barrel wheel to the minute wheel.

Click catch:
Unit consists of ratchet wheel, ratchet and ratchet spring. Locks the barrel to the gear train. In the opposite direction it allows the clock to be wound.

CNC:

Computer Numeric Controlled. Manufacturing of parts with computer

Compensation pendulum:

A specially designed pendulum that does not change its length when temperature changes.

Compensation tube:

Part of the pendulum. Sits on top of the regulation nuts and compensates for the linear expansion of the pendulum rod.

Concentric:

Two parts or circles have the same centre.

Concentricity error:

manufacturing in our workshop we are able to reduce the concentricity error to 0.02 millimetres.

Counter weight:

The minute hand is a unbalanced lever that absorbs power for half an hour, and supplies power for half an hour. To compensate this we installed a counter weight on the cannon pinion opposite to the hand.

Crutch:

Lever that connects the pallet arbor with the pendulum.

Cycloid:

Generating circle. A geometrical line, that appears when rolling a circle on a geometrical contour. Has served well for gears in clocks and is still used today.

D

Dome:

To dish. Method to enhance attraction of hands for example. For the M3 hand-domed and blued hands are available as an accessory.

Drop:

Free motion of the escapement wheel, after the escapement wheel tooth slipped off the impulse face of the pallet fork. Drop is necessary to avoid pallets bumping into escapement wheel teeth.

E

Eccentric bush:

Bushing with an off-centre hole. Mounted into the pallet arbor bridge. By turning the bush, the engagement distance of pallets and escapement wheel changes and the drop can be equalized.

Engagement:

Engagement is the gearing of wheel and pinion. The transmission of force is better the more teeth are in the engagement.

Escapement:

Unit consisting of escapement wheel and pallet arbor. The escapement transmits the power to the pendulum that is necessary to maintain its amplitude. It also ensures that the gear train runs down gradually with the escapement wheel turning once a minute.

Escapement wheel:

Part of the escapement. Wheel that engages the pallets.

In the Mechanica M3 it turns once every 60 seconds and is mounted with a bushing on the escapement wheel arbor to which the second hand is attached.

F

Fine regulation:
Exact adjustment of period of the pendulum by adding small weights on the fine regulation table. Adding weights speeds up the clock. Removing weights slows it down.

Fourth Wheel:
Part of the gear train between the minute wheel and the escapement wheel.

Friction:
When designing a movement, avoiding friction is a main goal. Therefore all gear train bearings are equipped with ball bearings. Sometimes friction is necessary, for example, at a friction spring acts as a slipping clutch in the motion work, to make setting hands possible.

G

Gear train:
Gear train transmits force to the escapement. It is calculated in a way that some arbors make a fixed number of revolutions relating to time measurement. These arbors carry the hands. Wheels are sometimes numbered from the slowest. Numbers vary with the running time of the clock. The month-running Mechanica has four. The escapement wheel is no regarded as a gear.

Graham escapement:
Dead beat escapement. Invented 1720 by clockmaker George Graham of London. Thanks to the special shape of the pallets the escapement wheel is stationary while the pendulum makes the supplementary arc. The Graham escapement was an enormous step in precision clockmaking and has served well for centuries.

H

Height of fall:
Distance, the weight can run down.

High grade steel:
compound with other metals like nickel or chrome, gives steel special properties like anti corrosion.

Hour wheel:
Part of the motion work. Turns once in 12 hours and is driven by the intermediate wheel pinion. The pipe of the hour wheel carries the hour hand.

I

Impulse:
Process where the driving force is transmitted to the pendulum.

Impulse face:
Inclined plane on the pallets. The tip of the escapement wheel tooth slides along the impulse face and transmits a driving impulse to the pendulum.

Intermediate wheel:
Part of the motion work. Sits on the intermediate wheel stud and is driven by the cannon pinion.

Invar:
Special Iron-Nickel alloy with 36.8% nickel. Tempered Invar has a thermal expansion ten times less than steel. The alloy was invented by Charles Edouard Guillaume at the end of the 19th century. Sigmund Riefler was the first to use it 1896 as material for pendulum rods in precision clocks.

Isochronism:
The constancy of the period of the pendulum with changes in amplitude. Only achievable with small changes at low amplitude.

L

Locking face:

Curved plane on the pallet which arrests the movement of the escapement wheel.

Lock nut:

Knurled nut mounted under the regulation nut and prevents the regulation nut from turning.

M

Maintaining power mechanism:

Movement unit, consists of maintaining wheel, maintaining power spring, maintaining click. Transmits power while winding the clock.

Minute wheel:

Part of the gear train. Riveted to the centre wheel pinion but free to rotate on the minute arbor. Linked to the train by a friction spring. Drives the fourth wheel pinion.

Motion work:

Unit with two engagements. Transmits the motion of the minute hand with the ratio 1/12 on the shaft of the hour hand. Motion work has cannon pinion intermediate wheel, intermediate wheel pinion and hour wheel.

O

Oil sink

Hemispherical hole at the outer opening of a bearing. The oil sink hold a small amount of oil as reserve.

P

Pallet:

Part of the pallet arm on the pallet arbor, made of hardened steel or jewel. The pallets are ring segments inserted in the pallet arm. The centre of the ring segments is identical with the rotation centre of the pallet arbor. The polished inclined planes are called impulse faces. In the future, jewelled pallets will be available for the Mechanica M3.

Pallet arbor bridge:

Bearing of the pallet arbor on the back plate.

Pendulum:

Still today's best mechanical oscillation device. The period is determined by the length of the pendulum and the force of gravity.

Pendulum bob:

Heavy cylindrical weight at the lower end of the pendulum rod. You can choose from stainless steel or bronze.

Period:

Strictly speaking, the time taken for a pendulum to swing from one extreme to the other and return. Clockmakers traditionally only consider the time taken to swing from one extreme to the other. Following this tradition, your Mechanica has a 5/6th second pendulum.

Pillar:

Also movement pillar. Keeps distance between the plates.

Pinion:

Gear with less than 20 teeth. Manufactured in most cases of hardened steel. The M3 has 5 hardened pinions. Intermediate wheel pinion, centre wheel pinion, fourth wheel pinion, escapement wheel pinion, minute wheel pinion.

Pitch:

The distance between two tips of teeth, i.e. the circumference of the pitch circle divided by the number of teeth.

Pivot:

Thin end of a shaft. Part of the shaft which turns in the bearing holes of the plates. The pivots in your M1 are made of hardened steel.

Plates:

Hold the bearings and are the base for all other movement parts. The M3 has anodised aluminium plates.

Precision pendulum clock:

Sophisticated timekeeper with extremely high accuracy. Clocks with compensated pendulums were used until the late 60´s as reference time for science and official standard time.

R

Rate:

Daily rate is the time difference between the clock being tested and the standard time (radio controlled clock).

Reading:

The time that the clock displays.

Regulation:

Refer to fine or rough regulation.

Regulation nut:

Knurled nut at the lower end of the pendulum. With the regulation nut the pendulum bob can be raised or lowered. Shifting the bob upwards makes the clock faster.

Regulation pin:

Stainless steel pin which has to be inserted into the lateral hole at the tip of the pendulum. With this pin you can hold the pendulum when turning the regulation nut and avoid damage of the suspension spring.

Regulation weights:

Zierreif für das Zifferblatt.

Regulator dial:

Classic precision clocks have this special way of displaying time with separate dials for hours minutes and seconds. This avoids the need for motion work but requires the gear train to be modified so that one arbor (for the hour hand) turns twice a day. The hour hand never obscures the seconds dial. An regulator dial for the M1 will be available in the future.

Rough regulation:

Adjusting the accuracy of the M1 with the regulation nuts at the tip of the pendulum. You can adjust the clock up to ca. 1 sec. a day.

S

Spring:

The beat adjuster has a coil spring.

Supplementary arc:

Oscillation phase of the pendulum. Outbound supplementary arc: pendulum travels from the end of the drop to the turning point. Inbound supplementary arc: pendulum travels from turning point to locking.

Suspension spring:

Spring steel strip between brass jaws. The suspension spring holds the pendulum.

T

Temper:
Carefully controlled heat treatment of the Invar rods to relieve stresses in the material. Only tempered Invar rods have predictable thermal expansion.

Torque
Zierreif für das Zifferblatt.

Transmission ratio:
Determined by the number of teeth in a pair of engaging gears. Expressed as the number of turns the driven gear makes when the driving gear turns once.

Tungsten:
Very heavy metal, density 19.3g/cm3.

W

Winding period:
Time a fully wound clock will run without rewinding. The winding period depends from the height of fall, the measurements of the barrel and the gear ratio. Your M1 has a 30 day winding period.

The movement

- Plates* made from 4 mm thick aluminium, anodised*
- Gear train* completely fitted in 10 ball bearings*
- Hardened steel pinions*
- Gear wheels with fine spokes, milled, finely ground and gold-plated
- Graham escapement* with adjustable agate pallets
- Dial made from hard anodised* aluminium
- Hands made from steel, hand-finished and blued*

The clock

- Seconds pendulum clock with 30-day power reserve
- Achievable accuracy: +/- three to four seconds over the course of a month
- Driving weight made from lead; 3000 g with pulley
- Case made from solid, untreated precious woods in cherry, and black lacquered in walnut or in alder
- Case sealed against dust
- Hidden shelf integrated into the base of the case for accessories
- Pendulum cock and movement holding arrows screwed directly onto the back panel of the case
- Engraved plaque available on request at no extra charge with the signature of the customer

The pendulum

- Pendulum rod made from heat-treated Invar*
- Solid pendulum cylinder* made from bronze*
- Temperature compensation
- Fine regulation table
- Seconds pendulum

We offer the following accessories to enable you to improve the technical characteristics (durability and accuracy) and appearance of your Mechanica M3:

- **Bevelled* mineral glass panels** — page 23
  For enhancing the visual aesthetics of your case.
- **Double barometer instrument** — pages 33 and 86
  For compensating for brief accuracy changes caused by air-pressure fluctuations.
- **Solid turned and polished pendulum bob*** — page 34
  Its aerodynamically optimised shape reduces air resistance and causes the pendulum to swing more steadily.
- **Set of fine-polished screws** — page 42
  A 29-piece set of fine-polished and fine-turned stainless steel screws* and washers.
- **Cutaway in the regulator dial*** — right-hand side
  Provides an unobstructed view of the seconds display.
- **Set of hand-worked hands** — page 63
  Hand-domed*, hand-polished and hand-blued hands.
- **Ball bearing rope pulley** — page 67
  Attractive appearance and reduced loss due to friction.
- **Set of precision adjustment weights** — page 74
  Twelve-piece set of fine adjustment weights* in a precious wood case.
- **And much more.**

The production of these extremely complex accessories depends heavily on the demand for each accessory and is subject to ongoing expansion. For more information, please contact Müller & Sattler Uhrenbausatz GmbH directly or visit our website:

www.uhrenbausatz.de

MODEL CLASSICA SECUNDA 1985

The great inspiration for your Mechanica M3 is the Classica Secunda 1985 precision pendulum clock from the clock manufacturer Erwin Sattler in Munich.

With its Classica Secunda 1985 model, Sattler is continuing the tradition of precision pendulum clockmaking in Germany. Clocks like this were used as scientific instruments up to the middle of the last century, and were engineered to perfection down to the last detail due to the importance of absolute precision.

With this in mind, the case, which is 142 cm high, 36 cm wide and 17 cm deep, is fitted with bevelled* glass panes on three sides and features lasting protection thanks to multiple coats of varnish. The hands are meticulously domed*, polished and then blued* by hand. They show the time precisely on the engraved and silver-plated regulator dial*.

The Invar pendulum compensates for changes in temperature and air pressure by changing the length of its pendulum, ensuring that it always swings at precise one-second intervals.

All components of the movement, which features a 30-day power reserve, boast a superb finish and are decorated with lacquer or gold plating. The high degree of perfection in the engineering of this precision pendulum clock not only ensures accuracy but also provides a delightful appearance thanks to the intricate mechanism.

The Classica Secunda 1985 model pictured and all other models in the Sattler collection are of course not available as construction kits. These clocks are sold exclusively by selected clock retailers.

If you share our joy and enthusiasm for the fascinating world of clocks, we would be happy to send you the latest Erwin Sattler catalogue, including a list of retailers, free of charge.

Erwin Sattler GmbH & Co. KG · Clock manufacturer
Lohenstraße 6 · 82166 Gräfelfing · Germany
www.erwinsattler.de

Accuracy table as a copy template

This accuracy table is designed to help you check the accuracy of your M3. The recordings will also be extremely helpful to you when performing regulation. When doing so, it is recommended that you note the number and size of the counterweights on the fine regulation table.

A standard radio-controlled clock is perfectly adequate for use as a reference when checking accuracy. With a little practice, you can notice differences of less than 0.5 seconds between the two clocks. Ideally, the two clocks should always be compared at the same time of day.

It is not absolutely necessary to record the temperature, air pressure and amplitude, but doing so can help you to draw conclusions about the cause of any accuracy fluctuations.

Formula for calculating the »accuracy«

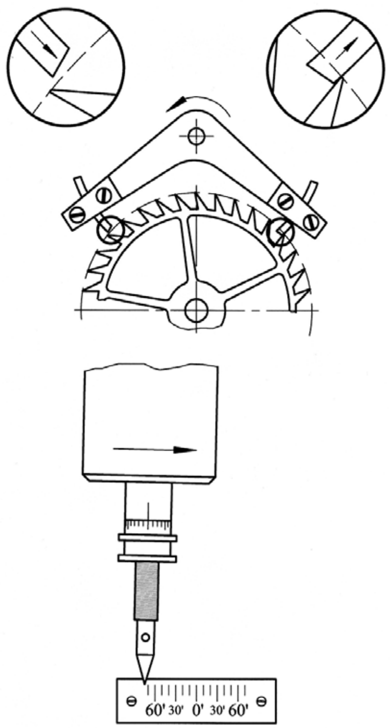
$$\frac{\text{Accuracy}}{\text{24 h}} = \frac{\text{difference between the status}}{\text{Time difference}} \times 24$$

Accuracy table

Date	Time	Temperature	Air pressure	Amplitude	**Status =** difference in comparison to the official time in seconds	**Difference between statuses** from one recording to the next	**Time difference** between the recordings in hours	**Accuracy** / 24 h in seconds	Comments

Functional sequence of the escapement — figures 3A to 3G

FIGURE 3A

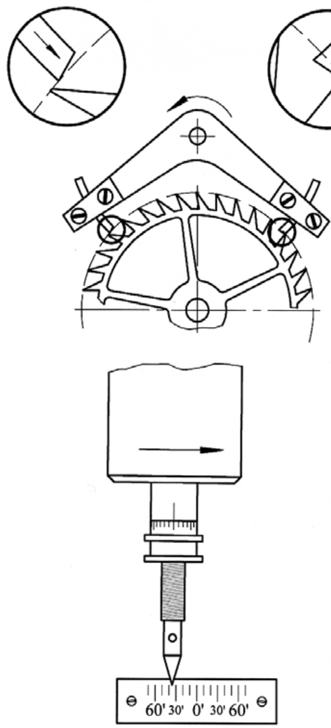


Escape wheel:
Resting against the locking face of the entrance pallet and does not turn, i.e. is »locked«.

Pallet lever:
Following the movement of the pendulum.

Pendulum:
Is located at the left-hand inversion point at the start of the inward swing before release of the escape wheel.

FIGURE 3B



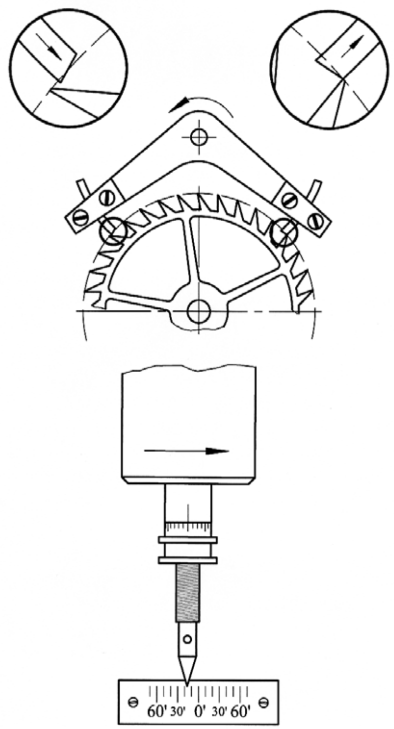
Escape wheel:
Is locked.

Pallet lever:
Following the movement of the pendulum.

Pendulum:
Is at the end of the inward swing before release of the escape wheel.

Is at the start of the locking angle.

FIGURE 3C

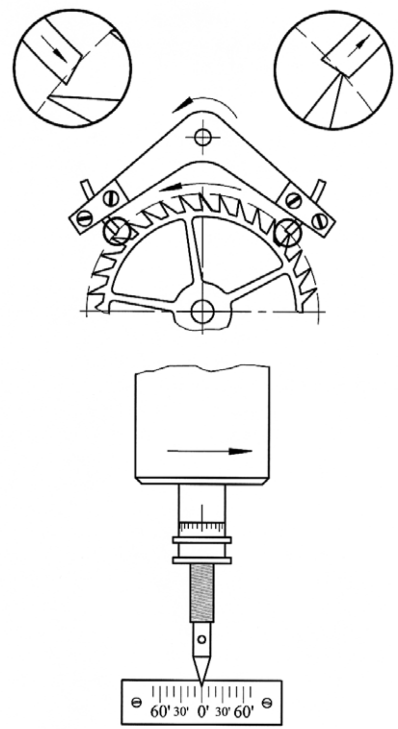


Escape wheel:
Is still locked.

Pallet lever:
Following the movement of the pendulum.

Pendulum:
Is at the end of the locking angle.

FIGURE 3D

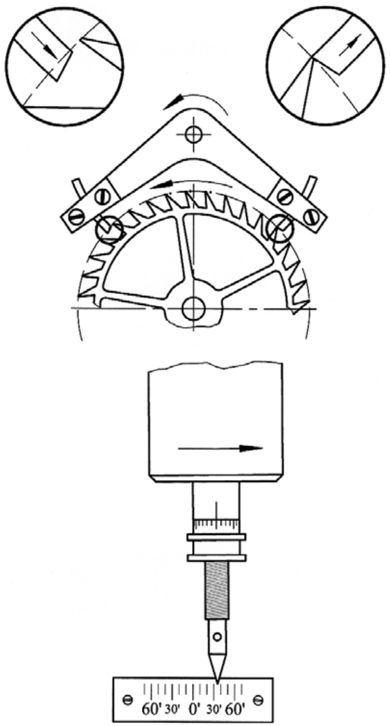


Escape wheel:
Sliding over the pallet face of the entrance pallet, lifting the pallet lever, providing an impulse.

Pallet lever:
Transferring the impulse to the pendulum.

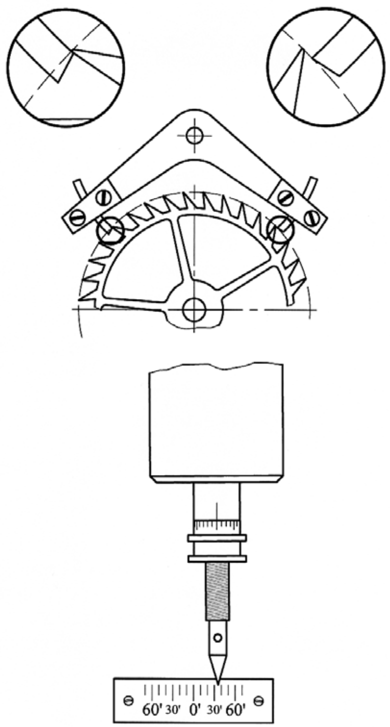
Pendulum:
Starting to receive the impulse (at the start of the lift angle).

FIGURE 3E



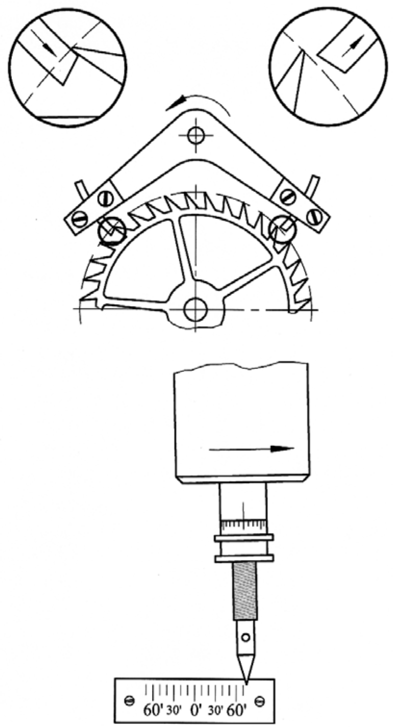
Escape wheel:
Is at the end of the pallet face, finishing the drive impulse, about to start falling.
Pallet lever:
Finishing transferring the impulse.
Pendulum:
Finishing receiving the impulse.

FIGURE 3F



Escape wheel:
Has finished falling.
Has just fallen from the pallet face and is now resting against the locking face of the exit pallet.
Pallet lever:
Following the movement of the pendulum.
Pendulum:
Has just finished receiving the impulse.

FIGURE 3G



Escape wheel:
Is locked.
Pallet lever:
Following the movement of the pendulum.
Pendulum:
Is finishing the outward swing.

BOOKMARK AND VISUAL BACKGROUND FOR CHECKING THE ESCAPEMENT

(Page 57)

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