

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

FILTERS FOR REMOVING PARTICLES FROM HYDROPROCESSER FEEDS - TYPE SELECTION AND DESIGN RULES

PTS 31.27.21.10

FEBRUARY 2010



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PTS No:	31.27.21.10
PTS Title:	FILTERS FOR REMOVING PARTICLES FROM HYDROPROCESSING FEEDS-TYPE SELECTION AND DESIGN RULES

This revision of PTS 31.27.21.10 – FILTERS FOR REMOVING PARTICLES FROM HYDROPROCESSING FEEDS-TYPE SELECTION AND DESIGN RULES (MARCH 2001, Revision 0) has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS 31.27.21.10 (MARCH 2001) will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

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1. INTRODUCTION

1.1 SCOPE

This new PTS specifies requirements and gives recommendations for the selection and design of feed filters for hydroprocessing units. Feed filters remove dirt particles from the liquid feed which would otherwise foul the hydroprocessing reactors or other equipment.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this document is confined to companies forming part of PETRONAS group and to Contractors nominated by them. This PTS is intended for use in oil refineries.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document that is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier/Vendor** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.1 Specific definitions

Separation (filtration) efficiency	The rate at which solids in the feed are retained by the filter. It depends on the characteristics of the filter and the particle size distribution and nature of the solids.
Grade efficiency	The fraction of particles of a certain size retained by the separator. It is a function of particle size, and the curve obtained by plotting the grade efficiency versus particle size is called the grade efficiency curve. Many types of separators have grade efficiency curves which run from 100 % separation for relatively large particles to 0 % separation for relatively small particles. Particles between the minimum and maximum sizes have a probability of being collected by the filter equal to the value of the grade efficiency, which can be read directly from the graph. The grade efficiency curve can be seen as a characteristic curve of the separator, although it will depend on the nature of the solids (free flowing, sticky). It is commonly used to calculate separation efficiencies of continuously operated separators such as cyclones. The representation of the separation characteristics of a feed filter is complicated by the fact that the separation is a transient process depending on the cumulative amount of solids collected. The grade efficiency is expected to shift to smaller particles as the cumulative volume of retained particles increases. For the purpose of selecting a filter, "average" grade efficiencies should be used.
Filter rating	A relative measure of the size of particles retained by the filter, expressed in microns. It is usually only used consistently for one type of filter supplied by the same Vendor. One single Vendor may use different ratings for different types of filters having the same particle removal efficiency. Different Vendors of the same type of filter may use different ratings for the same particle removal efficiency. Addition of the removal efficiencies for the specified filter rating makes it possible to compare the same type of filters from different Vendors. Different types of filters should be compared on the basis of the entire grade efficiency curve. The term absolute filter rating is used by a number of Vendors to indicate the particle size removed with an efficiency of 99.98 %. Other Vendors associate the term "absolute" with the invariance of the pore structure of the filter medium (some types of filter media release already collected particles beyond a certain pressure drop ("shedding") due to rearrangement of the pore structure; pore structures can be made "invariant" by gluing, coating or sintering the particles making up the filter medium). However, more factors, such as the flow, fluid, type and size distribution of the test dust and the dust concentration, have an influence on the rating of a filter.
Dirt holding capacity and potential dirt holding volume	An important parameter used for separators without continuous removal of the dirt. For separators suffering pressure drop increase due to fouling with dirt particles, the actual dirt holding capacity is the amount of dirt the separator has collected at the maximum pressure drop increase across the separator that is recommended to trigger the change-out of the filter elements. This amount can be expressed both as mass and as volume and is expected to be a function of the flow and the properties of the separated dirt such as dry bulk density and permeability. The potential dirt holding volume is the maximum net volume (volume corrected for the volume used by internals) in the separator available for holding dirt. The volume based actual dirt holding capacity is always smaller than the potential dirt holding volume.

Filtration area	The surface area of the filter medium used for filtration in parallel flow, independently of the porosity of the medium and the number of stacked medium layers. For multilayer pleated filters the unfolded surface area of a single layer should be used although a part of this area may be inaccessible for flow. In that case an effective filtration area can be defined as the filtration area accessible for fluid flow, but this may be difficult to quantify. Besides the filtration area, the open area is used for slotted and wire screen filter surfaces as the smallest cross sectional area accessible for flow. It is often expressed as a percentage of the filtration area.
Filtration time	The time needed for the pressure drop to increase (at given flux rate, fluid viscosity, dirt characteristics and dirt concentration) from the clean pressure drop to the maximum pressure drop recommended for initialising cleaning of the filter or replacement of the filter elements.

1.4 SYMBOLS AND ABBREVIATIONS

Unless stated otherwise, all symbols used in this PTS are expressed in the units given below:

D	internal diameter of vessel or large pipe	m
(DHC)	dirt holding capacity	kg or m ³
e	filter efficiency	-
F	mass flow rate	kg/s
K	friction loss factor	-
ΔP	pressure difference	Pa
Re	Reynolds number	-
t	time	s
v	velocity	m/s
η	dynamic viscosity	Pa.s
ρ	density	kg/m ³

Subscript:

b bulk

Superscript:

* potential

1.5 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets. All documents referenced in this PTS are listed in (12.).

1.6 SUMMARY OF MAIN CHANGES SINCE LAST EDITION

This PTS is a revision of the PTS of the same number dated MARCH 2001; the following are the main, non –editorial changes

Old Section	New Section	Subject
2.	2. paragraph 1	<i>Included Hydrocracking to plants that use filters</i>
2.	2. paragraph 2	<i>Included reducing catalyst deactivation rate as one of the benefits of installing feed filter</i>
3.	3.	<i>Added 3 more measures to be considered before considering adding feed filter.</i>
4.2.3	4.2.3	<i>Include Additional method for Toluene Insolubles analysis: ASTM D-4072</i>
5.1	5.1	<i>Additional filter type added. To clarify between liquid assisted backwash and gas assisted backwash</i>
5.1	5.1	<i>Table 1. Added performance of gas assisted backwash to the comparison table</i>
6.2	6.2	<i>Include the statement "This will be performed with support of vendor", when specifying solids loading and particle size distribution.</i>
6.2	6.2	<i>Include materials specification as an item to be defined by the contractor based on applicable Materials selection standards PTS 30.10.02.11 and PTS 30.10.02.13</i>
6.5	6.5	<i>Included PTS 80.45.10.12 and PTS 80.45.10.11 as additional standards. Updated PTS 80.45.10.12 title to : Design of Pressure Relief, Flare and Vent Systems</i>
6.5	6.5	<i>Added : gas assisted backwash (i.e.backflush) under vessel requirement filter housing specification</i>
12.	12.	<i>Added reference PTS 30.10.02.13: Non-Metallic Materials Selection and Application PTS 80.45.10.12: Emergency Depressuring and Sectionalizing PTS 80.45.10.11: Overpressure and underpressure-Prevention and Protection</i>

2. PURPOSE OF FEED FILTERS

Intermediate oil products in a refinery are often contaminated with various types of solid particles (dirt or dust) such as sand, clay, salts, coke, corrosion products, surfactants, oil oxidation products and oil polymerization products, which may foul up equipment and require cleaning and thus cause early expensive stops of equipment or a whole processing unit. Hydroprocessing and *Hydrocracking* plants use filters in the liquid feed ("feed filters") to remove the harmful dirt. Normally cartridge or candle types of filters are used, but sometimes other types as well such as deep beds of granules.

The purpose of a feed filter is normally to extend the unit's run length to the life of the catalyst by reducing the fouling rate of the reactor and/or *catalyst deactivation rate* or to extend the standing times of equipment such as coalescers and heat exchangers. The filter should be allowed to pass as many particles as can be accumulated and passed through the reactor until the next catalyst change-out. A feed filter is not necessary if the dirt holding capacity of the reactors is large enough to hold all the retained particles until the next scheduled shut down. It is also pointless to install absolute filters to trap particles that are so small that they will pass through all equipment. Hence, the filter should remove only the harmful fraction of the dirt. Absolute filtration of sub-micron particles is costly and usually not necessary. Fouling of evaporators by sub-micron particles can usually be reduced more efficiently by changing the design of the evaporator than by removing the sub-micron particles from the feed with a filter.

Translating the purpose of the feed filter into specifications requires the knowledge of the grade efficiency characteristics of the equipment to be protected (coalescer, heat-exchanger, reactor), the grade efficiency characteristics of the filter and the solids loading. This should not be left to the filter Vendor, since he has no knowledge of the grade efficiency characteristics of the reactor, which is dependent on other fouling abatement measures (graded layers, top bed filters, etc.).

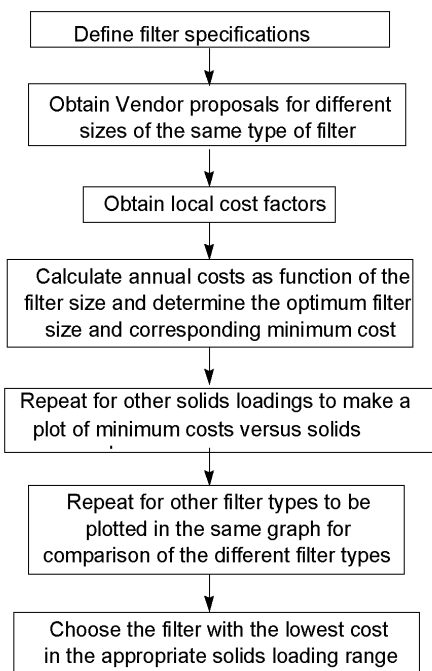
3. FEED FILTER SELECTION - OVERVIEW

Before considering application of a feed filter, the following measures should be considered:

- Reducing the dirt contamination of the feed by improved upstream process control and housekeeping;
- Achieving a better distribution of the dirt over the reactor internals and the length of the catalyst bed.
- *A use of graded materials with high void volume where possible such as Hydrotreaters reactors top. This includes use of improved and updated proprietary distributor for homogenous distribution of the feed*
- *If cracked feedstocks are used, storage of feedstocks should be under nitrogen blanket. This includes limiting the storage time for the cracked feedstocks as much as possible.*
- *Use of antioxidants and anti-fouling additives, provided these are compatible to downstream system.*

Optimum selection of feed filters should take the following into account:

- process conditions
- dirt characteristics
- required performance efficiency
- purchase cost
- installation cost
- operating costs (e.g. cartridge disposal and replacement)
- depreciation



Each of these steps is discussed in more detail in subsequent sections.

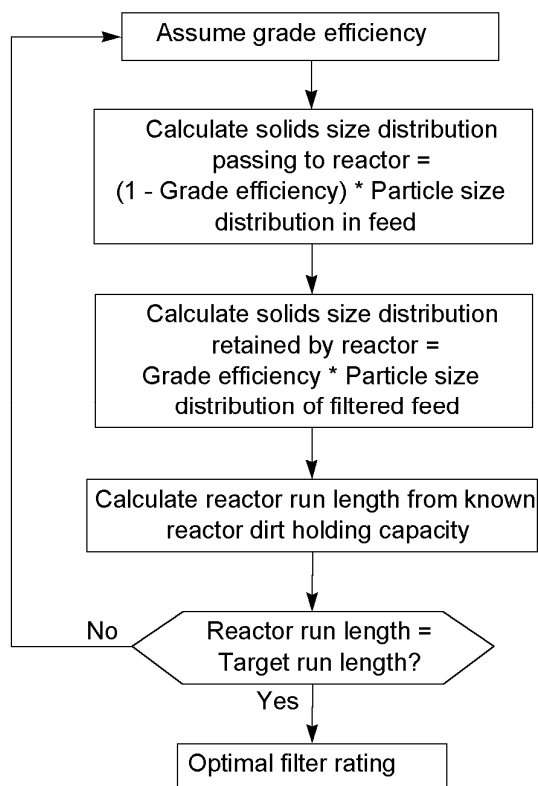
4. DETERMINING THE FILTER RATING

4.1 FILTER RATING PROCEDURE

Determining the rating of the feed filter requires the following parameters to be known:

- dirt concentration in the feed;
- particle size distribution of the dirt;
- dirt characteristics such as morphology and stickiness;
- dirt produced between filter and reactor;
- particle separation characteristics (grade efficiency) of the reactor and its internals;
- dirt holding capacity of the reactor and its internals;
- dirt holding capacity to be spared for by-passing;
- particle separation characteristics (grade efficiency) of the filter.

If these parameters are known, then the required filter rating can be derived as follows:



This procedure relates the filter requirements to the dirt separation/holding characteristics of the reactor (similar procedures apply for protecting the coalescer or the heat exchangers if these are limited by fouling). A reactor with a high dirt holding capacity will require a smaller filter than a reactor with low dirt holding capacity.

Each of the mentioned parameters and its possible measurement is discussed in subsequent sections. Some parameters may not be easily determined for various reasons (e.g. if sampling is not possible, the feed is not available or the plant is not yet built), in which case the best possible estimates shall be made, e.g. from experience with existing similar units.

4.2 DIRT CONCENTRATION IN THE FEED

4.2.1 General

The particle size distribution and the solids concentration of the feed need to be known in order to predict the run length of the reactor, if defined by fouling, to determine whether an external feed filter is needed and the rate at which solids have to be removed by the feed filter.

Several methods can be followed to characterise the solids in the feed. The best way is to use on-line sample filtration at the temperature of the feed. This may be difficult for high feed temperatures ($> 70\text{ }^{\circ}\text{C}$), in which case sample filtration may have to be performed in a laboratory. However, cooling and storage may precipitate additional solids, which might not completely redissolve when the liquid sample is heated to the original process temperature and this consequently results in analysis errors. Reasons for instability are the presence of asphaltenes or wax which may precipitate during cooling and the presence of reactive species which may polymerise (form gum) during storage. Appropriate sampling points should be upstream and downstream of the (potential) location of the feed filter, located and constructed so that representative samples can be taken (see PTS 32.31.50.10). Points of attention specific for solids are described in ISO 3170 and ISO 3171. A local sampling procedure should be prepared to cover these points.

4.2.2 On-line sample filtration

On-line sample filtration can be performed at ambient temperatures using portable filtration equipment. The Ssafcon sampler shown in Figure 1 has been developed in collaboration with Shell and is safer than the "hose end" sampling method of ASTM D 2276 for measuring the solids concentration in aviation fuel. It is easily plugged into a permanent sampling tray via self-sealing connectors. About 5 litres are passed through a $0.8\text{ }\mu\text{m}$ (Millipore) membrane filter as measured by an in-built volume meter. The filter is subsequently removed for gravimetric or colorimetric analysis. It can also be used for subsequent microscopic analysis for estimating the particle size distribution, and for elemental analysis. The Ssafcon sampler can be used at temperatures up to $70\text{ }^{\circ}\text{C}$.

The Ssafcon sampler provides only a spot measurement. A pilot type of filter should be used to collect larger samples of dirt for more accurate determination of the time averaged particle concentration and particle size distribution. The larger amounts of dirt collected in a pilot filter can also be used to determine the (compacted) bulk density of the dirt in liquid. Larger amounts of dirt can be used as test dust for laboratory filtration experiments.

On-line sample filtration devices for temperatures beyond $70\text{ }^{\circ}\text{C}$ are not commercially available.

4.2.3 On-line liquid sampling off-line sample analysis

If on-line filtration of the sampled feed is not possible then a sample of the feed needs to be tapped and analysed in the laboratory according to one or more of the various standard procedures available. The solids can be determined using standard methods such as the Hot Filtration Test (ISO 10307-1) and toluene insolubles (method AMS-581 MOD *and/or* ASTM D-4072) for residue feedstocks. Increased amounts of liquid may be needed to increase the accuracy of the methods. ISO prescribes the use of a glass fibre or equivalent filter. Membrane types of filter are more suitable if the filters are to be subsequently used for microscopic analyses to estimate the particle size distribution, but can only be used if the viscosity of the fluid and filtration temperature allows this. It is essential that sample bottles are clean and that the sampling line is adequately flushed prior to taking the samples (see ISO 3170).

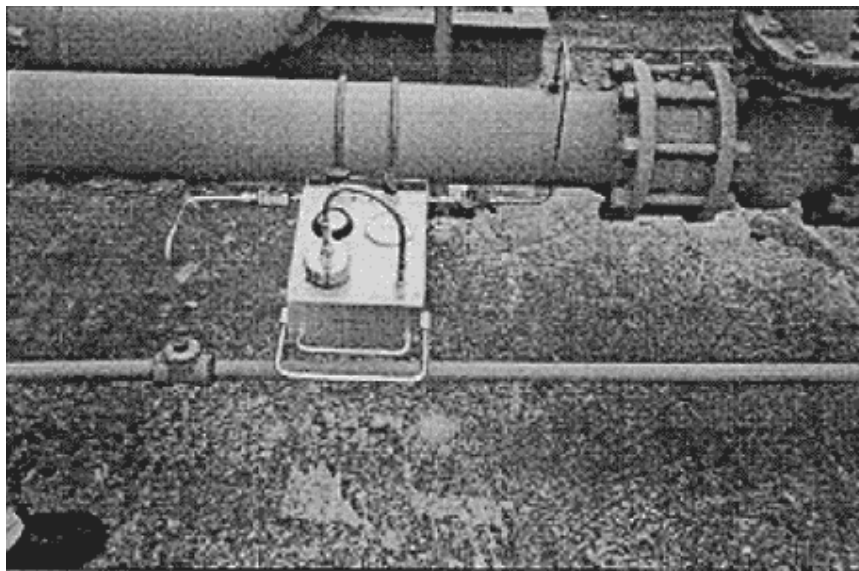
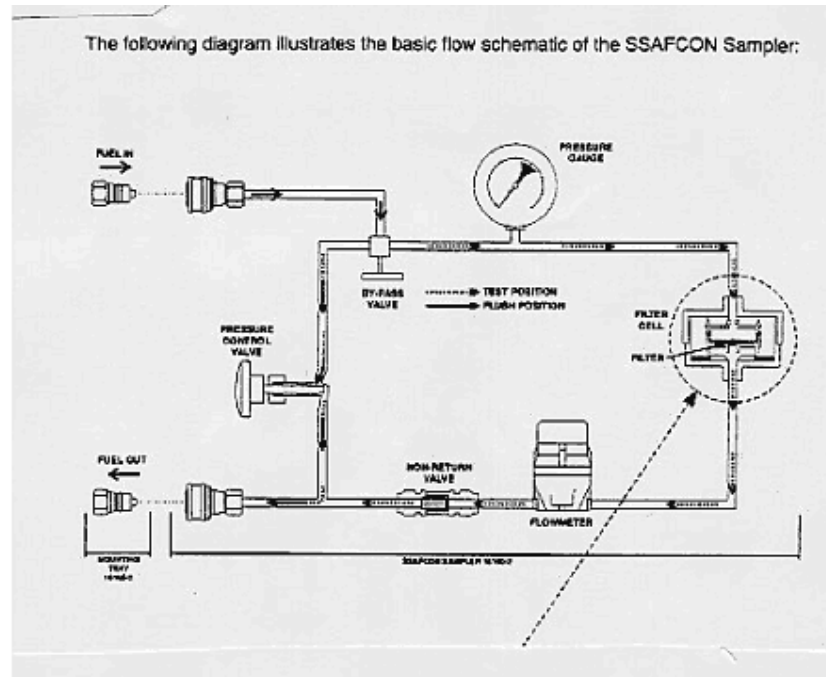


Figure 1 Stanhope-Seta Ssafcon sampler for on-line sample filtration at ambient temperatures