# Penetrant Testing of Standard Parts, Practical Examples of Process Optimisation

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**Abstract.** The penetrant testing of standard parts especially for the automotive industry requires some additional considerations regarding process reliability, process costs and waste management. The process usually comprises a fluorescent penetrant, water as the penetrant remover and some further defined developer. During the testing of serial parts quite significant amounts of waste water are generated out of the penetrant removing step while the penetrant concentration in the water rises constantly. In order to run a reliable testing process the water quality has to be closely monitored, otherwise the background fluorescence intensity rises. The use of a hydrocarbon free type of penetrant has a lot of advantages for the testing of standard parts compared to the usual hydrocarbon based material because the disposal of the water-penetrant mixture can be done through the sewage system without any further pretreatment. The process costs are reduced dramatically while using these new penetrants as proven by standard practical examples. The process reliability increases as well because the penetrant-water concentration is kept low. The new type of penetrants is comparable with the classic penetrants, containing hydrocarbons, in the point of process and sensitivity.

## Introduction

The use of penetrant testing in the automotive industry shows some significant differences compared to other testing procedures. In general the user has to deal with large quantities of identical parts out of the same alloy. In a lot of cases fully automatic penetration lines are in use although the inspection afterwards is mainly done visually.

Because of the throughput requirements this visual inspection has to be as efficient as possible. Particularly the background fluorescence has to be low enough to allow a quick and reliable inspection of bright indications.

## General requirement for a penetrant testing line.

Most commonly used are the following testing products
(according to DIN EN ISO 3452-2):

| | |
|---|---|
| Type 1 | Fluorescent Penetrant |
| Method A | Water as excess penetrant remover |
| Form a or b or c | Different forms of developer |

Depending on the throughput there are different numbers of stations inside the penetrant plant.
There are different process steps. The parts have to be cleaned and dried prior to the application :

1. Wetting of the parts with the penetrant (application). This can be achieved either by dipping or spraying.
2. Dwelling or draining step. The pieces are left with the penetrant in order to allow a thorough penetration.
3. Excess penetrant removal or rinsing step 1. A dip or spray rinsing where the main amount of penetrant is rinsed off by water.
4. Excess penetrant removal or rinsing step 2. This step is necessary if the throughput is high and a single rinsing step leads to an inefficient rinsing which causes high background fluorescence.
5. Further development steps, either drying and the use of dry developer or wet developing and then drying.

The treatment of the rinse water becomes an important cost factor for the whole penetration and has to be monitored closely.

**Treatment of the rinse water by activated carbon absorber.**

During the run of the penetration process the penetrant is transported via the wetted parts from the penetrant step to the rinsing step 1 followed by rinsing step 2 and the developing process and inspection. If no treatment of the rinse water takes place the water is loaded with penetrant up to a level where an efficient inspection becomes very difficult. A complete exchange of the rinse water is then necessary. In the case of smaller throughputs very often an activated carbon absorber system is used to remove the penetrant out of the rinsing water (Figure 1).

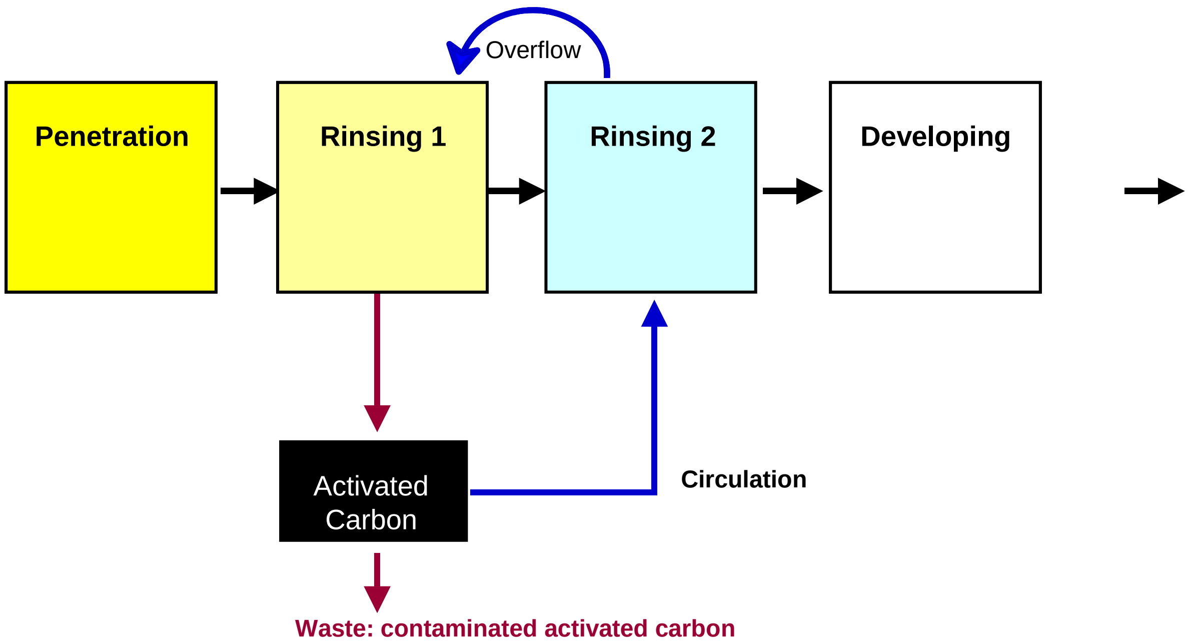


**Figure 1:** Flow chart of a penetration process with activated carbon absorber.

The water treatment with activated carbon is very expensive because of the limited loading capacity of the absorber system especially for hydrocarbon based penetrants and costs for the daily handling of the carbon system.

Therefore a lot of waste is generated combined with the required new absorption material.

Furthermore the risk of bacteria growth on the carbon surface is always present. Once the surface is contaminated with micro organisms a poor rinse water quality combined with an unpleasant odour is the result. The decontamination of the whole rinsing system is than necessary which turns out to be very difficult.

**Treatment of the rinse water by ultra filtration.**

If the throughput is higher an additional water treatment system is necessary because the absorber costs are too high.

A system which is often used is an ultra filtration instead of an absorber system. The ultra filtration is a membrane technology where a micro porous membrane is generating a retentate as waste which contains commonly still a majority of water (>60%) and the penetrant (Figure 2). The permeate is still coloured, and has to be run through a carbon filter system before it gets back to the rinsing station.

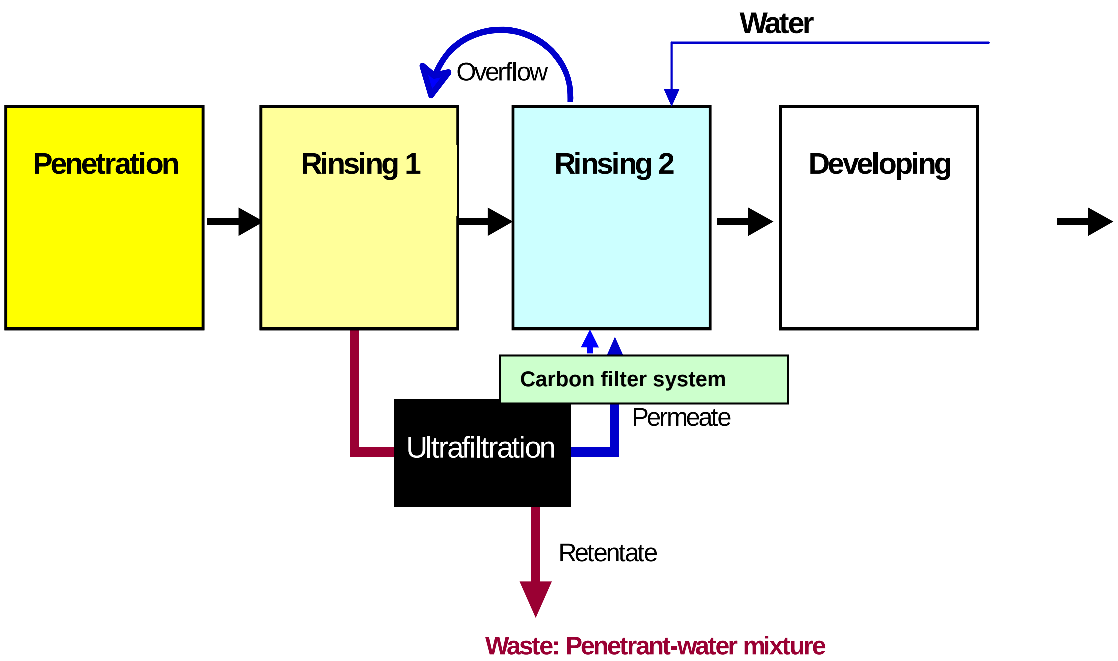


**Figure 2:** Flow chart of a penetration process with ultra filtration

The major drawback of this water treatment system is the very high investment costs combined with a bulky installation. Furthermore a significant amount of penetrant-water mixture is generated. This has to be disposed as special waste because it is not allowed to send the retentate down the drain due to its high hydrocarbon content. Additionally the contamination of the rinse water with micro organisms is always a risk.

**Disposal of the rinse water through the sewage system.**

This system is by far the most profitable one because it has the lowest investment and running costs as proven later. The fresh water is used in the rinsing step 2 and the first rinsing stage gets the water through an overflow. The water- penetrant mixture is finally sent down the drain (Figure 3).

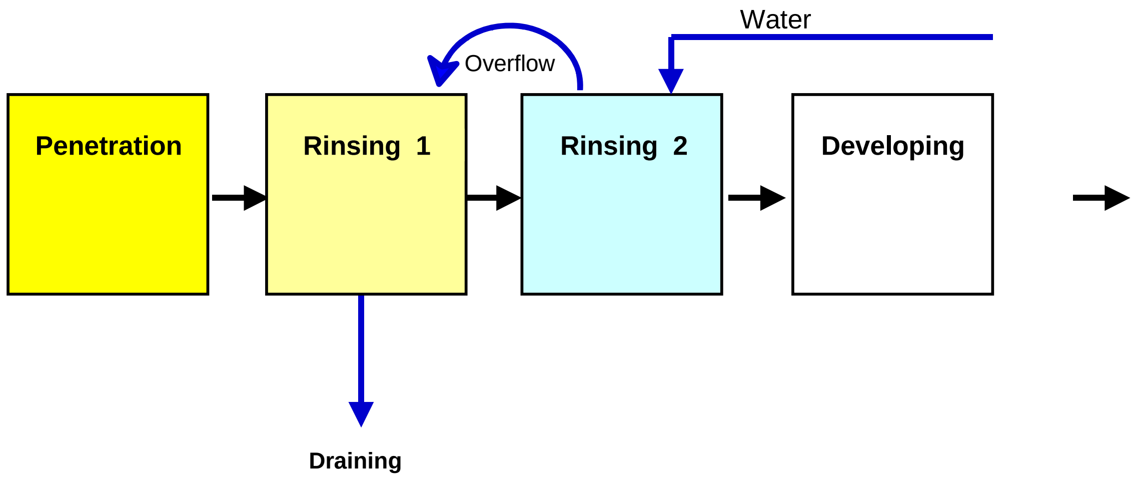

**Figure 3:** Flow chart of the disposal through the sewage system

In order to be able to send the rinse water down the drain some important properties of the penetrant and therefore the rinse water are necessary:

1. The penetrant has to be hydrocarbon free, because there are strict concentration limits of hydrocarbons in waste water. That's the reason why the retentate of the ultra filtration has to be disposed as special waste.
2. The penetrant has to be readily biodegradable. There are different tests, like Zahn-Wellens-Test, which simulate the conditions of the public biological water treatment system. These tests are necessary in order to get the allowance to drain the penetrant-water mixture.
3. The waste water should not be intensely coloured . A slightly yellow colour is in general accepted. This is another important factor because most penetrant system are intensively coloured, particularly on a high sensitivity level. But such a level is in general not required for the inspection of standard parts. The colour intensity can also be adjusted with the total water flow.
4. The rinse water shall not contain any substance which are harmful to the environment. The most important substances which are very often used in penetrants are the alkylphenolethoxylates (APEs). The APEs are very efficient surfactants and wetting agents which makes them very useful in penetrant systems. But the use of the APEs are in the meantime strictly limited in the EU and in the USA. For example the use of Nonylphenolethoxylates as the most important group of APEs is forbidden if waste water is generated during the application. The producer of penetrant material should in general avoid the use of APEs in his products.
5. The rinse water shall not contain any heavy metal ions which are harmful to the environment as well.

If the penetrant material is matching these requirements the rinse water of the penetration process can be send down the drain if the local waste water authorities are informed. The operating company has in general a written authorisation to drain the waste water if some maximum concentration levels are not reached. The usual concentration level which can be sent down the drain is around 1 % penetrant in the rinse water, which can be easily controlled. This concentration is in general enough to maintain stable inspection conditions, because the second rinsing step has concentrations of around 0.01 % penetrant in the rinse water.

If the operator has the approval to send the rinsing water down the drain the process costs are reduced significantly. Once the maximum concentration of penetrant in the rinse water is identified a flow calculation can be done which gives quite accurate operating costs for the different water treatment systems.

**Calculation of the running costs of two selected applications**

In order to demonstrate the cost advantages of the disposal system of the waste water two practical penetration applications are calculated with different water treatment systems. These calculations were made with some important technical boundary conditions:

- The maximum absorption capacity of the activated carbon is 100 weight %, which is only possible if the flow rate is very low.
- The maximum concentration factor of the ultra filtration is 15% penetrant in water, which is realistic under production conditions

Furthermore the penetrant has to have a viscosity of less than 20 mm²/s at 20 °C. If the viscosity is above this value the drag out into the rinsing water of the penetrant becomes higher (up to 100% more) and therefore more water or a more powerful treatment system is needed, which leads to even higher costs.

Only the running costs of the water treatment system are calculated. Investment costs, which are between 20000 € for activated carbon and over 50000 € for an ultra filtration unit and other running costs are not included. Also the penetrant consumption is not included, where difference of around 100% can take place between two penetrating agents for the same application. This important portion of production costs has to be calculated separately but it is evident that the penetrant price is not the only influencing factor.

1. Case: Small amount of casted Al-chassis parts to be inspected with a fluorescent penetrant. Penetrant consumption: 5 litres/ day, 6 hours/day, 220 working days per year.

| **Parameter** | *Unit* | **Ultra filtration** | **Draining of the rinse water** |
|---|---|---|---|
| Water costs | €/year | 22 | 385 |
| Cost of activated carbon | €/year | - | - |
| Disposal costs | €/year | 1687 | - |
| Energy costs | €/year | 2112 | - |
| Service cost (maintenance, spare parts) | €/year | 8889 | - |
| **Total running costs** | **€/year** | **12710** | **385** |

This calculation demonstrates that the water treatment by draining is by far the most cost effective version. Furthermore it is shown that for smaller throughputs an ultra filtration system will never be paid off.

2. Case: Large production of Al-chassis parts to be inspected with a fluorescent penetrant. Penetrant consumption: 80 litres/ day, 24 hours/day, 300 working days per year.

| **Parameter** | *Unit* | **Ultra filtration** | **Draining of the rinse water** |
|---|---|---|---|
| Water costs | €/year | 476 | 8400 |
| Cost of activated carbon | €/year | - | - |
| Disposal costs | €/year | 36800 | - |
| Energy costs | €/year | 8640 | - |
| Service cost (maintenance, spare parts) | €/year | 10972 | - |
| **Total running costs** | **€/year** | **56888** | **8400** |

In the case of larger throughputs the draining solution gives a big saving in the overall process costs. It is clear that the water treatment system is an important cost factor of an inspection line. Particularly in the automotive industry the reduction of process costs is always a big issue. Each production process and the inspection line as well has to be cost optimised. The solution of draining the rinse water is therefore a very attractive alternative for each user.

Furthermore the constant flow of fresh water through the rinsing steps guarantees always a defined rinse water quality and therefore a constant inspection result.

A general requirement is the use of a low viscous, readily biodegradable penetrating agent.

A lot of penetration lines are currently successful using the water treatment system by draining of the rinse water.