The MPS x-myrox bearing: The non-lubricated watch bearing

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Abstract
Lubrication of the moving parts in a mechanical watch movement has been a major concern of watchmakers for some time. In spite of technical advances in lubricants, ageing of the oils is one of the principal causes of the poor running of mechanisms over time. Cleaning and re-lubrication of the moving parts are recommended in principle at least every 5 years. MPS, in presenting a 4 point contact bearing which requires no maintenance other than ensuring impeccable cleanliness, is today regarded as a leader in its field. The manufacture Jaeger-LeCoultre is mentioned in this publication by reason of the important means invested in a program of tests which had a duration of one year aimed at quantifying the advantages associated with the use of the x-myrox bearing compared with a standard 4 point contact bearing (known as a watch bearing). The laboratory of Patek-Philippe, equipped with an anechoic chamber, carried out the tests dedicated to the comparative noise tests.

1. Design of the standard 4 contact point bearing

The 4 contact point ball bearing comprises 5 components: race, core, cone, cage or ball separator and balls.

The ring, core and cone are usually machined from 20AP (1.1268+Pb) chromium steel or in some cases all or partly from CuBe. The cage is stamped from CuBe (cuproberyllium). The balls are manufactured from 100Cr6 (1.3505) chromium steel, X105CrMo17 (1.4125) stainless steel, or, for moving part functions, from synthetic rubies.

2. Risks associated with the use of a non-lubricated bearing

After a length of time which depends on the speed and the mechanical stresses present, the use of a standard steel bearing with no added lubricant generates micro-welds on the surfaces of the components (race, core and balls) in contact under load.
Moreover, the steel micro-particles generated by this phenomenon may become detached and contaminate the movement or even cause it to stop.

3. Design of the x-myrox bearing

The construction of the x-myrox bearing is in all respects comparable to that of a standard bearing. The difference lies in the choice of materials.

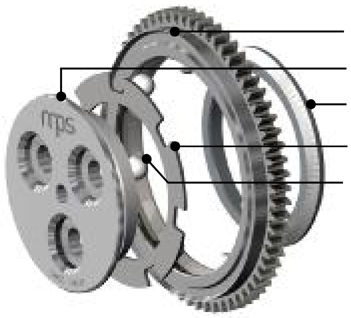

Fig. 1: Exploded diagram of x-myrox 4 contact point bearing

3.1 Material used for the ring, core and cone

MPS uses 4C27A (1.4197) stainless steel for machining the bearing races to minimise risks of corrosion.

3.2 Material used for the balls

The real innovation is the introduction of ceramic as the basic material for manufacturing the balls. In this way, the risks of micro-welds mentioned in section 2 are eliminated.

Moreover as mentioned in section 1, the synthetic ruby is already used in certain ball bearings for moving parts, but cannot under any circumstances be used in a bearing with oscillating mass, in a watch with automatic rewind.

In actual fact, the low shock-absorbing capacity of synthetic ruby balls means that they shatter at the moment of impact.

It was therefore a question of determining what type of ceramic would be able to meet the following specifications:

- Shock resistance up to 5000 g (drop hammer test).
- Expansion coefficient similar to that of steel in order to guarantee the same operating clearance at extreme temperatures.
- Production means and capabilities to make miniature balls up to 0.200 mm.
- Geometric quality and surface criteria identical to those of steel balls.

The ceramic which proved to be the most suitable material for these constraints is zirconium oxide (ZrO_2).

Its major advantages are:

- high hardness (ZrO_2: 1200 HV / Steel: 800 HV)
- modulus of elasticity similar to steel (ZrO_2: 220,000 Mpa / Steel: 210,000 Mpa).

Main characteristics of the zirconium oxide chosen:

Characteristic	Value
Density	6.0 g/ cm^3
Hardness	1150-1200 HV
Expansion coefficient	11x10^{-6}•K^{-1}
Tensile strength	10 Mpa•m$^{1/2}$
Bending strength	> 1800 Mpa

3.3 Material used for the cage

With the standard 4 contact point bearing, an analysis of several bearings observed after an operating time equivalent to several years showed the detachment of micro-particles of CuBe which, in contact with the lubricant, became transformed into a sludge, thus affecting the bearing's performance.

In addition, CuBe is sensitive to corrosion after a period of time. This leads to a change in colour of the material from yellow to red. This appearance, which has no effect on the bearing's operation, becomes critical in prestige watchmaking where aesthetic factors are highly important.

By eliminating the steel-steel contact under load between the balls and cage because ceramic is used to make the balls, it became possible to use a stainless steel suitable for cutting. The AISI 301 (1.4310) austenite steel has the following advantages:

- Better control of geometry after cutting (flat) than CuBe.
- Absence of micro-particles of matter becoming detached as a result of the ball / cage contact under load.
- Elimination of the risks of toxicity associated with the handling and machining of the highly toxic beryllium contained in the cuproberyllium (CuBe) alloy.

4. Efficiency and rewind capability tests

4.1 Type of test

Comparative tests have the advantage of showing the development of one solution compared to another. This is the principle that was chosen.

4.2 Basic principle

All the tests were performed by removing any risk that other components might falsify the results.

In other words, all the bearings tested were tested on the same basic movement JLC 889 and with the same reference oscillating mass.

4.3 Parts tested

5 standard bearings (20AP bearing races + CuBe cage + AISI 440C or 1.4125 stainless steel balls).

5 x-myrox bearings (4C27A bearing races + AISI 301 steel cage + myrox® balls).

5. Bearing sensitivity test

5.1 Principle of the test

The reference movement on which the test bearing was mounted comprised only the automatic rewind device (from the oscillating mass to the spring box).

The bearing was always tested with the same reference oscillating mass.

The principle of the test was to regularly measure the sensitivity of the bearing between two phases of the running-in programme with the following parameters:

Speed of rotation	: 110 rpm
Reversal of direction	: every 100,000 revolutions
Measurements	: every 100,000 rev. up to 500,000 rev.
Inclination of motor to 20°	: from 500,000 rev. **à** 1,000,000 rev.
Measurement	: after 1,000,000 rev.

5.2 Test equipment

The bearing to be tested fitted with the reference oscillating mass is mounted on the reference movement. The reference movement is driven into rotation by a motor in the horizontal position. The oscillating mass, because of its very mass, drives the automatic rewind mechanism.

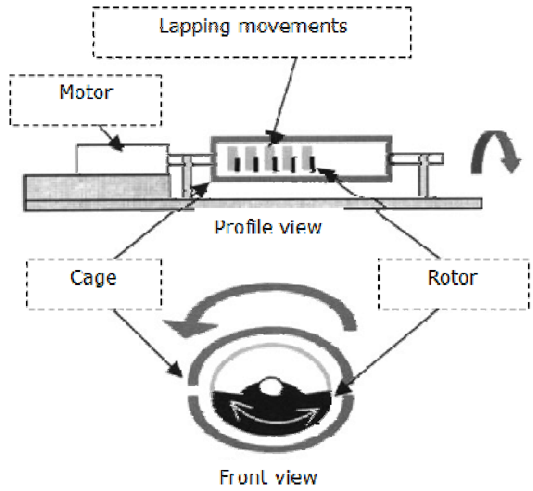

Fig. 2: Principle of running in the test bearings

5.3 Measurement equipment

A test device was specifically designed to carry out the measurement with the following principle:

A motor in the horizontal position whose spindle is set in the core (or inner race) of the bearing rotates at a speed of 2 rpm. The oscillating mass, joined to the bearing's outer race, by its very mass remains suspended on a vertical line. A device enables the motor's spindle to be moved from the horizontal position to the vertical position

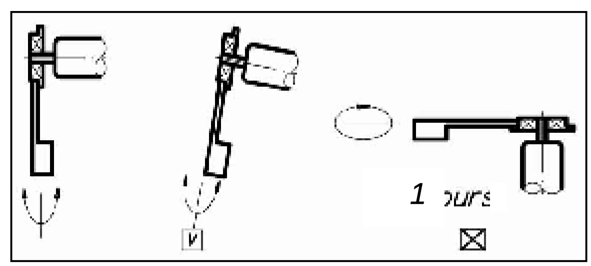

Fig. 3: Principle of sensitivity measurement

5.4 Performance of the sensitivity test

The different stages of the test on the bearings (see section 4.3) are as follows:

1. Running-in as per programme described in section 5.1.
2. For each measurement dismantle the rotor and place it on the sensitivity test device.
3. For each bearing tested, record the critical angle from which the oscillating mass (mounted on the bearing's outer race) is entrained with the motor's rotating spindle and executes at least 1 complete rotation around the spindle.
4. Calculate the mean and record the results in a table.

5.5 Results of the comparative sensitivity test

With regard to the standard bearings, after running-in for 200,000 revolutions, the sensitivity or efficiency increases. This is attributable to the change in condition of the lubricant, as shown by the appearance of the components after the test.

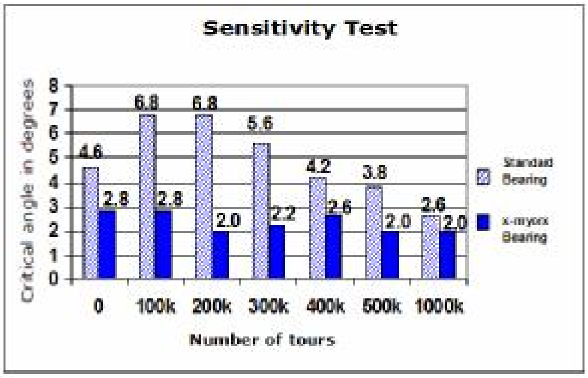

Fig. 4: Comparative measurements during the sensitivity test

The results showed that the good performance of the x-myrox bearing remained stable over a period of time.

5.5 Dismantling and observation of components after running-in

5.5.1 Observation of outer races

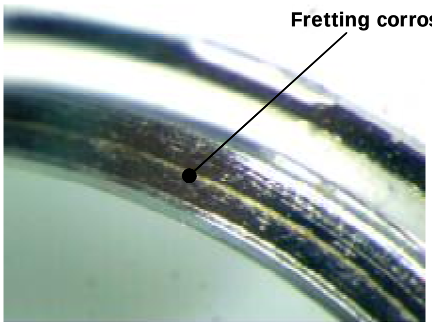

Fig. 5: Photo of an outer race (20AP) of standard bearing

After one million revolutions, it was observed that the initial film of lubrication used as a diffusion barrier was broken. This resulted in contact corrosion.

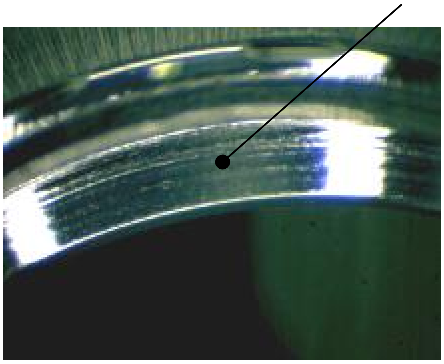

Fig. 6: Photo of an outer race (4C27A) of x-myrox bearing

After a million revolutions, slight strain hardening caused by the repeated passage of the balls was observed. The condition of the surface of the ball circulation groove was similar to that observed in the new state.

5.5.2 Observation of the cages or ball separators

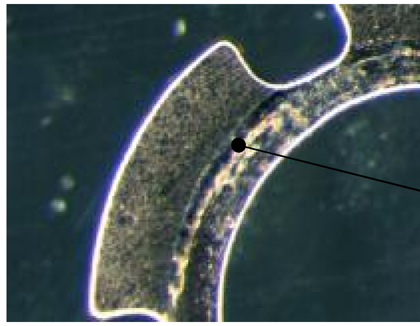

Fig. 7: Photo of a cage (CuBe) of standard bearing

The analysis of the deposit on the cage, sandwiched between the core and the cone, showed an amalgam of micro-particles of CuBe and lubricant adhered to the surface of the cage. The presence of this amalgam naturally has a direct influence on the bearing's efficiency.

Fig. 9: Photo of a cage (AISI 301) of x-myrox bearing

After one million revolutions, the state of the surface of the steel cage was similar to that observed in the new state.

6. Rewind capability test

6.1 Principle of the test

The bearings are mounted on complete, adjusted and fitted movements.

The principle of the test is to determine the reserve operating time stored in the spring box for the duration of the test programmed on a Cyclotest as follows:

Speed of rotation	: 4 rpm
Cycle	: 800 revolutions
Duration	: 3.33 h

The operating reserve is measured in time elapsed after winding up until the movement stops.

6.2 Test equipment

The first set of tests was conducted with 9 movements equipped with standard bearings, lubricated and not run in, mounted on standard oscillating masses.

For the second set of tests, the standard bearings were replaced by x-myrox bearings from the set run in for 1,000,000 revolutions and mounted on standard oscillating masses.

In both cases, particular attention was given to ensuring that no spurious friction occurred between the oscillating mass and the plate or case.

6.3 Measuring equipment

The device used to conduct this test was a Cyclotest automatic-test from Reglomat.

6.4 Performance of the rewind capability test

The various stages of the test are as follows:

1. Fit standard bearings on 9 movements.
2. Mount the movements on the Cyclotest and start the programmed test as specified in section 6.1.
3. Measure the operating reserve time stored in the spring box for the standard bearings.
4. Take the same movements, dismantle the rotors fitted with the standard bearings and replace them with versions with x-myrox bearings.
5. Mount the movements on the Cyclotest and start the programmed test as specified in section 6.1.
6. Measure the operating reserve time stored in the spring box for the x-myrox bearings.
7. Compare the results.

6.5 Results of the comparative test on rewind capability

Below are given the results recorded for the first set of tests for 9 movements fitted with standard bearings (20AP bearing races + CuBe cage + AISI 440C or 1.4125 stainless steel balls), and for the second set of tests for the same movements fitted with x-myrox bearings (4C27A bearing races + AISI 301 steel cage + myrox balls).

Mvt no.	Standard bearings	X-myrox bearings
1	36 h 05 min	38 h 21 min
2	36 h 26 min	38 h 47 min
3	36 h 10 min	38 h 05 min
4	34 h 30 min	38 h 03 min
5	37 h 00 min	39 h 04 min
6	36 h 20 min	38 h 25 min
7	37 h 45 min	37 h 50 min
8	35 h 03 min	38 h 20 min
9	34 h 13 min	37 h 10 min
mean	36 h 23 min	38 h 09 min

Fig. 10: Table comparing the results of the Cyclotest

The test on rewind capability on the Cyclotest confirms the results recorded for the sensitivity test. The x-myrox bearing improves the rewind performance by 1h46 min.

7. Wear test

7.1 Principle of the test

The movements fitted with the bearings to be tested were fully assembled and entrusted in this state to members of staff of Jaeger-LeCoultre.

The wearers were selected in accordance with their activity, which determined their aptitude for rewinding the energy reservoir.

The principle of the test is to determine the reserve operating time stored in the spring box for the duration of wear established as follows:

Duration of wear : 8 h 00

7.2 Test equipment

The first set of tests was conducted on 7 watches equipped with movements comprising standard bearings.

For the second set of tests, the standard bearings were replaced by x-myrox bearings. The two sets of tests were carried out by the same wearer.

7.3 Performance of the wear test

The various stages of the test were as follows:

1. Fit the movements with standard bearings.
2. Completely finish the watches.
3. Give each watch to its wearer for 8 hours.
4. Measure the reserve operating time.
5. Remove and replace the standard bearings with x-myrox bearings.
6. Give each watch back to its wearer for 8 hours.
7. Measure the reserve operating time.
8. Compare the results.

7.4 Results of the comparative wear test

7.4.1 Results recorded for the 7 watches fitted with movements comprising standard bearings (20AP bearing races + CuBe cage + AISI 440C or 1.4125 stainless steel balls).

Wearer	Watch 1	Watch 2	Watch 3	Watch 4	Watch 5	Watch 6	Watch 7
1	22h30	31h05	24h50	36h15	34h30	26h10	29h25
2	22h05	24h20	34h40	40h00	29h10	39h10	22h45
3	29h20	35h25	33h20	34h30	39h35	24h00	24h00
4	34h15	32h10	25h20	24h05	20h10	28h15	28h10
5	23h20	25h05	31h50	36h30	17h50	24h55	32h30
6	28h50	27h25	19h05	22h05	21h30	36h30	23h50
7	40h27	22h25	29h30	28h05	36h10	26h00	24h30
mean	28h41	28h16	28h22	30h12	28h25	29h17	26h27

Fig. 11: Results of the wear test for standard bearings

7.4.2 Results recorded for the 7 watches fitted with movements comprising x-myrox bearings (4C27A bearing races + AISI 301 steel cage + myrox balls).

Wearer	Watch 1	Watch 2	Watch 3	Watch 4	Watch 5	Watch 6	Watch 7
1	42h01	30h10	30h55	27h35	32h16	28h19	34h29
2	43h26	34h26	34h52	38h10	33h17	40h35	41h52
3	41h45	34h27	33h02	34h27	40h15	41h06	45h17
4	27h31	28h09	35h26	34h25	36h25	33h45	26h45
5	34h08	29h25	35h30	37h19	25h26	36h20	27h20
6	27h32	28h22	38h03	30h04	27h11	30h05	34h27
7	35h19	40h40	28h45	31h40	35h40	33h46	34h43
mean	35h57	32h14	33h47	33h22	32h55	34h50	34h59

Fig. 12: Results of the wear test for x-myrox bearings

7.4.3 Conclusion of the wear test

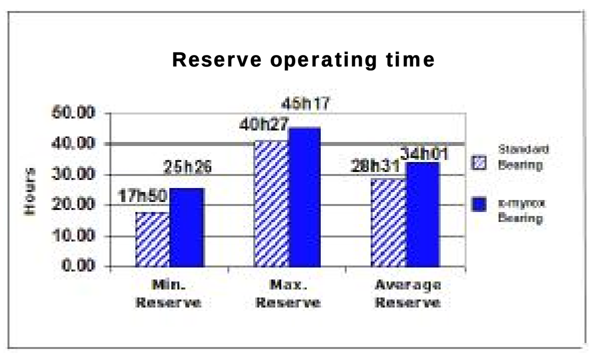

Fig. 13: Table comparing the results of the wear test

For a duration of wear of 8h00 the average gain, for all the wearers together, provided by the x-myrox bearing is 5h30min, i.e. an increase in performance of 19% compared to the standard bearing.

8. Shock resistance of the x-myrox bearing

8.1 Principle of the test

Shock measurement in watchmaking is done using a drop hammer. This device simulates a shock corresponding to a fall from a height of 1 m, i.e. a speed of 4.33 m/s at the moment of impact. This corresponds to an acceleration of 5000g. The watch is then declared to be shock resistant. The test was conducted in accordance with the NIHS 91-10 standard.

8.2 Result of the drop hammer test (mouton-pendule)

5 watches fitted with x-myrox bearings passed the test.

After dismantling and observation, no damage was observed.

9 Resistance to corrosion of the x-myrox bearing

3 bearings were placed in a saline fog atmosphere for 30 hours at 40°C.

3 bearings were subjected to the synthetic sweat test for 30 hours at 40°C.

A meticulous examination of the 6 parts did not show any trace of corrosion.

10. Resistance to thermal shock

3 bearings were heated up to 200°C and then drenched in water.

All the components withstood this test without breaking or showing an incipient break.

11. Noise measurements

In watchmaking, noise is often assessed with reference to an ear and not in terms of measurements. It is therefore dependent on the judgement of a person and may be qualified as being subjective. In addition, the casing (case + base) can cause a "resonance box" effect and amplify the noise.

11.1 Principle of the test

This test compares the level of intrinsic noise measured for each of the two types of bearing at different speeds inside an anechoic chamber.

11.2 Test equipment

10 standard ball bearings and 10 x-myrox bearings were fitted with oscillating weights. The rotors were then fixed onto Patek-Philippe 315 calibre plates.

11.3 Measurement equipment

The plate was fixed onto the spindle of a motor using a Delrin cylindrical support. A microphone was placed in the extension of the spindle at a distance of 2 cm from the bearing (see Fig. 14). The system was placed horizontally inside an anechoic chamber.

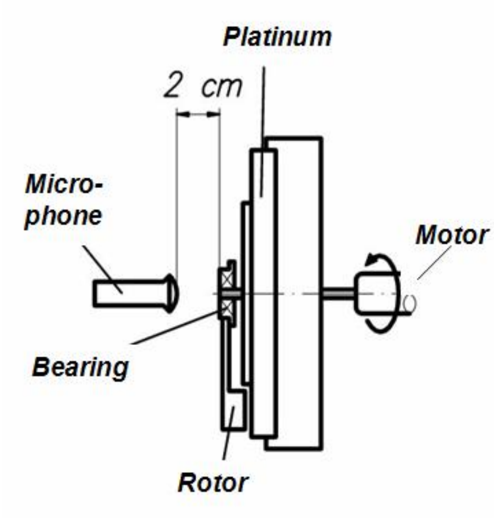

Fig. 14: Principle of noise measurement

11.4 Performance of the noise measurement test

The recordings were made for 20 seconds at the speeds of 200, 350, 500, 1000, 1300 and 1600 rpm. The low noise level of the motor and its distant position from the recording point enabled its effect on the measurement to be disregarded.

11.5 Results of the comparative noise measurement test

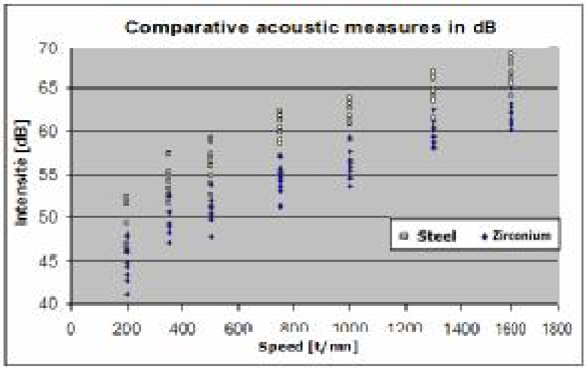

Fig. 15: Graph of the results

Figure 15 clearly shows that the noise intensity of the bearings fitted with steel bearings is significantly higher, by a factor of 1.5 to 2, compared to that recorded by the x-myrox bearings. The intensity is expressed in dB. Thus a difference of 1 dB is not perceived by the human ear. A value of 3 dB is required to render the difference perceptible and a difference of 6 dB is equivalent to doubling the intensity.

If other elements of the rewind mechanism are added to the above-mentioned test, the difference is less perceptible at the low speeds, but increases significantly as the speed increases.

12. Lubrication of the x-myrox bearing

What happens when an x-myrox bearing is lubricated by a customer or by a customer's retailer?

There are two cases:

1. Lubrication is a high dispersion of high-pressure watchmaking oil in a solvent (as done by MPS in the standard bearing).
2. Lubrication is done by oilcan (1, 2, 2 1/2 or 3 drops of high-pressure watchmaking oil).

In case No. 1, the results of a sensitivity test on 800,000 revolutions (conducted under the conditions described in section 5) show that the results are very similar to those recorded for the dry x-myrox bearing.

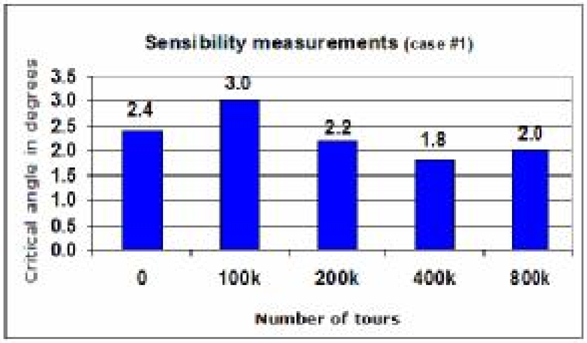

Fig. 16: Table of results of sensitivity test on lubricated x-myrox version

In case No. 2, the loss of efficiency (sensitivity) is all the greater the larger the number of drops of oil inserted in the bearing. This is true of both the standard bearing and the x-myrox version.

In short, if the movement has a low rewind power, the lubrication technique becomes prominent for both the x-myrox bearing and the standard bearing.

13. Conclusion

The results of all the tests make it possible to clearly measure the advantages of the x-myrox bearing compared with the standard version:

1. Lubrication may be eliminated because of the removal of the steel-steel contact under load, by introducing ceramic balls.
2. Shock resistance (tested up to 5000g as per NIHS 91-10 standard).
3. Maximum efficiency (+19% compared to the standard bearing in the wear test).
4. Stability of efficiency over a period of time (tested on 1,000,000 revolutions, i.e. the equivalent of 4.5 years of daily wear).
5. Reduction in the level of intrinsic noise.
6. Simplification and reliability of maintenance for the watchmaker and national and international after-sales points.
7. Very long duration of damage-free storage (no more fears about the behaviour of oils after ageing).
8. By eliminating CuBe as the material of the cage or ball separator, the adoption of AISI 401 steel helps eliminate the risks of toxicity associated with the handling and machining of the highly toxic beryllium contained in the cuproberyllium alloy.

In conclusion, the x-myrox bearing by MPS Micro Precision Systems AG answers the main preoccupations of Switch watch manufacture in this field. The first is always to offer better reliability, the second is to reduce operating noise and the third is to increase the time interval between maintenance operations.

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