Treatment

Stop-oil

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1. Lubrication

Introduction, general remarks

Engineers, mechanics and horologists are constantly faced with the problems of friction and wear. Yet friction, in its general effects, is a vital necessity. Without it, no form of life could exist: it would be impossible for man or animal to move from place to place. Not only would walking itself be impossible, but there would never have been any stage coaches, railway trains, cars or planes. It would be impossible to reap corn or to gather fruit. It would be just the same if, conversely, friction were very much greater than nature had intended: we should be unable to breathe, and the ambient air, due to friction, would also prevent us from moving about. Matters have thus been neatly arranged, in this respect as in so many others. From the beginning of time we have been provided with self-lubricated joints – arms, legs and fingers lubricate themselves. As for wear, it does not in fact exist, since the cells reproduce themselves automatically and naturally in the event of deterioration. It is only old age, also no doubt intended by nature, that puts a stop to this marvellous process of rehabilitation and constant renewal. In return, nature leaves it to us to find remedies for friction and wear in the machines and equipement we construct; and we are bound to admit that there is still a great deal to be learned and achieved before reaching a full and satisfying solution. We cannot indeed eliminate friction but only reduce it by a judicious choice of the materials in contact and for their surface finish, and by suitable lubrication. Nor can we eliminate wear either, or copy nature by causing worn particles to renew themselves automatically. We can only guard against wear to a certain extent and prevent, by means of lubrication, direct contact between materials, by controlling or limiting the relative movements of parts of equipement or machines we design and manufacture.

Coefficient of friction

Suppose a body of weight *P* grams is at rest in a horizontal plane, it will only move from its position of rest when subjected to a driving force. If this force acts horizontally (i. e. parallel to the plane), motion will only occur when the force exceeds a certain determinate value which, generally speaking, is **less** than the weight of the body. It may, for instance, be 10% of the weight, perhaps 20% or even more. This relationship is called the **coefficient of friction.** If the coefficient of friction between two bodies is given as 0.14, this means that a force equal to 14% of the weight will be required to start horizontal motion. Once this motion has started, the force necessary to maintain it is generally somewhat less.

A distinction must therefore be made between, on the one hand, the coefficient of friction at rest or the static coefficient of friction (also known as the starting coefficient or the **coefficient of adhesion**), and the other, the coefficient of friction applicable to moving bodies, known also as the **coefficient of sliding friction**. The coefficient of friction may thus be defined as follows: suppose we have a plane that can be inclined to a greater or lesser degree by means of a hinge *O (Fig. 1)*.

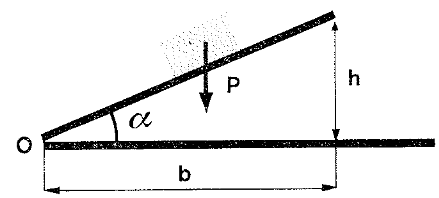


Fig. 1

If a body of any weight *P* is placed on the plane and the latter is tilted more and more until weight *P* starts to slide along it, the coefficient of friction is given by the ratio h/b.

Mathematically, this ratio is also the tangent of angle α. It is also possible to determine a **pivoting coefficient**, which is the ratio of the torque required to cause a pivot to rotate and the load carried by the pivot. Basically, according to the elementary rules of technology, the frictional force is independent of the area of surface contact *(Fig. 2)*.

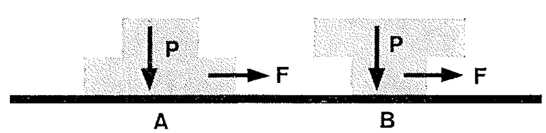


Fig. 2

Thus in both *A* and *B* the frictional force *F* is the same, for example 14% of weight *P*. Again according to these rules, the coefficient of friction depends only on the materials forming the contact surfaces: cast iron on cast iron, steel on bronze, steel on ruby or sapphire, etc. etc. In each case there would be **a** coefficient of friction. Thus, the coefficient of friction for **steel on bronze** with mineral oil lubrication is given as 0.16 *(Bowden, GB)*.

In reality, things are far less simple. They are in fact so complicated that it may be said that we are still only at the beginning of a period of laborious research to throw some light on to this problem of friction and wear. In recent years more and more research has been done, and literature on the subject has become more and more abundant. To sum up, we may say that it is no longer sufficient to talk of **a** coefficient of friction between two materials such as steel on bronze. There is in fact **a whole range** of coefficients, the extent of which depends very largely on surface conditions and on the kind of lubrication. Reference may be made here to an experiment carried out by *Bowden (GB)*, in which two flat, **absolutely clean** pieces of steel are placed one against the other. The coefficient of friction may exceed 100, i. e. it may reach 10,000%. In other words, a horizontal thrust of 1 kg is required to cause a load of 10 grams to slide. The pieces « stick » together. However, this experiment requires special precautions, without which the parts exposed to free air will be covered almost immediately with a thin film which forms a sort of poor self-lubricant. The latter does, however, reduce the coefficient of friction to something like the normal values. It should also be mentioned that tests recently carried out in the Seitz laboratories with hardened and ground steel spindles in ruby bearings, have resulted in a range of coefficients of friction extending from 0.08 to 0.40 (i. e. from 8% to 40%), although it has so far proved impossible to determine **with certainty** the cause of such wide differences as one to five. As for wear, this is probably due to the fact that, however perfect the surface condition or polish thereof, the pieces of material can only come into contact on a few highspots *(Fig. 3)*.

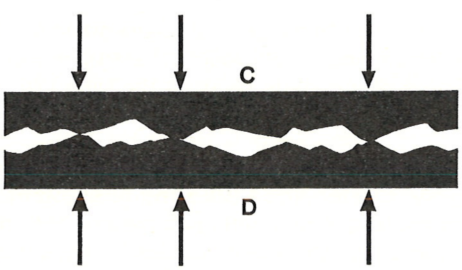


Fig. 3

The pressure at these points is therefore considerably greater than the average pressure calculated by dividing the load by the geometrical area of contact. These points are crushed, hammered, sheared and torn away by friction. The bonding force between surface imperfections is particularly strong in the case of unoxydised metals of identical or similar nature. It is therefore necessary to avoid direct contact between two solids moving in relation to one another. For this purpose, the rubbing surfaces are separated by a chemically different substance having a low shearing force. This substance is called a **«lubricant»** and the process **«lubrication»**. In this way, it is possible to lessen friction on the one hand, and to reduce wear, on the other *(Fig. 4)*.

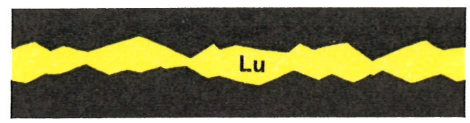


Fig. 4

between C and D:
Lu = film of lubricant

Hydrodynamic and unctuous lubrication

A distinction must be made between what is known as hydrodynamic lubrication and that used in horology, which is known as unctuous lubrication. The former concerns two surfaces which are moving in relation to one another at a fairly high velocity and at comparatively low pressure, and carrying along continuously a film of oil which operates on a closed circuit and is perpetually renewed from a chamber (of relatively low capacity) acting as a reservoir. This is the conventional method of lubrication which is known as oil-ring lubrication. In horology, specific pressures are high and speeds low. The speed of the moving parts is insufficient to carry and maintain a film of oil. Special lubricants are required having molecules with the property of bonding to the surface, thus forming a very thin unctuous coating. When the pressure at a contact point exceeds a certain limit, the film may break down locally, and particles may get caught up and torm away in spite of the lubrication. Unctuous lubrication cannot therefore completely eliminate wear. The choice of a suitable lubricant is thus a more delicate matter than it is in the case of hydrodynamic lubrication. To limit wear, it is mainly a question of getting a film that will stand up to high pressures, while at the same time reducing the coefficient of friction. This is what is meant when speaking of the unctuousness of oils used in horology. This property cannot be defined precisely enough to be expressed as a numerical value. It must not be confused with viscosity which is a measure of the internal friction between two adjacent layers of liquids. Viscosity can be expressed numerically in *poises* or in *Stokes*. It is largely dependent on temperature and may vary by as much as 5 or 6% per degree centigrade. Certain oils may double their viscosity when the temperature falls by 12 to 15° C. A high viscosity implies an additional loss of energy which occurs in the drop of oil, outside the point of friction. It would therefore be desirable to use an oil having the lowest possible viscosity, in other words, a fluid oil. But a fluid oil **will not keep in place**, and we must therefore be content with a compromise. These are only some of the conditions that must be satisfied by a watch oil. There are others: the oil must not vaporise, it must be resistant to cold, it must be chemically stable, it must fulfil certain conditions as regards acidity, and it must not corrode the components of the watch. The multiplicity of types and makes of watch oils is the outcome of attempts made to reconcile as far as possible the various and sometimes conflicting requirements mentioned above.

Application to horology

Features peculiar to horology

The watch or chronometer possesses certain characteristics which are only rarely found in other apparatus or machinery.

A watch is not expected to re-transmit energy. All the energy supplied to it is used solely to overcome friction. In other words, its energy output is nil. Any saving in energy gained from a reduction of friction is therefore greater, in proportion to the total energy, than in other types of mechanism.

In most conventional watches, energy is stored up in the mainspring which, as it unwinds, drives the wheel train ending in the escape wheel. The barrel makes only a few turns every twenty-four hours. As a rule, the escape wheel does ten turns per minute, which is 600 turns per hour or 14,400 in twenty-four hours. Thus the speed of rotation is multiplied several thousand times. Such speed multiplication is not found in other mechanisms, in which it would most probably be impossible. It can be achieved in the watch only through reducing friction to the absolute minimum.

The forces which come into play are slight, but the components affected by them are of such small dimensions that the specific loads are in actual fact enormous and usually far heavier than those normally permitted in other types of mechanism.

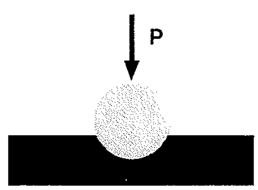


Fig. 5

Steel ball pressed into soft material (plastic), large contact area, low specific pressure. High pivoting torque.

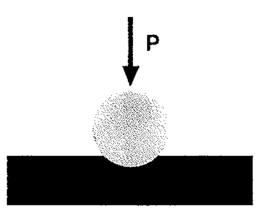


Fig. 6

Steel ball pressed into semi-hard material (metal), medium contact area, medium specific pressure. Medium pivoting torque

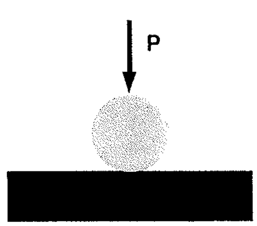


Fig. 7

Steel ball pressed into hard material (ruby), very small contact area, high specific pressure. Negligible pivoting torque

A watch is expected to function twenty-four hours a day, which, in conventional watches, means that the second hand jerks forward 432,000 times a day. This goes on year after year, always in the same rhythm and with a degree of accuracy far exceeding that of most other apparatus or machinery.

Other features peculiar to horology could be mentioned here, but we have confined ourselves to the four points detailed above, because of their importance in the essential reduction of friction and wear; in other words, the need for particularly efficient lubrication suited to the operating conditions of watches and chronometers.

Before dealing with the problem of lubrication itself, we would point out that all the component parts of a watch perform either complete or partial rotations, so that their friction results in opposed couples. Given the same coefficients of friction, the smaller the pivot diameters, the weaker the couples will be (certain pivots are less 1/10 mm in diameter – balance staffs).

Suitable materials (see *Figs. 5, 6 and 7*)

The various points outlined above demonstrate the need for materials which allow of high specific pressures with low coefficients of friction and little wear. Adequate lubrication must also be provided, without thermal or chemical corrosion. The only possible materials which can be used are corundum, ruby or sapphire. The compressive strength of ruby is 21,000 kg/cm², it will take an extremely high polish (technipoli), it has high chemical inertia and a low coefficient of friction ruby to metal. For other technical constants, see the *Seitz guide, pages 8 and 9*. Since the early days of the watchmaking industry jewelled bearings have been in use, and there is nothing superior even today, providing, of course, the jewels are of top quality and satisfy certain technical requirements. This is in fact so true that one cannot conceive of a quality watch with its balance pivots turning in brass or steel bearings. Invariably jewels are used, and more particularly rubies. In various quarters, particularly among purchasers of watches, it has even become the custom to assess the quality of a watch by the number of jewels it has: a 15-jewel watch, 17 jewels, 21 jewels, etc., and in some automatic watches 57 jewels or even more. We should mention in passing, that such nomenclature is subject to official control, and refers to working jewels only. The frictional qualities between ruby and metal have also been put to use in designing shockabsorbers for watches *(Ruby Shock)*. There is at present a tendency to substitute bearings of synthetic material for at least some of the jewels, and we are therefore giving this problem our close attention. In this connection, many experiments have already been made and a number of patents taken out. It may be that certain results will be achieved, but these will in no way detract from the industrial properties of corundum which no doubt remain one of the means, and in some cases the only means, of solving certain industrial problems of wear and friction where small parts are concerned.

Watch oils

At the present time there are three main groups of watch oils:

Conventional oils

These are a mixture of mineral oil and animal oil (from the hooves of calves or sheep). Mixtures containing a high proportion of animal oil have good non-creep properties and excellent oiliness, but their stability is poor. Mixtures with 50% or more of mineral oil have better chemical stability, and though their oiliness is somewhat reduced, it is generally speaking adequate. These oils contain anti-oxydants and in some cases, colorants. They keep well in bottles, but once they have been applied to the watch movement, a certain amount of gumming (resinification) can be expected.

Non-saponifying synthetic oils

The chemical term »*saponifying*« means « able to be converted into soap ». These oils are the outcome of attempts to obtain high stability without anti-oxydants and if possible, good non-creep properties. However, the latter are insuficient if the parts have not received further treatment with epilame after ultrasonic cleaning. Yet despite the use of additives for oiliness, these oils remain less unctuous than conventional oils. This comparative lack of oiliness has no practical consequences except where the pressure is particularly high and the rotational speed low (on the centre wheel spindle, for instance).

Ester based synthetic oils

« Ester » is a chemical term denoting a substance formed by the action of an acid on an alcohol, with the elimination of water. Ester based oils are an attempt to obtain a greater degree of chemical stability than is possible with animal oils. The other properties are regarded as less important, and vary from brand to brand of oil. It is therefore impossible to give any general indications.

Choice of watch oils

Let us say at the outset that there is no single method of lubrication which is uniform and superior to other methods. A chronometer that is being entered for an observatory contest will not be lubricated in the same way as a watch being exported to a tropical country with adverse climatic conditions. In the first case, a very unctuous oil of reduced viscosity and preferably one which is unaffected by variations in temperature, should be used, for example, stabilised neat's-foot oil with a small admixture of synthetic oil as and if required. Before lubricating, the bearings and spindles should be coated with epilame. In the second case, greater importance should be attached to stability, and synthetic, non-saponifying oils are therefore indicated. Medium-sized, jewelled calibres may be lubricated with an oil having a viscosity of about 1.2 **Stokes** at 20° C. For small-sized calibres and for watches which have to be kept at low temperatures, a more fluid oil would be used.

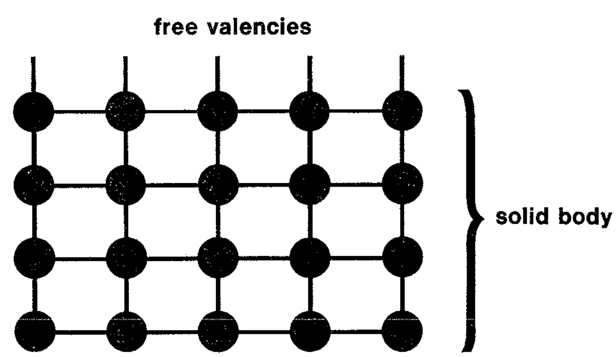
2. Surface phenomena

Introduction

The previous chapter has demonstrated the extreme complexity of our ideas on lubrication and friction. As a general rule, however, lubrication considerably improves frictional conditions. Indeed, there are some cases (hydrodynamic film under pressure) in which the nature of the rubbing surfaces is no longer of any consequence. For normal conditions, discrimination should be exercised in the choice of materials coming into contact, and of lubricants. In horology, however, there is no question of changing the nature of the materials used *(ruby, brass, steel)*, and it is therefore necessary to bring an improvement to the conditions of lubrication. It should be borne in mind that the good performance of a watch depends, among other things, on correct lubrication of the bearings and the pallet stones. It is commonly found, however, that oil applied to these parts creeps, providing superfluous lubrication for the adjacent parts and abandoning the areas subject to friction, where its presence would be more necessary. To overcome this difficulty, a treatment known as « epilame » (stearic acid) has been applied. Etymologically, the word « epilame » means « boundary layer », but the nature of this is not precisely stated. In horology, however, the word « epilame » has taken on a more limited meaning, inasmuch as it refers to the boundary layers whose active property consists of their oil-repellent[1] effect. We shall now examine the nature and possible uses of such treatments.

The surface of solids, the adsorbed layer

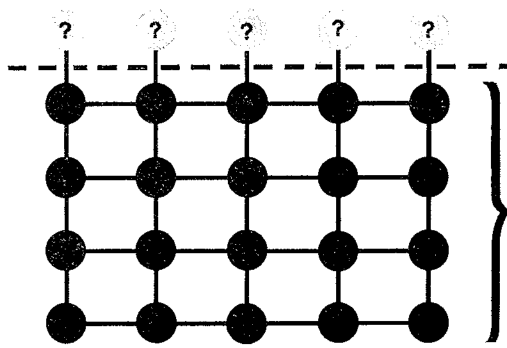
An insight can be gained into what happens on the surface of a solid body, when it is stated that the atoms of a structure exchange valencies with one another, and those which form the boundary of the solid, that is to say the surface, each have at least one unsaturated and therefore free, valency.



The result must therefore be a field of forces on the surface of the solid body, capable of attracting and retaining atoms or molecules belonging to adjacent bodies.

[1] **Oil-repellent:** we shall see how this property can be turned to advantage.

Various experiments have confirmed this theory, and the layer which thus covers the surface of the solid body is known as the **adsorbed layer**.



Properties and nature of the adsorbed layer

Thus it will be seen that under normal conditions, this layer is **always** present. To prevent it from forming, it would be necessary to « manufacture » the surface in a vacuum, taking certain precautions. To destroy it, it would have to be subjected to the combined action of a vacuum and of high temperature. The nature of the molecules forming the adsorbed layer is in general little known. It depends, in effect, on the nature of the substances present at the time the surface was formed. Moreover, in most cases its composition is not fixed: some molecules escape and are replaced by others. Thus the result of adsorption is a statistical balance where the average condition depends on the substances that are present. From the standpoint of its relation with the solid body, the adsorbed layer may be merely a « juxtaposition » (stearic acid), a chemical combination, or sometimes a diffusion. The action of external agents on this layer is more marked in the case of simple juxtaposition. Finally, it should be pointed out that adsorption consists not only of the attraction but also of the orientation of the captured molecules.

Consequences of the existence of the adsorbed layer

Friction

It is immediately obvious that when we measure the coefficient of friction of steel on ruby, for example, we are really measuring the coefficient of friction of the adsorbed layer of steel on that of ruby, and in view of what just been said about the composition of these layers and their instability, the wide differences in the measured results are hardly surprising.

Oil creepage

It is equally obvious that creepage of the oils is governed by the characteristics of the adsorbed layer, and consequently, there is nothing surprising in the confused observations which have been made in this connection.

Oil creepage

When a drop of oil is placed on a solid surface it assumes a balanced shape which is defined by its cohesion, its weight and the affinity ot fhe solid for the oil in question. If there is no affinity, the drop assumes the shape shown in *Fig. n*; if there is affinity, it assumes the shape in *Fig. m*, characterised by an angle α which depends, among other factors, on the affinity. α may be zero.

In the case of creepage by affinity, the drops of oil, if small enough, assume the shape of a segment of a sphere [1]).

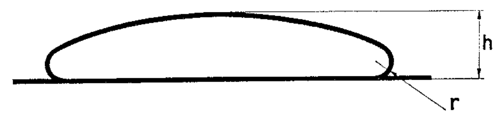


Fig. n.

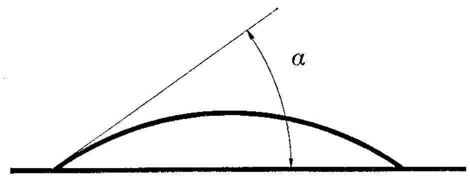


Fig. m.

Stop-oil treatment

Stop oil treatment is achieved by modifying the nature of the adsorbed layer which is then composed in the main of molecules chosen for its oil-repellant properties. This modification is carried out in such a way that the result of the operation is a **chemical combination**. Consequently, this layer can only be dislodged by chemical action and, of course, by any mechanical action which might eat away the surface. Originally developed for rubies, Stop-oil has subsequently been greatly improved, and this treatment can now be given to the majority of metals. The following chapters demonstrate the properties of the treatment and the uses to which it can be put.

[1]) For additional information, see Morlock's thesis upheld at the Faculty of Science at Marseille on 27th March, 1946.

3. Stop-oil treatment: its characteristics and effects

Field of application

Stop-oil treatment can be applied to ruby, sapphire, glass, and most metals and alloys, particularly steel, brass, nickel silver and beryllium. In certain cases, slight discoloration may be noted.

Stability of Stop-oil treatment

Stop-oil treatment is resistant to all the usual solvents, even when hot and with simultaneous ultrasonic action. Stop-oil treatment can be destroyed by the action of:

– Acid or alkaline solutions

Whenever parts which have been given Stop-oil treatment have to be brought into contact with such solutions, it is advisable to carry out checks. May we say, however, that such checks, carried out under simulated conditions, may often lead to false conclusions. The destruction of the treatment under such conditions is generally more marked and more rapid with metals than with corundum, and becomes apparent through a more or less significant reduction in the angle of wetting, according to the nature and duration of the reaction.

– Deliberate or accidental mechanical erosion

A frequent cause of accidental wear and tear is the rubbing of the parts against the baskets containing them during cleaning or electrolytic treatment.
Slight though this action is, its effects nevertheless become apparent after about ten washings.

– High temperature in an oxydising atmosphere (600° C.)

Corrosion resistance of metals after Stop-oil treatment

The treatment has a slight, though always favourable, effect on the corrosion resistance of metals subjected to it (*SLHR Report*). In no circumstances, however, can Stop-oil treatment replace the anti-corrosion treatment which must, of necessity, be applied beforehand.

Angles of wetting

Parts treated, washed in trichlorethylene with ultrasonic action for 5 minutes.

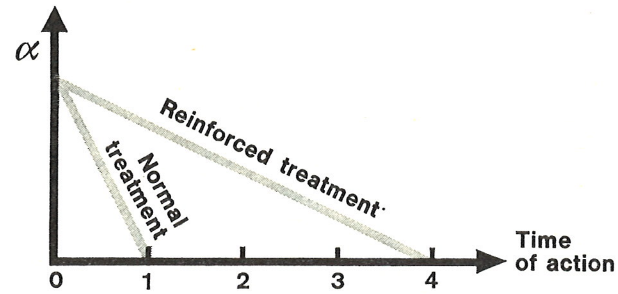
Ruby – three types of treatment:

	α initial	α after 3 days
Treatment 3	48°	42°
Treatment 4	52°	46°
Treatment 5	57°	48°

Two densities of treatment:

Normal treatment Reinforced treatment	No difference in the α values, but in the resistance to destruction.

Example: Action of a normal soda solution



Metals

Reinforced treatment applied systematically:

Brass	$\alpha = 40°$	Little change in α in relation to time.
Nickel silver	$\alpha = 42°$	
Steel	$\alpha = 30°$	

The purpose of the information given below is to enable the user to answer the questions: where should treatment be given and what form of treatment should be chosen?

Unbalanced effect

Suppose, for example, we have a circular plate of diameter *ab*. To the left of this diameter line the surface is treated, and to the right, it is untreated. If a drop of oil is placed astride the line, it will be found that the oil is repelled by the treated surface and spreads over the whole of the surface that has not been treated *(Fig. 1)*.

Fig. 1 after 30 secs. after 1 min.

This effect is observed whenever the oil is in contact with a treated and an untreated surface at the same time. Nevertheless, it will be all the more noticeable and more rapid as: a) the treated surface is more highly polished, and b) the angle of wetting α is greater.

Barrier effect

As a corollary to the unbalanced effect; if a drop of oil is placed on an untreated surface *(Fig. 2)*, it will spread over it completely but will not cross the line representing the diameter, just as if the latter were a barrier.

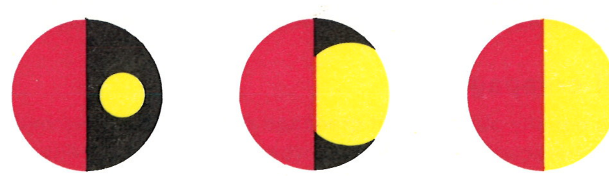


Fig. 2 after 30 secs. after 1 min.

Reduction of pollution

The fact that Stop-oil treatment increases the wetting angle has a corollary in the reduction of the external surface of the drop of oil which is in contact with air, for a drop of given volume. It is through this surface, which we shall call the **pollution surface,** that atmospheric dust, oxygen, moisture, etc. penetrate into the drop, and it is through this surface, also, that evaporation is produced, thus causing the moving parts of the watch to dry up. It is clear that, by reducing the so-called pollution surface area, the above-mentioned drawbacks are reduced to a like degree.

Conclusions

Considering jointly the unbalanced effect, the barrier effect and certain essentials for lubrication, we arrive at the following general conclusions:

- Wherever the presence of oil is necessary (areas of friction, oil sinks), **no treatment should be applied;**
- The areas thus defined should be surrounded with surfaces treated with Stop-oil, so as to form a barrier to prevent the oil running away (Swiss and foreign patents).

4. Applications for Stop-oil treatment in watch movements

The following question must be asked: where, on which moving part, is the problem of oil retention most accute? At the present stage of our research we are able to classify the four main categories, in ascending order of priority, as: the arbor pivots and bearings generally, the shock-absorbers and capped jewels, the endpieces, and the escapement. Fully documented evidence supports the assertion that the problem of the pallet stones must be solved first.

Present uses

Stop-oil treatment, which is resistant to conventional cleaning methods, has a wide range of uses, and it is for the technician to decide where its application is desirable. Seitz & C°. are using Stop-oil for the treatment of hole jewels, pallet stones, bearings, spindles, endpieces, moving parts, plates and bushings.

Possibility of application

Apart from a few general principles, each case must be treated as a special case. The « barrier » solution, ideal though it may be, cannot always be adopted. It is necessary to make a distinction between the ideal solution, which outlines the technical difficulties and their economic consequences, and the acceptable solution, which takes account of its own limitations. Stop-oil treatment facilitates lubrication during assembly, prolongs the period of good timekeeping and cuts down on repair costs.

List of possible combinations of Stop-oil treatment

There are three possibilities for each component: untreated, barrier, treated complete.

Moving parts and mechanism casing

Spindle untreated	Jewel untreated	– poor
	Jewel barrier	– Relates back to the previous case
	Jewel treated	– Poor
Spindle barrier	Jewel untreated	– Poor
	Jewel barrier	**– Ideal**
	Jewel treated	No justification
Spindle treated	Jewel untreated	– Poor
	Jewel barrier	– Good (shock)
	Jewel treated	– Acceptable (economical)

Shock absorber and setting combined

Spindle untreated	Whole untreated	–
	Whatever parts may be treated (screw threads and jewels)	– Poor
Spindle barrier or spindle treated	**Jewel barrier, Counter pivot barrier**	**– Ideal**
	Jewel untreated Counter pivot treated	Almost barrier
	Jewel untreated Counter pivot untreated	– Doubtful

The screw thread must always be treated

Counter pivot plates

Same remarks as for the shock absorbers.

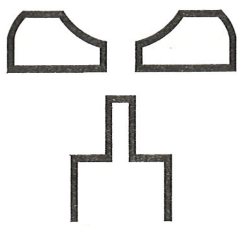
Spindle barrier or treated + jewel barrier or treated	Counter pivot jewel and plate untreated	– Poor
	Counter pivot jewel barrier	**– Ideal**
	Counter pivot jewel treated	– Acceptable

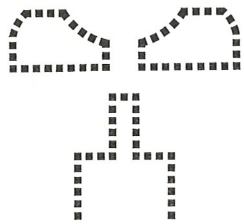
The barrier may be obtained a) by withdrawing treatment on the plate or on the counter pivot, b) by having an untreated counter pivot set in a treated plate.

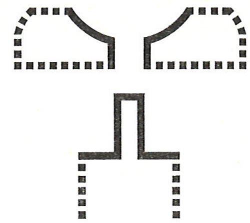
Anchor wheel and pallets

Stop-oil treatment is also applied to the escapement, on which various combinations of barriers are possible.

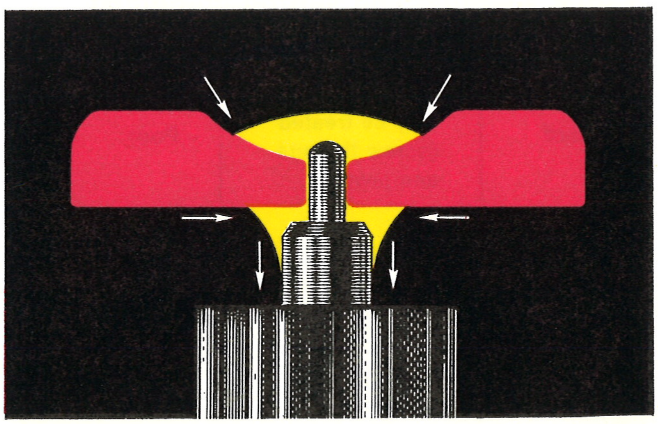
Examples of applications

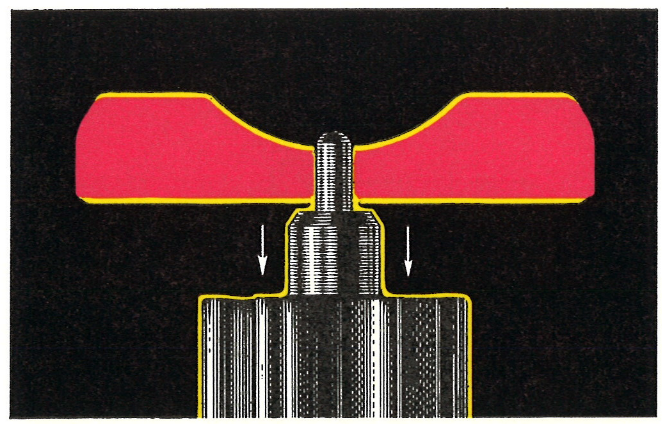

Jewel and spindle untreated


Jewel and spindle treated


Jewel and spindle « barrier »

Jewel untreated, spindle untreated



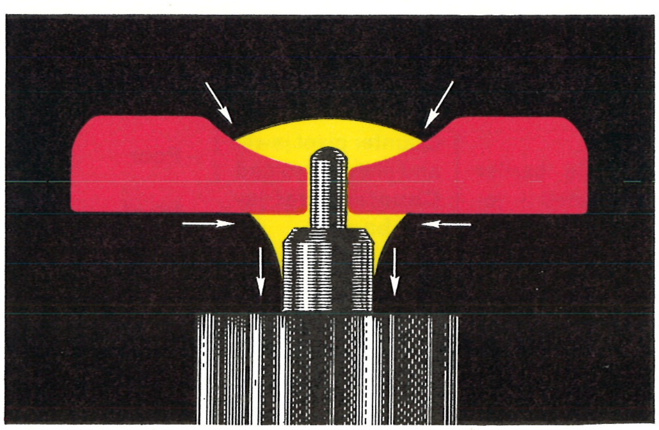


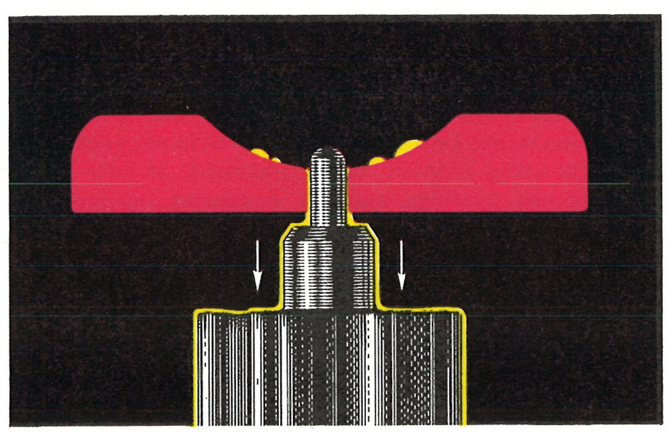
Initial stage
By capillary action, oil deposited in the hollow collects in the angle between the jewel and the spindle, where it assumes the form of a meniscus.

By affinity (see the chapter on « Creepage of oils » *), the oil gradually advances over the whole surface area, even where its presence is undesirable.

Final stage
There remains only a thin film of oil which is insufficient to ensure adequate lubrication.

Jewel treated, spindle untreated



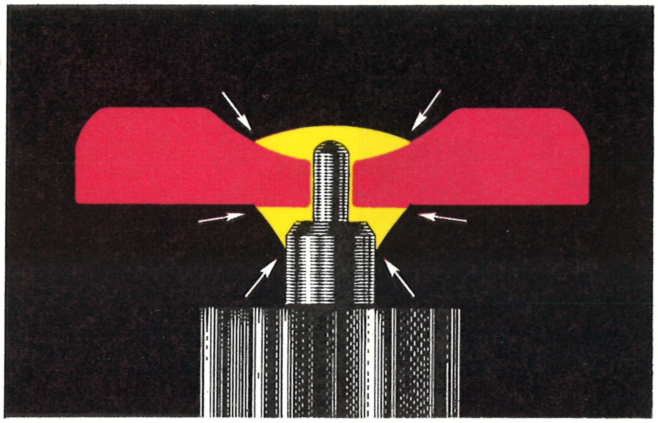


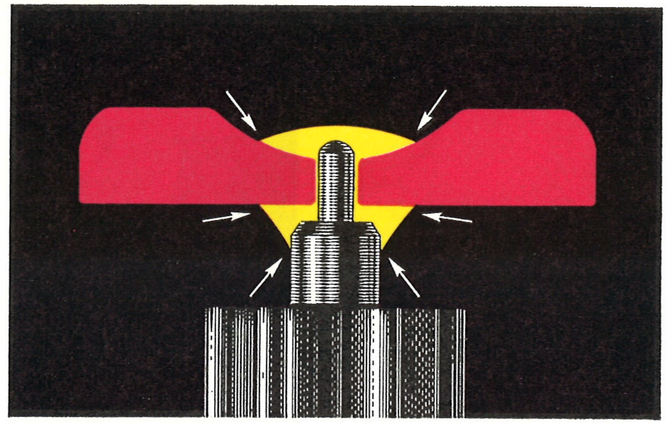
Initial stage
By capillary action, oil deposited in the hollow collects in the angle between the jewel and the spindle, where it assumes the form of a meniscus.

Owing to the effect of unbalance (see the chapter on « The unbalanced effect » *), the oil moves away from the treated parts (jewel) towards the untreated parts (spindle), and reaches areas where its presence is undesirable.

Final stage
Only a thin film of oil remains on the spindle and scattered droplets in the oil reservoir (itself not touched by the oil).

Jewel treated, spindle treated





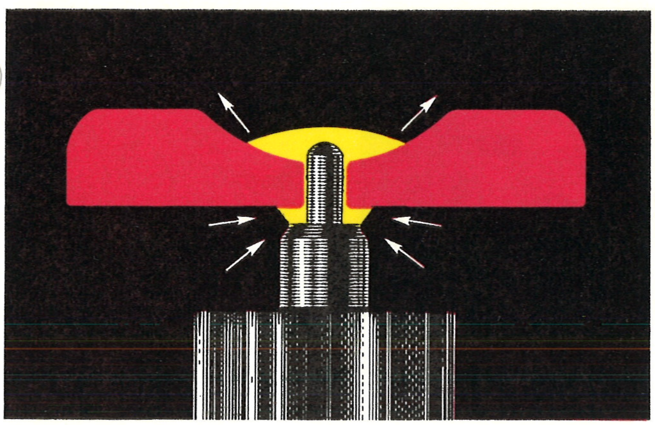
Initial stage
By capillary action, oil deposited in the hollow collects in the angle between the jewel and the spindle, where it assumes the form of a meniscus.

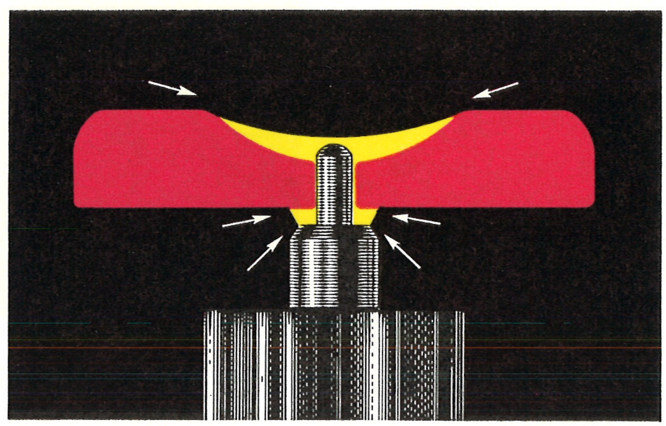
The oil cannot spread since it is everywhere in contact with oil repellant surfaces, and the outline of the drop of oil cannot be altered, except by shock, **since the surfaces are not oil-wetted and the oil therefore does not catch on to them.**

Final stage
Identical to the first stage, but without shock.

Jewel barrier, spindle barrier

(Ideal solution)





Initial stage
By capillary action, oil deposited in the hollow collects in the angle between the jewel and the spindle, where it assumes the form of a meniscus.

The oil spreads over the untreated surfaces (which are thus completely oil-wetted), bounded by the barriers (spindle and jewel), but cannot cross these barriers (see chapter on « Barrier effect » *).

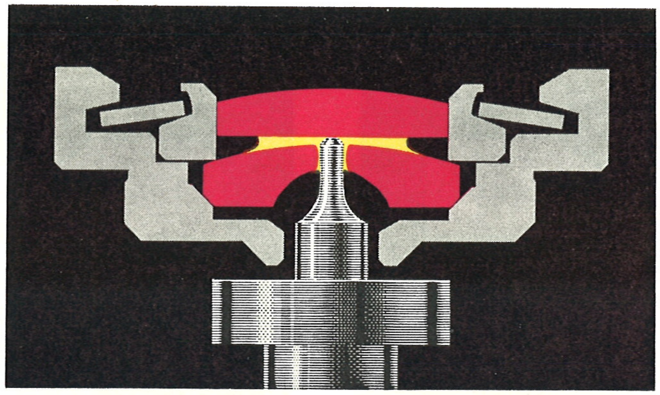
Final stage
The oil covers all the untreated surfaces. In the event of shock, there is no displacement of the oil.

Note: In the first two cases (jewel untreated, spindle untreated, and jewel treated, spindle untreated), there is a smooth progression from the initial to the final state, which may, according to the qualities of the oil, extend over several months.

In the last two cases (jewel treated, spindle treated, and jewel barrier, spindle barrier), the final stage is reached in a few seconds and is maintained.

*) Reference to the technical document on Stop-oil treatment.

Shock absorber



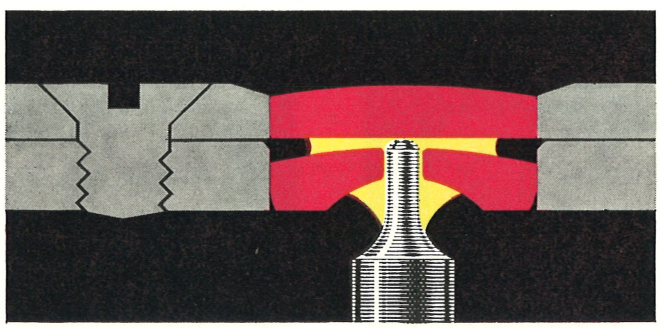
For example, the screw threads, the balance wheel spindle and the counter pivot are treated, but not the hole-jewel.

The treated parts form barriers with regard to the hole-jewel and prevent the leakage of oil. In the event of shock, the hole-jewel – oil wetted – retains the oil.

The best result is obtained by using a hole-jewel with barrier treatment.

Counter pivot plate

Jewel, spindle and counter pivot treated



Is reduced more or less to the case of « jewel treated, spindle treated ». The difference is due to the presence of an oil chamber between the jewel and counter pivot.

Treatment with an oil repellant surface is of interest only if the unbalanced effect and the barrier effect are made full use of, and this, as far as Stop-oil treatment is concerned, is precisely the object of the Seitz patents.

Seitz

Appendix 1
Escapement

Stop-oil Treatment

Seitz+Co 2416 Les Brenets/Switzerland

Application of Stop-Oil treatment to the escapement

Recapitulation of basic principles

1. Creeping

When a liquid mass is deposited upon a solid surface, it takes on a configuration defined by three types of forces:

- forces of cohesion, which determine the surface tension of the liquid and tend to form a compact drop
- the weight of the liquid mass, which tends to cause creeping
- the forces of affinity resulting from the possibility that molecules of the liquid may be captured by the field of forces on the solid surface.

Forces of cohesion and weight are always present (under normal conditions).
Two types of creeping may be distinguished, according to the presence of absence of forces of affinity: **creeping by affinity** and **mass creeping.**
In general, drops of liquid take on the forms shown in figure 1.

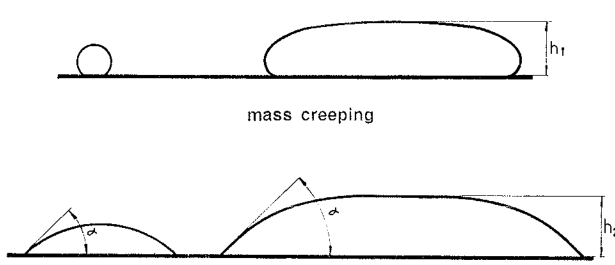


Figure 1

h^1 has a maximum value characteristic of the liquid

α is characteristic of the affinity between the solid and the liquid (it is called the angle of moistening)

h^2 has a maximum value characteristic of the liquid and of α.

It should also be noted that in the case of mass creeping the solid is not moistened by the liquid. When it moves, a drop of liquid leaves no trace behind it. This peculiarity may also be noted in certain cases of creeping by affinity and, notably, an oil of the usual kind will not moisten a surface that has been given Stop-Oil treatment.

2. Surface discontinuities

The term « surface discontinuity » is conventionally used to denote the dividing line between two surface states which have different affinities with the same liquid. Surface discontinuities have peculiar properties, which manifest themselves in:

The effect of disequilibrium

Surfaces A and B *(fig. 2)* are separated by the line a – b. If A has no affinity and B great affinity with a given liquid, a drop of that liquid deposited on the line a – b will not be in a state of equilibrium, because surface B has forces of affinity which are not present on surface A. The resultant of these forces is directed from A to B, causing the drop of liquid to move away from surface A and to creep over surface B. This phenomenon is comparatively rapid.

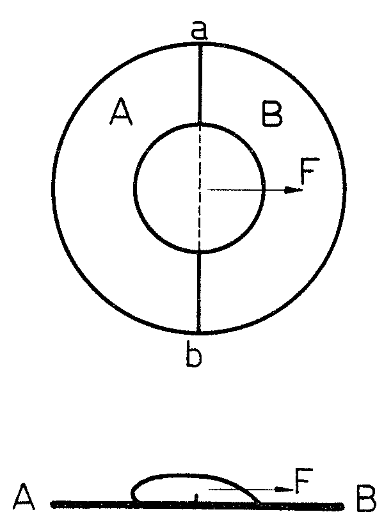


Figure 2

The barrier effect

A drop of liquid deposited on surface B will creep over it, but will be unable to cross the line a – b, for otherwise it would come into a state of disequilibrium. The line a – b thus acts as a barrier.

Examples of surface discontinuities

- The dividing line between a surface that has been given Stop-Oil treatment and a clean untreated surface.
- The sharp edge between two secant surfaces.

Let us imagine a surface S′ extending surface S. On the S′ side there is no affinity. For obvious reasons, there can be no effect of disequilibrium, but the barrier effect will manifest itself in the normal way *(fig. 3)*.

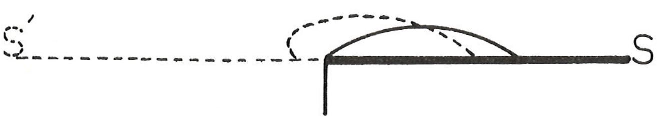


Figure 3

It will be understood that by using the barrier effect it is possible to maintain a certain quantity of oil within a desired area. If the oil moves outside that area while remaining in contact with it, it will be brought back by the effect of disequilibrium. These principles and properties have been used with a view to improving, in particular, the lubrication of the escapement.

A possible solution is suggested below, bearing in mind:

- the results to be obtained
- the practical possibilities
- the cost price.

Suggested treatment of pallets and escape-wheels

Preliminary remarkes

Stop-Oil treatment gives a surface state which has the minimum affinity possible under present conditions. It follows that alterations in the state of a treated surface will have the effect of increasing the affinity.
A clean untreated surface (ruby, steel, brass) has the maximum affinity. Any alteration in the state of that surface may either have no effect or cause the affinity to decrease. Stearic-acid treatment is intermediate between Stop-Oil treatment and a clean surface. Therefore nothing can be said **a priori** about the consequences of an alteration in the surface state, which may cause either an increase or a decrease in the affinity.

Treatment of the pallets

If we apply what has been said and treat the jewelled lever completely, we shall note the following:
After a short period of operation (a few hours), the treatment has come away from the point on the impulse-face of each pallet which is rubbed by the teeth of the escape-wheel. The barrier effect and the effect of disequilibrium maintain the oil in the area thus uncovered *(fig. 4)*.

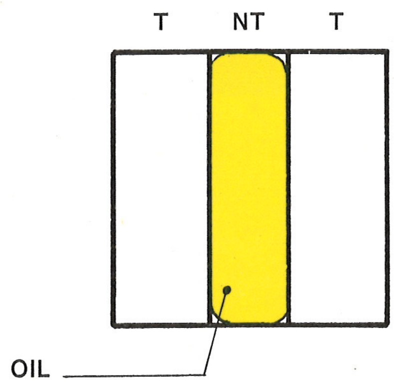
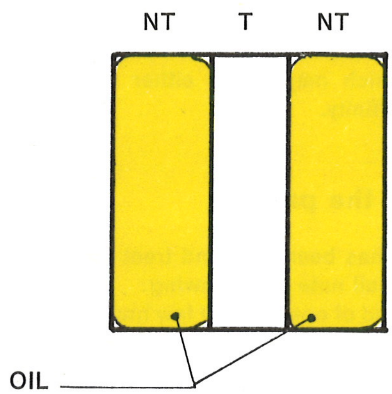


Figure 4 (Longines photograph)

If the impulse-face is not treated, it is found after a few hours' operation that the area touched by the escape-wheel teeth has its surface state altered so that the affinity is decreased. The result of this is shown in fig. 5 and it is obvious that this is not what is required.



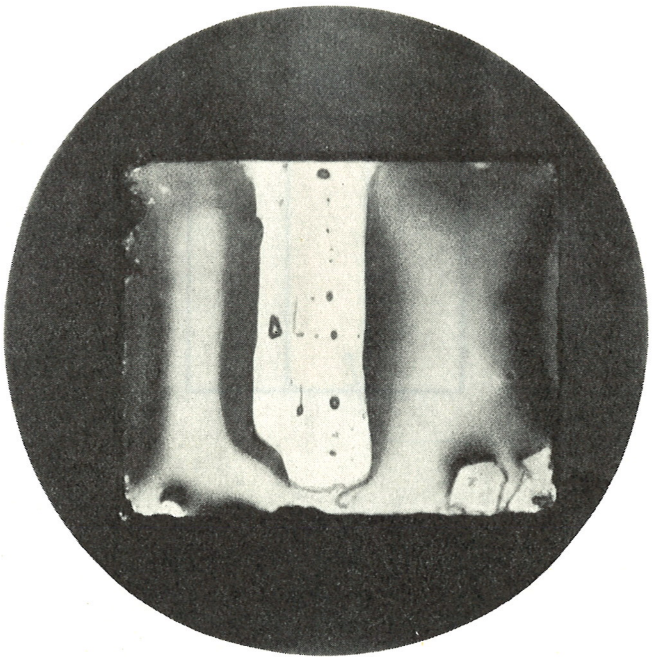


Figure 5 (Longines photograph)

It should also be pointed out that stearic-acid treatment very often behaves in exactly the same manner as that shown in fig. 5.
In the case illustrated in fig. 4, it cannot be claimed that the oil driven away from the untreated area by the crushing effect of a tooth has time to return before the passage of the following tooth. As we lack the necessary means for the time being, we shall have to make these observations later on. But we think this is not very important, for two reasons:

1. The untreated area is moistened by the oil, which forms a layer that cannot be removed (except by washing).
2. To be explained in the following chapter.

Treatment of the escape-wheel

We wish to maintain a reserve of oil available in the vicinity of the area of contact between the pallet and the escape-wheel tooth. We have just seen that the creation of such a reserve of oil on the impulse-face of the pallet is problematic. Therefore we must try to create reserves of oil on the escape-wheel teeth. A possible solution is the following *(fig. 6)*:

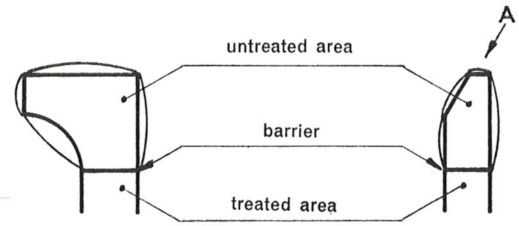


Figure 6

As this solution can be adopted without too much difficulty, we have made it the object of careful investigation. The oil is stored as shown in fig. 6.
Of course, the oil which serves a useful purpose is that which is situated in area A. And in this connexion we may make the same remarks as for the impulse-face of the pallet. This oil is driven towards the neighbouring areas when contact occurs with the impulse-face of the pallet. But the situation is different, for though the oil on the pallet has only a fraction of a second for its recuperation, on the escape-wheel tooth it has the time taken by the escape-wheel to make a complete revolution, i. e. several seconds, and this is quite sufficient. To improve still further the conditions for the return of the oil, it is advisable to destroy the natural barriers due to the presence of the discontinuities d^1, d^2 and d^3 by giving them the form suggested in fig. 7.

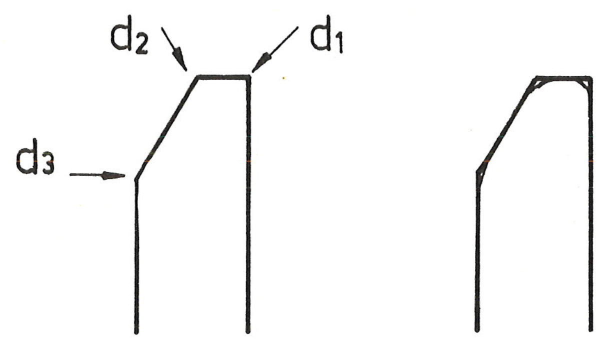


Figure 7

This is the point at which we have arrived at present; experiments and observations are continuing, and the question remains an open one for the time being. This document will be completed as our investigations develop.

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Statement of the possibilities now available to industry

Having made many experiments and investigations with the kind collaboration of the horological engineers, we have published this technical document, which deals with the problems of lubrication and surface phenomena in general and with the Stop-Oil process in particular.

We wish to make it clear that in chapter 4, « Application of Stop-Oil treatment in watch-movements », we have mentioned all the types of treatment that have so far been tried out in the laboratory. At the present stage of our work, we can offer the following possibilities for the industrial use Stop-Oil treatment:

1. Complete treatment

- jewels of all types
- metal parts of every description
  including: staffs and arbors
  wheels
  small plates
  turned parts
- jewelled levers.

2. « Barrier » treatment

- domed jewels (balance-jewels)
- escapement (escape-wheel teeth)
  As regards barrier treatment for escape-wheels, we wish to state that:
  - for testing purposes, we are able to make barriers on small series of parts;
  - for manufacture in large series, we provide complete Stop-Oil treatment, giving full information to enable the user to make these barriers himself.

According to the interest shown by the watch industry in the matter of further applications, we will examine the possibility of making these available for industrial use.

Furthermore, we would point out that the list of possible combinations given on page 9 is by no means exhaustive, and that other possible uses, both in watchmaking and in industry generally, are now being investigated.

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