Optimal windshield cleaning performance

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A Thesis Work

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Foreword
This thesis work comprises 20 weeks and has taken place at Volvo Car Corporation in Gothenburg. We have had a nice and instructive time at Volvo. We would like to thank our examiner Jan Lundberg at Luleå University of Technology and our instructor Lars-Olof Janefeldt at Volvo Car Corporation. We would also at this point like to express our appreciation to all departments and personal at Volvo concerned.

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Abstract

The goal with this thesis work was to specify the parameters that affect the wiper system cleaning quality of the windshield. The most important parameters were tested so that Volvo can optimise and state requirements on the cleaning system and surrounding details.

After studies the parameters were reduced to the three following parameters:
- Wiper blade wear
- Wiper blade geometry
- Windshield surface

To get a better understanding of how these parameters affect the cleaning quality, following three products were tested:
- SAFE SIGHT-concept. Small stripes that are supposed to clean and shape up the wiper blade were applied to the windshield.
- Coated windshield. A windshield with a hydrophobic coating was tested. The coating forms the water to droplets instead of film. The droplets flow away with the airflow.
- Bosch Flatblade Technology. A new wiper blade with a flat spring design. Has many advantages compared to ordinary blades. The lack of joints and the even pressure over the blade is the most useful.

The tests were made in a test rig and in company cars. Two inquiries were answered by the company car drivers about the cleaning quality with the SAFE SIGHT-concept. The tests gave the following results:
- The SAFE SIGHT stripes improved the cleaning quality but they peeled off too easy and caused some noise. After a longer time, they wore the blade that resulted in a decreased cleaning quality.
- The need of the wiper system is highly decreased with the coated windshield. This improves the active safety. However, the coating needs an increased durability and decreased cost.
- These new wiper blades from Bosch is remarkable good. The cost for these blades is higher compared to the ordinary blades but will decrease in the future when the product is introduced to the market.

The coated windshield and the Bosch Flatblade Technology gave the best improvement to cleaning quality compared to ordinary wiper systems. The ordinary wiper blade showed wide stripes after 33000 cycles in the test rig. The new Bosch wiper blade showed no stripes at all after 119500 cycles. The coated windshield has been successfully tested and received by the test drivers.

We recommend Volvo to further development and tests of the coated windshield and the Bosch Flatblade Technology.
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1 Introduction
The windshield cleaning system is a part of the active safety system. The cleaning is accomplished in the most cases with a windshield wiper. In the beginning the wiper was driven by hand with a handle on the inside, nowadays they are electrical driven. The cleaning system must fulfil a number of legal requirements that varies between different countries. Often these legal requirements involve wiped area and high speed cleaning quality. Depending on the design of the cars this can be difficult to accomplish.

1.1 Background
As a manufacturer for the “Premium Automotive Group”-part in the FORD Corporation, Volvo will be leading in safety technology. In every situation must the customers be able to trust the car safety equipment. They have high demands. The sub-contractors of the windshield wiper systems have much knowledge in the area. Volvo states customer demands to the sub-contractor.

1.2 Goal
The goal is to specify the parameters that affect the wiper system cleaning quality of the windshield. The most important parameters will be tested so that Volvo is able to optimise and state requirements on the cleaning system and surrounding details.

1.3 Limitations
This work does not include wiper blade construction, wiper system mechanics, washer fluids or surrounding constructions. The surrounding constructions include the hood, spray mechanics and windshield geometry.

1.4 Implementation
The thesis work begins with finding information and stating a project plan. The testing will be done in a test station and full size cars, like Volvo S80. If necessary, manufacturers will be contacted (Bosch and/or Valeo). To have a better connection to reality a smaller test with company cars will be done. Documentation and smaller presentations will be done continuously. At the end, this will result in a technical report and a presentation on both Volvo Car Company and Luleå University of Technology.

1.5 Technical aids
To accomplish this work a number of technical aids will be used. In computer software there is many programs that will be used like Catia, MS Project and Word. Test rig and company cars will be used. Volvo Car Corporation has many different departments that will be used, for example Materials laboratory.
2 Getting information
To get a good background and understanding the different problems associated with windshield wiping an extensive information seek was done. The information seek will continue through the whole work.

2.1 Internet search
The common big technical databases such as Compendex and SAE Global mobility database was used to get information. Ordinary search-engines on the Internet such as Altavista and Yahoo were used. Volvo Cars and Ford Intranet has also been useful to find information.

2.2 Libraries
Two different libraries were visited in Gothenburg, the Volvo Car Corporation library and the library of Chalmers University of Technology. In these cases the libraries internal search systems were mainly used.

2.3 Result
The amount of information found was poor and rather old, from the 60’s to late 80’s. The most useful information came from the sub-contractor Bosch. Much information has also been collected from different persons and departments at Volvo. The FORD Intranet was very useful.
3 Wiper system

Bosch and Valeo is the supplier of the wiper system for many Volvo cars. They supply all the parts for the wiper system. For the Volvo S80 the whole wiper system is manufactured by Valeo.

A complete wiper system contains a wiper motor, cranks, wiper arms and wiper blades. The washing system contains an electric pump, hoses, container washer fluid and nozzles (2 or 3). These two systems form a complete cleaning system.

The windshield wiper system must meet the following requirements:

- Removal of water and snow.
- Removal of dirt (mineral, organic or biological).
- Operation at high and low temperatures (+80°C - -30°C)
- Corrosion resistance against acids, alkalis, salts (240h) and ozone (72h).
- Service life 1.5 million wipe cycles for a passenger car.
- Stall test.

There are also legal requirements involving the areas of vision (Europe, USA and Australia). These requirements are the most important. A car can not be sold if the wiper system do not accomplish the legal requirements.

3.1 History

About ten years after the first automobile was made the first windshield wiper was invented. The idea for windshield wiper was born when the president of the TRICO Company in the United States was driving his car on a rainy day. Unfortunately, he hit a boy because of the fact that he couldn’t see the road properly. The boy wasn’t hurt badly, but the driver was shaken and decided to do something about the problem with bad sight in rainy weather. This brought about the birth of the windshield wipers.

The first windshield wiper was a rubber blade on the windshield that was rotated manually. Off course, this design had its disadvantages and it was soon replaced by a vacuum driven wiper system.

However, this system was plagued by the fact that its speed of operation changed with the speed of the vehicle.

This failure finally led to the attachment of an electrical driven motor to the wiper arm. This is essentially the design that is still in use.

All of the latest progress with the wiper blade is about materials. The latest research is focusing on the possibility to use synthetic rubber instead of natural rubber. Figure 1 shows the evolution of the blade.
3.2 Wiper mechanics

There are different wiper systems to manage to keep the windshield clean. The most important wiper systems on the market are shown in Figure 2. The most common is the tandem system that has two arms. In some cases, the tandem system is controlled by a four-link mechanism to change the wiped area. BMW use this kind of system. The wiper arm on the right side has this mechanism for increasing the wiped area. They can also use the system unmodified to all markets (even the right side driven like Great Britain) which is an economic advantage. The aerodynamics can be a problem for the tandem system so some manufacturers have changed it for better aerodynamic characteristics by using spoilers for example. For cars in the Sports-Utility-Vehicle-segment, the opposed system has become quite common. It has a non-wiped area behind the mirror. Citroën and Mercedes-Benz have used a single-arm system that has been both controlled and not controlled. This system has not been sufficient good. Both Citroën and Mercedes seemed to put it to the history.

Figure 1: The wiper blade evolution.
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3.3 Function description wiper system Volvo S80

The function of the wiper system mechanics to the Volvo S80 is quite simple.
Mainly the system contains wiper links, motor and arms.
Figure 3 below shows the wiper system the way it is mounted in the car.

Figure 2: Survey of windshield cleaning systems.

Figure 3: Wiper system in a Volvo S80.
3.3.1 Activation
Due to different driving conditions, there are different ways to activate the wipers.
1. Activation when using the washer
The wipers wipe a couple of times and then stop.
2. Interval wiping
The control is set to the interval position. Different wiping delay is possible to choose by a control.
3. Continuous wiping
The control is set to either position 1 or 2. Position 2 has a greater wiping velocity than position 1.

3.3.2 Function
Figure 4 below shows the mechanics of the wiper system. When the driver activates the wipers, the motor (1) rotates a link that is mounted on the motor axis. This leads to an oscillating motion of the two links (2). The links (3) transform this back and forward oscillating motion to a rotating-reversing oscillating motion that gives the wiper arms (4) their characteristic movement.

![Figure 4: Wiper system.](image)

3.4 Wiper blades
Most wiper blades are in lengths between 260 to 1000 mm. They have between 4 and 10 pressure points. Most commons are the blades with 6 to 8 pressure points and a length between 430 and 700 mm. In some cases, aerodynamic deflectors are integrated in the wiper arms or blades to press the blades against the windshield.

3.4.1 Blade geometry
The rubber element is the most important component of the wiper blades. It has double microedges that are pressed against the windshield. The microedge has a point of contact that is only of approximate 0.01 mm of width. This can be studied in Figure 5. When moving across the windshield the wiper blade must overcome coefficients of dry friction of 0.8 to 2.5 and coefficients of wet friction of 0.6 to 0.1. The correct combination of wiper blade profile and rubber properties must be chosen so that the wiper lip can
wipe the complete wiped area of the windshield surface at an angle of 45°. Figure 6 describes the wiper blade against the windshield.

### 3.4.2 Blade material

There are 3 different combinations of the rubber compound:

- Natural rubber.
- Synthetic rubber.
- 2-component with either synthetic-synthetic or natural-synthetic rubber.

The rubber properties are important for the wiping quality at different temperatures. The lowest temperatures are the most difficult to get a good wiping quality because the rubber get stiff when it get cold. Tests have shown that natural rubber is the most effective in low temperatures.

![Microedge of the wiper blade.](image)

**Figure 5:** Microedge of the wiper blade.

![Rubber wiper element in working position](image)

**Rubber wiper element in working position**

1 Claw bracket, 2 Spring strip, 3 Lip, 4 Double microedge, 5 Windshield.

**Figure 6:** Wiper blade against the windshield.
3.5 U. S. Federal Motor Vehicle Safety Standards

Volvo Car Corporation follows the U.S. FMVSS regulations regarding the windshield wiper system. The regulation considering the size of the wiped area of the windshield is divided into three different areas.

Figure 7 shows the three different areas, A, B and C, and how they are related to the windshield.

The demands state how much (in percent) the windshield wipers must wipe of the actual area. This means that 99% of area A, 94% of area B and 80% of area C have to be wiped by the wipers.

The U.S. FMVSS regulations are one of the strictest regulations. Most car manufacturers ambitions are to fulfil these regulations. There are some other regulations for example, European, Japanese and Canadian.

Figure 7: Field of vision regulated by FMVSS.
4 Choose of test parameters
The cleaning quality is affected by many parameters. At first, all conceivable parameters are listed. The parameters are divided into four different areas such as geometry based, material based, environmental based and those that are depending on other factors like speed.

4.1 Parameters
The parameters that affect the windshield cleaning quality are listed below in the different areas.

4.1.1 Geometry dependent parameters

- **Wiper blade wear.**
  New wiper blades is cleaning the windshield good. The more they are worn the poorer will the cleaning quality be.

- **Wiper blade geometry.**
  There are from 4 to 10 pressure points on the wiper blade. The profiles are also varied. Every manufacturer has own blade geometry and often they even have different blade geometry in different models.

- **Windshield geometry.**
  The windshield curvature affects the wiper arm pressure. If the curvature is large, the geometry of the wiper blade is also affected. The angle between wiper blade and windshield changes with the curvature of the windshield.

- **Aerodynamics.**
  With good aerodynamic design of the hood, the cleaning quality is increased. The airflow over the windshield affects the arm pressure and the washer fluid distribution.

- **Spray geometry.**
  The distribution of the washer fluid at the windshield gives different cleaning results. The better distribution over the windshield the better cleaning quality.

4.1.2 Material dependent parameters

- **Wiper blade material.**
  Most of the wiper blades are made of natural rubber. There are 2-component wiper blades. Some of them are synthetic-natural rubber and the rest are whole synthetic.

- **Windshield surface.**
  This subject is rather unknown. How will the roughness of the surface affect the cleaning quality? The water contact angle is important. With a high angle, droplets will occur and these will flow away with the airflow.
and gravity. Some car manufacturers use coatings to get lower polarity of the surface to prevent water film. Wiper system manufacturers prefer a low contact angle to prevent chattering and smear.

4.1.3 Environmental depending parameters

- **Amount of rain.**
  Much rain is more difficult to sweep of the windshield than less rain. Chattering can occur when the rain amount is small.

- **Rain/dirt substance.**
  The amount of particles and their origin affects the cleaning quality. The wear of the blades will increase with increased amount of particles.

- **Temperature.**
  The rain will have different properties with different temperatures. The wiper blade performance is affected depending on the rubber properties that change with different temperatures. There are for example winter blades, which performs better in cold temperature.

4.1.4 Other depending parameters

- **Wiper arm speed.**
  If the arm speed is to high aquaplaning of the wiper blade will occur.

- **Speed of the car.**
  When the car have higher speed the arm pressure becomes to low because of the airflow and this will result in blade lift-off. To prevent this there are aerodynamic deflectors integrated in the wiper arm. The deflectors press the blade against the windshield and the arm pressure increases.

- **Wiper arm pressure.**
  Too high pressure will damage the blade. In parking position, the wiper blade will have permanent deformation if the arm pressure is too high. Too low pressure will give poor cleaning quality in high speeds.
4.2 Test parameters

The 13 parameters were reduced to 6 because of the limitations that were stated in the beginning of this work. The parameters left at this point were:

- Wiper blade wear
- Wiper blade geometry
- Windshield surface
- Amount of rain
- Rain/dirt substance
- Temperature

The 3 last parameters are environmental parameters that change constantly depending of where the car is. Therefore these 3 parameters can be cut out.

The parameters left to be tested are

- Wiper blade wear
- Wiper blade geometry
- Windshield surface

To somehow be able to test the influence of the 3 parameters, a translation of these parameters to 3 concepts were done. Each of these 3 concepts should include at least one of the parameters. The purpose was to find concepts that:

- Decrease the wiper blade wear.
- Increase the cleaning quality by improved wiper blade geometry.
- Increase the cleaning quality by an improved windshield surface.

Following three concepts were tested because they are rather new and unknown for Volvo and concerns one or more of the above parameters listed.

4.2.1 “Safe Sight” concept

The “Safe Sight”-concept is a tape that have four small “stripes” that are supposed to keep the wiper blade cleaner and sharper than without the stripe. The test will measure the wear of the “stripes” and the wiper blade. A test on 9 company cars that concerns noise and cleaning quality based on subjective judgements by the drivers is done.

4.2.2 Coated windshield

The best solution is to not have any wipers at all if the cleaning quality is necessary good. If they don’t exist, they can’t disturb the driver. The less the driver gets disturbed the safer he/she is driving. This can not be implemented today because water and dirt can’t just disappear from the windshield surface. Glass manufacturers research has given a coating that repels water. If this hydrophobic coating is used on the windshield surface, water will form droplets that will run off by the wind. This will happen if the car has a speed more than 70 km/h. The result of this is that the wiper system doesn’t have to strike as often than usual and the driving is safer. The test is supposed to measure the wear of this coating and the everyday test concerning cleaning performance, noise and durability.
4.2.3 Bosch Flatblade Technology
The new wiper blade from Bosch is a slim wiper blade with a flat spring design. It has a deflector over the whole blade that will distribute the pressure over the blade. Bosch means that this new blade has a better wipe quality, less wear, wind noise and better winter performance. It is less expensive because the number of components is less and therefore the weight is decreased. In December 1999, only Mercedes uses this wiper blade to their most expensive cars. The test will measure the wear of the wiper blade. It will also be used on a car for an everyday test concerning cleaning performance, noise and durability.
5 Measurement methods
To be able to evaluate the tests concerning the wiping quality some different methods are tried out and used. This chapter discusses these methods and explains why they are used or not.

5.1 Windshield surface measurements
To find a good way to measure how the wipers affect the surface of the windshield, and in general, what properties the windshield surface has, a study in this area was made.

5.1.1 Study of the windshield surface
To get more knowledge of the properties of the windshield surface the Material Laboratory at Volvo was contacted. The purpose of this study was measuring the surface roughness of the windshield.
A small sample of an ordinary windshield was placed in an electron microscope and examined.
The study gave no information about the surface roughness. Glass surface is very fine and therefore it is very hard to detect irregularities.
The only thing that was visible was small collections of silicon on the windshield surface.
This leads to the conclusion that windshields of modern cars have a very high surface roughness.

5.1.2 Contact angle
A good measurement of the properties of the windshield surface is the contact angle. The contact angle describes how, in general, for example a liquid behaves on a surface.
One way of measuring the contact angle is to use a magnifying glass. A small droplet of distilled water is applied to the windshield surface. It can be 3 or 5 µl. Then the magnifying glass is used to measure the diameter of the droplet. The droplet diameter is translated to a contact angle with help from a table.
This method is very easy to use and it has a good accuracy so therefore it is a good method to use.

5.2 Wiping quality measurements
To be able to judge how good the wipers clean the windshield a good measurement method is needed.

5.2.1 Rain sensor
The rain sensor recognises rain droplets on the windshield, making it possible to trigger the windshield wipers automatically. This function was tested if this method could be used to measure the thickness of a film of water. Bosch made the rain sensor that was tested but there are other manufacturers too. Figure 8 shows the rain sensor. It has a light source (1), LED, and a light receiver (2), a photodiode. The infrared beam is directed at an angle towards the windshield (4). If the windshields outer surface is dry, it will reflect the beam back to the receiver undisturbed. When water
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droplets (5) are present on the outer surface some of the light will refract outwards and the receiver will measure a weakened signal.

If the sensor can detect water droplets, will it detect a film of water? The rain sensor RS2ZS from Bosch was tested. It was attached to a smaller part of a windshield. Both the voltage and resistance was measured over the photo-diode in both dry and rainy conditions. This model of the rain sensor is dependent of a data signal to work properly. The data signal was not available at the time for the test so the measurements over the photo diode gave wrong results. The sensor was also too slow for required measurements and therefore it will not be used further in the tests.

However, it would be interesting to find out if the sensor could work with a data signal. Small changes could maybe make it faster and in that way useful in measuring the cleaning quality. This could be interesting to analyse in the future. Yet, this work won’t discuss the rain sensor any further.

5.2.2 Other methods
Manufacturers of wiping systems mainly use visual judgement methods. Often the water that’s sprayed on the windshield is prepared with colour pigment to easier be able to see the result of the cleaning quality. An ordinary camera is used to document the tests.

5.3 Wiper blade wear measurements
To measure the wear of the wiper blades an electron microscope is used. The microscope doesn’t give a value of the wear, but it is possible to get a good picture of how the wiper is worn.

5.4 Conclusion
The magnifying glass, the electron microscope and the visual judgement are the measurement methods that are best and easiest to use for our purposes.
6 Test rig

To be able to test the cleaning system a test rig is used. The rig has three main parts:

- A box of Plexiglas that is big enough for a complete windshield with cleaning system.
- A funnel and a pump are used to mix water and dirt (feldspar).
- To control the whole test rig a PLC is used. Figure 9 shows the test rig.

![Test rig](image)

**Figure 9: Test rig.**

Water and dirt is mixed with a ratio of 5:1. The pump distributes the mix to the test rig by a hose. To prevent stoppage in the funnel a circulation is needed. The pump that pumps the mix back to the bottom of the funnel achieves the circulation and this will stir the mix during the test.

Two smaller funnels are filled with the mix of water and dirt by a hose from the pump. Compressed air is used to distribute the mix to the windshield. Clean water is sprayed on the windshield from three small nozzles. The clean water and the mix distribution are controlled by a PLC. Figure 10 shows the PLC and the dirt distribution. All tests are performed in +20°C and with a wiping speed of 44 strikes/minute.
Two generating units are used, one with 24 V output and the other with 12 V output. 24 V is required for the compressed air valve. 12 V is for all other valves and for the wiper motor. The pump that distributes the mix of water and dirt is driven by compressed air. A valve controls the pressure. Figure 11 shows one of the generating units.

6.1.1 Sysmac-P0

Sysmac-P0 is a sequence control system that has programmable memory and can control outputs. To be able to control a process the process needs to be divided into smaller parts. These smaller processes must be implemented in right order.

The difference between Sysmac-P0 and an ordinary PLC (Programmable Logical Control) is that the PLC requires that conditions are stated to change status for the outputs. Sysmac-P0 requires that the conditions for the next step are stated.

Specifications for Sysmac-P0 are found in appendix 1. Figure 12 shows the Sysmac-P0.
6.1.2 Programming

The Sysmac-P0 is programmed step-by-step with an operation instruction. This instruction contains a command that can be a logical calculation, a jump to another step or a timing function. Outputs are specified for each step. A short example of a program is found in Table 1.

<table>
<thead>
<tr>
<th>Step</th>
<th>OP</th>
<th>Data 1</th>
<th>Data 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>TIM</td>
<td>10</td>
<td>, 0</td>
</tr>
<tr>
<td>02</td>
<td>JMP</td>
<td>06</td>
<td>-</td>
</tr>
<tr>
<td>06</td>
<td>END</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1: Program example.

Step 01: Timer will be counting in 10 seconds.
Step 02: A jump to step 06.
Step 06: The program ends and returns to step 01 without executing.
A table of all operation instructions is in appendix 1.
7 SAFE SIGHT concept

Figure 13 below shows the principle of the concept and how the tape is applied above the wipers parking position. The tape should be applied with a small angle, according to the wiper blade, and at a distance of 20-30 mm.

![Figure 13: The SAFE SIGHT concept.](image)

When wiper blades pass over the tape, they are supposed to be cleaned from all dirt and the dangerous traffic film disappears.

The benefits according to the manufacturer should be:
- A safer vision for the driver.
- Extended life of the wiper blades.
- Less usage of windshield washer fluid.
- Easy to use - fits any type of vehicle.
8 Coated windshield

There are coatings for several different needs. In concern of the wiper system the change of the contact angle on the windshield is the most important as discussed below. A contact angle of more than 80° is needed to have a hydrophobic surface. There are different kinds of coatings. For example, Titanium oxide and fluorine-silicon compound. The thickness of the coatings is about 1 µm or thinner. The legal requirements about the optical properties of the windshield are very strict so the coating can not be too thick.

8.1 Thermodynamic adsorption theory

The theory says:

If two materials come close enough to each other, they will connect. The union of these two materials is stronger than the weakest material.

Good adhesion is achieved if the surface of the windshield is not completely smooth and has a higher surface tension than the water. In this case, good adhesion is undesirable so these conditions require smoother surface and a lower surface tension of the windshield.

When the liquid has a higher surface tension than the material, the liquid will become a droplet. On the contrary, when the liquid has a lower surface tension it will wet the material.

This behaviour comes from the thermodynamic adsorption theory because the surface tension of the windshield has been lowered under waters.

What is surface tension?

All materials aim to get the smallest surface in comparison to its volume. With liquids, it is easy to see this behaviour – they form droplets. Even solid materials will have this behaviour. When melting metals the material will form to droplets. This ambition to form spheres causes a tension on the surface – this is surface tension. The stronger bonding in the material the higher surface tension it has. This gives the hydrophobic behaviour and the contact angle is a value of it.

8.2 Contact angle

The water contact angle is important for how water will behave on the windshield (or any kind of surfaces). With a low angle, the water will spread to a thin film. In addition, with a high angle it will form droplets. Figure 14 describes the angles. Depending on what angle the wiper blade have designers must keep in mind of this contact angle. Coatings will higher/lower the polarity of the surface. These will increase/decrease occurrence of water film/droplets. Ordinary windshields without any treatment have a contact angle about 20°. Some coatings change this angle to about 90° or more. This operation doubles the cost compared to an ordinary windshield.
Figure 14: Contact angle between windshield and water droplet.
9 Bosch Flatblade Technology

Bosch has developed a new wiper blade that has a flat spring design. When it becomes commercial, it will be manufactured of a 2-component synthetic rubber called TZ. Figure 15 shows the new wiper blade.

The advantages of the Flatblade Technology according to Bosch is:

- Wipe quality
- Wear
- Wind noise
- Winter performance
- Blade height
- Number of components
- Weight
- Air resistance
- Performance/Torque requirements
- Impact/pedestrian protection

The wiper blade can be extruded instead of moulded and this makes it less expensive. The number of parts is less and that will make it cheaper to produce.

Ordinary wiper blades have 4-8 pressure points where the pressure is highest. At these pressure points, the wear of the blade will be at the most and this occurs in wider stripes that are disturbing the vision. The Flatblade Technology has a flat spring design that will make the pressure against the windshield more even along the blade compared to ordinary wiper blades. This should make the cleaning quality higher than with the older wiper blades.

The flat spring design and the low blade height make it less visible for the driver and give a nicer appearance.

![Figure 15: Bosch Flatblade Technology](image.png)
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Figure 16 shows the airflow over the current product and the new Flatblade Technology. The new wiper blade will reduce noise due to less turbulence in the airflow.

The winter performance is improved because the lack of joints. These joints tend to freeze in cold weather that make the wiper blade stiff. This results in uneven blade pressure and a poorer wiping quality.

Figure 16: Difference between current wiper blade and the Flatblade Technology.
10 Test of the SAFE SIGHT concept

In the first test the “SAFE SIGHT” concept is evaluated. Two different tests are done one in laboratory environment in a test rig and the other on real cars in real driving conditions.

10.1 Test in rig

An ordinary Volvo S80 Pilkington windshield and Valeo wiper system is used. The windshield with the wiper system is placed in the test rig as shown in Figure 17.

The PLC is programmed to control the distribution of water, dirt and the activation of the wipers. The program can be found in appendix 2.

The SAFE SIGHT stripe was applied only to the driver side.

Figure 17: Windshield in test rig.

The purpose of this test was to see if the SAFE SIGHT concept gives less wear on the windshield and if the wiper blade get better cleaning quality than the ordinary system. A test protocol is found in appendix 3. After the test, the wiper blades were scanned in an electron microscope. Figure 18 shows how a wiper blade looks like before it is used.
10.1.1 Result
In the beginning, the side that had the SAFE SIGHT stripe had a better cleaning quality than the side without. When the stripe began to peel off, the cleaning quality on that side decreased. The SAFE SIGHT stripe peeled off after 77700 cycles. When the stripe peeled off it was replaced with a new one. There were some problems with the fastening of the new stripe to the windshield. Dirt or grease at the surface of the windshield may have caused this.

Figure 19 shows the microedges of the wiper blades when the SAFE SIGHT stripe has been used for 155000 cycles. After the point when the stripe peeled off (77700 cycles) the side without the stripe cleaned better because the stripe had worn the wiper blade badly. Figure 20 shows the microedges of the wiper blades without the SAFE SIGHT stripe after 155000 cycles. The pictures show that the wiper blade that had the SAFE SIGHT stripes is more worn than the blade without it. The important microedges had been rounded and did not function properly.

The blades were cleaned by hand at 101000 cycles with a paper towel. The wiper blade that strokes the stripe was less dirty than the blade without the stripe. This shows that the SAFE SIGHT stripe prohibits dirt to fasten to the blade.

The wiper framework has more looseness in its joints than a new wiper blade. This will probably result in more noise, chattering and poorer cleaning quality.
Figure 19: The wiper blade using SAFE SIGHT concept after 155000 cycles.
10.2 Test on company cars

To evaluate the concept in real driving conditions 9 company cars on Volvo was equipped with the SAFE SIGHT stripes. The cars were distributed in models as follows: 3 S80, 4 S70, 1 850 and 1 V40. To be able to evaluate the test in a good way the drivers answered an inquiry both before and after the test. The purpose of the inquiry before the test was to get knowledge of the drivers opinion about the wiper system. The stripes were mounted in a garage by the authors. The garage was used because of the fact that the stripe needs at least 10°C when mounting, and the windshield needs to be completely clean. After using the SAFE SIGHT stripes for about 2 months, from November to January, a second inquiry was answered by the drivers. That showed how the SAFE SIGHT concept affected the wiper system.

10.2.1 Result

A conclusion from the first inquiry is that the majority of the drivers are quite pleased with the cleaning quality. Complains that exists are focused on the passengers side and refers to water film and stripes from the wiper blade. Another disturbing factor for 8 of the 9 drivers was noise and chatter from the wiper blades. The noise occurs when the wipers turn position.
In the second inquiry, all of the drivers had complaints about the durability. The stripes peeled off too easy. Most of the drivers also had complaints about the noise that occurred every time the wiper blades stroke the stripe. The drivers answers of the two inquiries are found in appendix 4.

10.3 Conclusion

The test with the test rig shows that the SAFE SIGHT concept cleans the wiper blades. In the beginning, the side with the stripes had a better cleaning quality than the side without. However, the wear was too much and the cleaning quality decreased after a longer period compared to the wiper blade without the stripes.

The company car test showed also that the cleaning quality in the beginning was very good for most of the drivers. They all had problems with the durability. For some of them, the stripes peeled off in 2 weeks. They all complained about the durability and some of them complained the noise that occurred every time the wiper blades stroke the stripes. Figure 21 describes the cleaning quality as a function of time. There is a break point where the SAFE SIGHT stripes no longer give an improved cleaning quality. To get more specific numbers for when the break point occurs more testing are needed.

![Figure 21: Cleaning quality as a function of time.](image-url)
11 Test of the coated windshield

To increase the contact angle between water and the surface of the windshield a hydrophobic coating is used. This coating is applied at the factory that makes windshields. There are many questions about this coating. The coating is very sensitive to wear. The contact angle for an ordinary windshield is about 20-25°. The coated windshield has a contact angle of 105-110°. The driver side had a SAFE SIGHT stripe to see if this concept can make the sensitive coating last longer.

11.1 Test in rig

The ordinary windshield was changed to a coated windshield. This coated windshield was manufactured by Pilkington Ltd. Test protocol is found in appendix 5.

11.1.1 Contact angle measurement

Figure 22 describes 3 different areas. Area 0 is the area where the wipers don’t wipe i.e. no wear from wiper blades. In area 1 only one wiper blade can wipe and the wear is less than in the area 2 where both wipers wipes. The measurement of the contact angle will be at 3 points per area.

![Areas of measurement](image)

Figure 22: Areas of measurement.

11.1.2 Result

The wiper blades chattered a lot especially when there was quite much water on the windshield. When the dirt was sprayed on the windshield the chattering almost stopped. The chattering weakened as the test continued. The contact angle was measured every 5 hour. The result of this measurement is found in appendix 6. At the beginning there was no or small change of the contact angle. After 22000 cycles the contact angle had decreased from 105-110° to 88-99°. After about 35000 cycles, the windshield surface was much worn in the area where both wiper blades were working. The contact angle had decreased to 40-60°. This area was clearly
seen from the drivers field of view. Where only one wiper blade where working the wear was not as deep. The side with the SAFE SIGHT stripe was worn more than the other side. At the change points a small edge had developed.

11.2 Test in company car
Two company cars (S80) has these kinds of windshields. One of them has also the new wiper blades from Bosch.

11.2.1 Result
There are many advantages with this coating but unfortunately, some disadvantages too. When the problems are solved this can and will be a good solution if the active safety must increase.

Advantages:
+ Very good sharpness and visibility even tough the rain amount is high.
+ Wiper wipes dry in one or two strikes.
+ The need of the wiper system is less.
+ Precipitation as rain, snow, ice, etc is easier wiped off.

Disadvantages:
− Wiper blades chatter.
− Blinding and reflections from outer lightning when driving in darkness.
− Cost. It’s expensive at the moment.
− Durability: 1-3 years.

11.3 Conclusion
The rig test showed that the coating was worn uneven over the wiped area. The result was that the area where both wiper blades wiped was clearly seen from the inside. This variation of the contact angle can be disturbing for some drivers. The results of the company car test were over all very positive. All drivers was very pleased with the visibility except when driving in darkness.
12 Test of Bosch Flatblade Technology

It is not common that the wiper blade manufacturers develop totally new wiper blades. Often they only make small changes in materials and profiles. Bosch has developed a new blade that is not a new idea but it is improved more than ever. The Flatblade Technology is about a flat spring instead of the old skeleton. It will be made of a new 2-component synthetic rubber.

12.1 Test in company car

Two company cars have been equipped with Bosch new wiper blades. One of the cars has also a windshield that has a hydrophobic coating. The car with the coated windshield has a wiper blade made of the 2-component synthetic rubber called TZ. The other one has a natural rubber blade called M-stof. When this blade will be more commercial than today it will have the TZ composition. The natural rubber blade was made only because when Mercedes wanted it there was nothing else that was tested. These two different types of blades have also different profiles. The synthetic rubber is stiffer than the natural rubber in cold weather and to make the wiper blade softer Bosch had to let it have two waists compared to the natural with its one waist.

12.1.1 Result

The new wiper blade was only tested for about 2500 strokes in the company car. The cleaning quality was very good during the whole test and the wiper blade did not show any wear. The test in the rig will show how the wiper blade performance is changed by the wear. The blade did not show any tendencies to lift off in different wind speeds. Some noise and water came from the fastening point but according to Bosch, this problem will be solved to the next version.

12.2 Test in the rig

An ordinary windshield to a Volvo S80 was used. The new wiper blade from Bosch called Flatblade Technology with a special wiper arm was tested. The blade was the 2-component TZ that has been tested in company cars. The purpose off this test was to see the difference between this new product and the “old” ordinary wiper blade. The test was performed with the same equipment and program as earlier so that the test can be compared correct. The test protocol is found in appendix 8.

12.2.1 Result

Overall, the cleaning quality was better than the ordinary wiper blade for a Volvo S80. The ordinary wiper blade showed wide stripes after 33000 cycles in the test rig. The new Bosch wiper blade showed no stripes at all after 119500 cycles. Some squeegee sound occurred after 67000 cycles. Smaller stripes occurred at the top of the blade on the drivers side. These stripes were only visible from the outside of the windshield not from the inside. There is nothing else to remark on. The test stopped after 119500 cycles. The cleaning quality was very good during the whole test. The blade has a tendency to lift off at the top because of the decreasing pressure at the ends.
Compared to the ordinary blade that was tested before this new blade showed no tendencies to get loose. The noise from loosened joints can therefor never occur.

12.3 Conclusion

These new wiper blades from Bosch is remarkable good. According to Bosch, the small problems that have occurred will be adjusted to the next generation of wiper blades. The cost for these blades is higher compared to the ordinary blades but will decrease in the future when the product is introduced to the market. We recommend these wiper blades without hesitation.
13 Recommendations and further development

In the two chapters below our recommendations and some further developments are discussed based on the results from the tests.

13.1 Recommendations

We recommend further development and tests of the coated windshield and the Bosch Flatblade Technology. These two concepts should be taken into production as soon as possible because of the positive improvement they give. The coated windshield could be included in a safety package or as a feature. The new wiper blade should be introduced to all models as a standard equipment.

13.2 Further development

These concepts are not fully developed and they all need some more work.

- The Bosch Flatblade Technology has some noise problems that come from the fastening point. Some water can be left at the middle of the blade around the fastening point. According to Bosch these problems are known and will be solved to the next version that will come in the beginning of 2000. The blade has a tendency to lift off at the top because of the decreasing pressure at the ends. The squeegee sound that occurred should be adjusted. Winter performance and some environmental factors like UV, wear and ozone should be tested.

- The SAFE SIGHT concept had a very good cleaning quality as long as it lasted before it peeled off according to the test drivers. The noise when the wiper blade stroke the stripes was however very annoying. Development to increase durability and decrease the noise is necessary.

- The test drivers positively received the coated windshield. Wiping was decreased to almost zero. The problem with the wipers that chatters and the coatings durability must be solved before it can be introduced. The manufacturers are aware of the low durability. Today the coating should last for 1-3 years. The ambition is to make it last about 5 years. Some of the drivers experienced disturbing light refraction from road lights when driving in dusk. Winter performance should be tested. New wiper blades that are optimised for coatings are needed to decrease the chattering.
14 References


Clarke, J.S. and Lumley, R.R., 1960, "Problems associated with windshield wiping", Society of Automotive Engineers, NY, SAE Summer meeting Edgewater Beach Hotel Chicago, SAE 197A


Lundkvist Sven-Olof and Helmers Gabriel, 1993, "Siktsträcka till hinder vid nedsatt syn och/eller sliten vindruta", Väg- och Trafikinstitutet, VTI Nr 382


Optimal windshield cleaning performance


## APPENDIX

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</tr>
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Appendix 1 Sysmac P0 specifications

Surrounding:

Temperature: Storage –15 / +65°C
In use 0 / +50°C

Humidity: 65 +/- 20% RH without condensing.

Voltage: 110/220V 50 Hz +/- 10%

Power consumption: ~55 VA

Weight: ~5 kg

Function data:

System type: Memory programmed sequence control system

Number of Instructions: 12

Number of program steps: 64

Number of in- and outputs: 12 inputs
12 outputs

Programming and program panel: Programming in C-MOS RAM with keyboard in panel. Numerical program indicator.

Signal frequency: 10 Hz max, pulse width: 50 ms.

Time functions:
(1) 0-9 h, 59 m
(2) 0-59 m, 59 s
(3) 0-59, 9 s
Accuracy: +/- 1 % +/- 10 ms

Counter: 1-99 pulses/step

Repetition function: 1-99 times/step

Internal time monitor: 0-99 s
Accuracy: +/- 7% max

Interrupt function: 2 levels

Protection in power supply interrupt:
(1) Battery –back-up for RAM-memory
(2) Protect data: Step nr, number of repetitions, flag-, timer-, counter- and initial status.

Memory durability in power supply interrupt: More than 60 days in max 60°C.
<table>
<thead>
<tr>
<th>Function</th>
<th>OP</th>
<th>Data 1</th>
<th>Data 2</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nop</td>
<td>0 NOP</td>
<td>-</td>
<td>-</td>
<td>No task, go to next step.</td>
</tr>
<tr>
<td>End</td>
<td>1 END</td>
<td>-</td>
<td>-</td>
<td>Program ends. Go to step 01 and wait for start command.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01</td>
<td>-</td>
<td>Program ends. Go to step 01 and restart automatically.</td>
</tr>
<tr>
<td>Return</td>
<td>2 RET</td>
<td>-</td>
<td>-</td>
<td>Go to the step where the interruption was and wait for start command.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01</td>
<td>-</td>
<td>Go to the step where the interruption was and restart automatically.</td>
</tr>
<tr>
<td>Jump</td>
<td>3 JMP</td>
<td>00-63 (step no)</td>
<td>-</td>
<td>Jump to step given in data 1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00-63 (step no)</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>If the condition in data 2 is satisfied jump to step no according to data 1. Else, wait.</td>
</tr>
<tr>
<td>And</td>
<td>4 AND</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>When the conditions in data 1 and data 2 are satisfied then go to next step. Else, wait.</td>
</tr>
<tr>
<td>Or</td>
<td>5 OR</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>When the conditions in data 1 or data 2 are satisfied then go to next step. Else, wait.</td>
</tr>
<tr>
<td>Counter</td>
<td>6 CNT</td>
<td>01-99</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>When the input given in data 2 has received the number of pulses given in data 1 then go to next step.</td>
</tr>
<tr>
<td>Condition al jump</td>
<td>7 CIP</td>
<td>00-63 (step no)</td>
<td>01-12 (input no) 71-74 (flag no)</td>
<td>If the condition in data 2 is satisfied, go to the step given in data 1. Else go to next step.</td>
</tr>
<tr>
<td>Repeat</td>
<td>8 RPT</td>
<td>01-99</td>
<td>00-63 (step no)</td>
<td>Repeat program from step no given in data 2 as many times given in data 1.</td>
</tr>
<tr>
<td>Timer</td>
<td>9 TIM</td>
<td>h/min/s</td>
<td>min/s/0,1s</td>
<td>Go to next step when the combination of times given in data 1 and 2 is expired.</td>
</tr>
<tr>
<td>Flag set</td>
<td>FSR</td>
<td>71-74 (flag no)</td>
<td></td>
<td>Hit the flag given in data 1.</td>
</tr>
<tr>
<td>Flag reset</td>
<td>FSR IN</td>
<td>71-74 (flag no)</td>
<td></td>
<td>Reset the flag given in data 1.</td>
</tr>
</tbody>
</table>
### Appendix 2 Test program

<table>
<thead>
<tr>
<th>Step</th>
<th>Operation</th>
<th>Data 1</th>
<th>Data 2</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>TIM</td>
<td>02</td>
<td>.0</td>
<td>Out 2 and 4 on. Dirt for 2 s.</td>
</tr>
<tr>
<td>02</td>
<td>TIM</td>
<td>10</td>
<td>.0</td>
<td>Out 2 on. Wipers on for 10 s.</td>
</tr>
<tr>
<td>03</td>
<td>TIM</td>
<td>08</td>
<td>.0</td>
<td>Out 2 and 6 on. Water on for 8 s.</td>
</tr>
<tr>
<td>04</td>
<td>TIM</td>
<td>10</td>
<td>.0</td>
<td>Out 2 on. Wipers on for 9.8 s.</td>
</tr>
<tr>
<td>05</td>
<td>FSR</td>
<td>74</td>
<td></td>
<td>Flag 74 on. Counter.</td>
</tr>
<tr>
<td>06</td>
<td>FSR IN</td>
<td>74</td>
<td></td>
<td>Flag 74 off.</td>
</tr>
<tr>
<td>07</td>
<td>JMP</td>
<td>01</td>
<td></td>
<td>Go to step 01</td>
</tr>
</tbody>
</table>

Cycle time is 30 s. Wipers on during the whole cycle.
## Appendix 3 Test protocol SAFE SIGHT

<table>
<thead>
<tr>
<th>Date / Time / Cycle nr.</th>
<th>Comments: Driver side SAFE SIGHT stripe</th>
<th>Comments: Passenger side</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/11 09.00 17 PHOTO!</td>
<td>Seems OK!</td>
<td>Small and thin film. Weak stripes at the top of the wiper.</td>
</tr>
<tr>
<td>4/11 10.00 40</td>
<td>OK!</td>
<td>Problems with the secondary dirt funnel. It doesn’t fill properly.</td>
</tr>
<tr>
<td>4/11 11.44 89 GO!</td>
<td>Funnel is stuck.</td>
<td></td>
</tr>
<tr>
<td>5/11 08.20</td>
<td>Main dirt pump broken. Gasket broken.</td>
<td></td>
</tr>
<tr>
<td>5/11</td>
<td>Change of pump.</td>
<td>Change of pump.</td>
</tr>
<tr>
<td>8/111 8.45 623</td>
<td>Test start again</td>
<td>Test start again</td>
</tr>
<tr>
<td>8/11 10.40 854</td>
<td>Funnel is stuck.</td>
<td></td>
</tr>
<tr>
<td>8/11 10.58 856</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>8/11 13.11 1120 PHOTO</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>8/11 16.25 1506</td>
<td>Day ends.</td>
<td></td>
</tr>
<tr>
<td>9/11 9.19 1506</td>
<td>Start up</td>
<td></td>
</tr>
<tr>
<td>9/11 12.56 1937</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>9/11 16.15 2331</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>10/11 9.34 2338</td>
<td>As earlier.</td>
<td>As earlier. Inside: Weak stripes at the top of wiper.</td>
</tr>
<tr>
<td>10/11 13.20 2787</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>10/11 16.39 3182 3182</td>
<td>Day ends.</td>
<td></td>
</tr>
<tr>
<td>Date / Time / Cycle nr.</td>
<td>Comments: Driver side SAFE SIGHT stripe</td>
<td>Comments: Passenger side</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>11/11 8.36 3182</td>
<td>Day starts.</td>
<td></td>
</tr>
<tr>
<td>11/11 13.07 3722</td>
<td>One stripe peeled off. Otherwise as earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>11/11 16.11 4086</td>
<td>As earlier. Day ends.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>12/11 11.54 4455</td>
<td>3 stripes have peeled off.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>15/11 12.01 4455</td>
<td>All stripes removed and changed.</td>
<td></td>
</tr>
<tr>
<td>15/11 13.13 4468</td>
<td>Strong stripes at the bottom of the wiper. A fold at the middle of the stripes at the top. May peel off.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>15/11 16.07 4814</td>
<td>The Safe Sight stripes have peeled off.</td>
<td></td>
</tr>
<tr>
<td>16/11 9.20 4820</td>
<td>The stripes are changed. Wide stripes/film at the bottom</td>
<td>Wide stripes/film at the top.</td>
</tr>
<tr>
<td>16/11 9.25 4825</td>
<td>The wipers have been cleaned. Not so dirty. Not as good wipe quality.</td>
<td>Very dirty. Better wipe quality than with SS.</td>
</tr>
<tr>
<td>16/11 14.53 5478</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>16/11 16.36 5683</td>
<td>As earlier. Day ends</td>
<td>As earlier.</td>
</tr>
<tr>
<td>17/11 8.55 5684</td>
<td>Day starts. As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>17/11 13.09 6190</td>
<td>As earlier.</td>
<td>As earlier.</td>
</tr>
<tr>
<td>17/11 16.32 6592</td>
<td>As earlier. Day ends</td>
<td>As earlier.</td>
</tr>
<tr>
<td>18/11 16.10 7370</td>
<td>Two SAFE SIGHT stripes has peeled off. STOP.</td>
<td>Stop</td>
</tr>
<tr>
<td></td>
<td>New test.</td>
<td></td>
</tr>
<tr>
<td>24/11 10.20 1</td>
<td>Good cleaning quality.</td>
<td>Good cleaning quality.</td>
</tr>
<tr>
<td>24/11 14.42 522</td>
<td>Small fine stripes. Some thicker stripes at the pressure points.</td>
<td></td>
</tr>
<tr>
<td>24/11 16.25 716</td>
<td>One SAFE SIGHT stripe had peeled off. STOP.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4 Inquiry from company cars

Inquiry 1
This inquiry was sent to the company car drivers before the SAFE SIGHT-stripe was applied to the windshield.

1. Mileage per year?

2. How often are the wiper blades changed?

3. How do You experience the cleaning quality?

4. Are You disturbed by stripes, water film or anything else caused by the wipers?

5. Are You disturbed by noise or chattering from the wipers?

6. In which driving conditions do You find the cleaning quality to be poorest? (Rain, snow or slushy weather)

7. Do You use any other technology to improve the cleaning quality? What kind of technology?

8. Do You have any new ideas to improve the cleaning quality?

Comments:
Inquiry 2
The second inquiry was sent to the drivers after 2 months driving with the SAFE SIGHT concept.

1. Have You had any problems with the stripes during the test period? Has it peeled off?

2. How do you experience the cleaning quality has improved / not improved?

3. What advantages/disadvantages do the SAFE SIGHT- stripe have?
   
   Advantages:
   
   Disadvantages:
   
4. Would You recommend others to use this product? Why? Consumer cost is 70 sek.

   Comments:
Inquiry 1

Driver 1: S80 1999

1) Approx. 33000 km/year

2) Every service (approx. every 20000 km, usually they last that long).

3) The right side is not good, especially around 0°C, when the salt makes it even harder to us poor drivers. Gets seldom clean.

4) Too many stripes are not good, else not.

5) Yes I do, but it is not common.

6) In drizzle, when it takes time for the windshield to get wet. Also in slushy weather when it is much salt on the road and you get an annoying film on the windshield that has to be washed off.

7) No.

8) Things have happened during the 90’s on the cars regarding sound and quality. I’m quite pleased at the moment.
Driver 2: S70 1997

1) 30000 km

2) At service occasions.

3) Good.

4) Yes.

5) Yes.

6) Slushy weather.

7) No.

8)
Driver 3: V40 1997

1) Approx. 20000 km.

2) Every 6th month.

3) Good in the beginning, worse at the end.

4) Yes, on the right side.

5) No.

6) Rain and snow.

7) Sometimes degreasing.

8) Improved wiper blades.
Driver 4: 855 1996

1) 30000 km.

2) Every service, 15000 km interval.

3) When the service is approaching it gets worse.

4) Yes, especially when they are getting old.

5) This is a difficult question. Right now I think it’s OK (new wipers). Else noise when turning direction can appear.

6) I don’t know. Presumably in connection with salting.

7) No.

8) No.

Comments:
A. It occurs that the right side is not efficiently cleaned. This can be very annoying. I try to wash it away, but it seems to be a film when the fluid dries. This only occurs on the right side (I only use Volvo original washer fluid).

B. It is hard to remember any possible problems that I have had. Right now, the function is good.
Driver 5: S80 1999

1) Approx. 35000 km.

2) Check and change if it is required.

3) I think it is good.

4) In some cases by streams of water that pulls up on the windshield when driving with the interval level on the wiper system.

5) Yes, sometimes when starting the system the wiper blades can chatter and it sounds terrible.

6) It is too long time since I drove in snowy and slushy weather and therefor I cant determine this against rain.

7) I use to rub the rubber etches with a sponge to remove bug and tar particles from the wiper blades.

8) Nothing else than change wiper blades regular and clean it when I wash the car.
Driver 6: S70 1997

1) 30000 km/year.

2) At every service occasion, 15000 km.

3) Poor at the right side.

4) Both stripes and film.

5) Chattering wiper blades on the right side.

6) Dirt on the roads.

7) A piece of paper soaked with washer fluid.

8) A spoiler on the right side too.
Driver 7: V70 1998

1) Approx. 45000-50000 km/year.

2) At least on every service occasions.

3) Can be better.

4) Yes, sometimes.

5) Yes.

6) Rainy, snowy, and slushy weather.

7) No.

8) Not in the present-day situation.
Driver 8: S70 1997

1) 33000 km/year.

2) Every service occasion, 15000 km interval. Sometimes between these too.

3) Right side poorer.

4) Stripes on the right side.

5) Just before change there occurs chattering.

6) Light rain.

7) No.
Driver 9: S80 1999

1) 35000 km.

2) 8-9 months interval.

3) Good.

4) Not yet (the car is only 2 months old).

5) No.

6) No apprehension.

7) Only anti-freeze.

8) Not at the moment.
Inquiry 2

Driver 1: S80 1999

1) The stripe has almost peeled off, partially because of wear from the wiper blade but most because of the scraping when removing ice and snow from the windshield.

2) While the stripe was not peeled of the visibility was improved especially lower fourth of the windshield on the driver side where the visibility is most important when the windshield is large as on S80.

3) Advantages: The cleaning of the windshield is improved a lot.

Disadvantages: Except that the durability is almost zero there is a scratching noise every time the wiper strikes over the stripe. This is naturally because the cars are more silent now and every noise is easier to hear. Can be a matter of habit.

4) Low cost motivates mounting at least during the winter to improve the visibility, however the durability must increase. I have had the stripes for about 2 months and there is a very small part left on the windshield.
Driver 2: S70 1997

Hi,
Unfortunately, the garage has changed the windshield due to a crack (flying stone).
That’s why I have not been able to test the stripe.
**Driver 3: V40 1997**

1) It has partially peeled off because ice on the windshield. When it was removed, the stripe peeled off on the passenger side.

2) On the driver side, it is still there, it functions well. It worked well as long as it was still left on the passenger side.

3) Advantages: Slightly better cleaning of the wiper blade.

Disadvantages: The stripe wasn’t mounted in an angle that resulted in a disturbing noise. It peels off too easy.

4) Only if there is severe problems and the wiper blades function is disturbing.

Comments: Can be a good thing if You don’t have problems with ice on the windshield.
Driver 4: 855 1996

1) It has peeled off completely on the left side and almost completely on the right side (I don’t scratch the windshield because I have a heater).

2) It got worse. I bought new wiper blades today, the old ones were worn out.

3) Advantages: None.

Disadvantages: Noise. It was better after remounting but has never been good. Increased wear of the wiper blade. Peels off.

4) No recommendation! Sucks!!

Comments:
Mileage: 111740 km
Driver 5: S80 1999

1) Yes, I have had problems. The problem was adhesiveness on the left side when it was mounted. There is only 15 cm left of the lower two double stripes.

The stripes have been exposed to scratching when removing ice. On the driver side, the ice has been scratched with a Plexiglas scrape from A-beam towards the middle of the windshield and on the passenger side from the middle to the A-beam. The stripes on the driver side have obviously been exposed to more wear because of this. The stripes on the passenger side seem unaffected.

2) Advantages: Often the cleaning is quicker = less strikes to good visibility.

Note:
If the car is very dirty and the road is wet but not rainy, the turning point for the wiper blades can be very dirty. It won’t be cleaned by the washer fluid. The dirt is pushed upwards on the windshield partially = it becomes striped between the sweeping area where the washer fluid hits.

3) Advantages: In the most cases fever strikes to get a clean windshield.

Disadvantages: Turning point noise! Peels off. Sensitive for mounting disturbance/ ice scrape?

4) No, I wouldn’t recommend this product because the disturbing noise at the turning points.
Driver 6: S70 1997

1) It peeled off after about 2 weeks when wet snow and frost that resulted in that the wiper blades froze stuck. When the blades came lose the stripe was damaged.

2) During the short time I had the stripe I noticed an improvement on the right side.

3) Advantages: A slightly improved cleaning especially on the right side. I don’t know the function after a long time of use regarding the wear.

Disadvantages: Noise. The wiper blades have a terrible noise when they strike the stripes.

4) No. The stripe is too sensitive to mechanical effect that peels it off and the noise it makes is unacceptable.
Driver 7: V70 1998

Hi
After you had applied the stripes for the third time they peeled off and got stuck on the front fender. They were very hard to get clean.

I have not noticed any difference.

I’m not sure if I could recommend this to anyone if it costs 70kr every time!
Driver 8: S70 1997

1) ¾ of it has peeled off.

2) Hard to say. The day before the stripe was applied was the wiper blades changed. I have noticed that the wiping quality gradually gets worse. It is not sure that the stripe has delayed that.

3) Advantages: See answer 2.

Disadvantages: Some noise when the wiper blade strikes the stripes.

4) NO! The positive effect, if there is any, will be small compared to the irritation when the stripe peels off.

The idea is good, but my recommendation is that this model should NOT be sold (by using Volvos name) to customers.

Comments: To be able to evaluate more exactly and to find out the effect of the stripes, it should be applied to cars where the customers have complaints about the cleaning quality.
**Driver 9: S80 1999**

1) They have partly peeled off due to ice scraping. Otherwise they seem to be attached.

2) No problems with stripes i.e. wiping quality has improved.

3) Advantages: Better wiping quality.

   Disadvantages: Loud noise at the turning point.

4) Yes I should recommend these.

Comments: My wiper blades are about 4.5 months old and show no signs to be worn.
### Appendix 5 Test protocol Water repellent coating

<table>
<thead>
<tr>
<th>Date / Time / Cycle nr.</th>
<th>Comments: Driver side</th>
<th>Comments: Passenger side</th>
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<tbody>
<tr>
<td>13/12 13.42 1</td>
<td>Test starts.</td>
<td></td>
</tr>
<tr>
<td>13/12 17.49 480</td>
<td>Wiper blade chatters.</td>
<td>Wiper blade chatters.</td>
</tr>
<tr>
<td>14/12 09.00 480 CA</td>
<td>Measure of contact angle gives no changes.</td>
<td></td>
</tr>
<tr>
<td>14/12 09.15 480</td>
<td>Test starts.</td>
<td></td>
</tr>
<tr>
<td>14/12 15.05 1163 CA</td>
<td>Weak stripes at the pressure points.</td>
<td></td>
</tr>
<tr>
<td>14/12 19.33 1614</td>
<td>Day ends.</td>
<td>Visible change of surface where both wipers wipes.</td>
</tr>
<tr>
<td>15/12 09.05 1614</td>
<td>Test starts.</td>
<td></td>
</tr>
<tr>
<td>15/12 11.09 1849 CA</td>
<td>Weak fine stripes.</td>
<td>Weak fine stripes.</td>
</tr>
<tr>
<td></td>
<td>Inside: Clear change of surface where both wipers wipes.</td>
<td></td>
</tr>
<tr>
<td>15/12 16.20 2400 CA</td>
<td>One SS has peeled off.</td>
<td>Stripes at the pressure points.</td>
</tr>
<tr>
<td></td>
<td>Bad wipe quality. Smear the dirt.</td>
<td></td>
</tr>
<tr>
<td>15/12 19.00 2730</td>
<td>Day ends.</td>
<td></td>
</tr>
<tr>
<td>16/12 11.00 2730</td>
<td>Test starts.</td>
<td></td>
</tr>
<tr>
<td>17/12 10.20 3022 CA</td>
<td>Test start.</td>
<td></td>
</tr>
<tr>
<td>17/12 16.15 3683</td>
<td>Day ends.</td>
<td></td>
</tr>
<tr>
<td>20/12 10.28 3683 CA.</td>
<td>TEST ENDS.</td>
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</table>

CA: Measurement of contact angle.
## Appendix 6 Contact angle measurements

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<tr>
<th>Wiper cycles</th>
<th>Area 0 3µl / 5µl</th>
<th>Area 1 3µl / 5µl</th>
<th>Area 2 3µl / 5µl</th>
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<tbody>
<tr>
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<td>2.1 / 2.5</td>
<td>2.3 / 2.7</td>
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<tr>
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<td>2.1 / 2.9</td>
<td>2.5 / 4.0</td>
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<td>2.5-2.6 / 2.9-3.0</td>
<td>3.2-4.0 / 4.4-4.5*</td>
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</tbody>
</table>

The values describe the droplet diameter in mm.
*Difficult to measure because of misshapen droplets.

The areas that was measured.
## Appendix 7 Droplet-contact angle table

### Contact angles for a 3µl droplet.

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<tr>
<th>Diam (mm)</th>
<th>CA (Degrees)</th>
<th>Diam (mm)</th>
<th>CA (Degrees)</th>
<th>Diam (mm)</th>
<th>CA (Degrees)</th>
<th>Diam (mm)</th>
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### Contact angles for a 5µl droplet.

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## Appendix 8 Test protocol Bosch Flatblade Technology

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<td>17/1 09.05 1</td>
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<td>17/1 11.07 243</td>
<td>Weak stripes on the whole blade.</td>
<td>Weak stripes on the whole blade.</td>
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<td>18/1 12.40 840</td>
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<td>18/1 17.10 1343</td>
<td>Weak stripes on the whole blade.</td>
<td>Slightly stronger at the end of blade.</td>
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<td>18/1 19.48 1657</td>
<td>Stop</td>
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<td>19/1 8.17 1657</td>
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<td>19/1 11.29 2036</td>
<td>Weak stripes at the lower side of the blade.</td>
<td>Some water left at the middle. Weak stripes, some wider.</td>
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<td>19/1 15.50 2557</td>
<td>Lifts at the upper end. Else as earlier.</td>
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<td>19/1 19.57 3046</td>
<td>As earlier. Some squeegee sound. Day ends.</td>
<td>As earlier.</td>
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<td>20/1 8.45 3046</td>
<td>Start. 10 cm at the top worse cleaning quality.</td>
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<td>21/1 8.55 4410</td>
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<td>Some more small stripes.</td>
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