Tips and tricks for getting the most out of paper filtration

cytiva

Contents

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Introduction

Choosing the right filter paper helps make filtration more efficient, but how does your workflow and the nature of your samples affect filter paper selection?

Scientists have used filter papers to separate solids from liquid for many years. Filter papers remain an effective, frequently used technique, both in industry and in research.

At first glance, filtration appears to be a simple technique, however, there are many ways to carry out paper filtration. By understanding the basics, you will often find there are simple changes that can improve the quality or speed of your filtration.

In this ebook, we'll discuss some initial considerations (below), the properties of filter paper, handling and folding, and selecting appropriate paper for your sample.

Filter paper: what else to consider

Understanding the basics of filtration begins with understanding your samples. What do you need to know about your samples that will affect filtration? Many parameters will play a role, including solids content, method of precipitation, temperature, particle size, and particle shape.

With this in mind, you can start thinking about how you would set up your filtration. Consider:

- Do I need to carry out quantitative analysis?
- Do I need to do any purification or other preparative work?
- Do I need to filter using a vacuum?
- Is the liquid likely to react with or affect the filter paper?

In various industries, filter methods are highly standardized - usually for a good reason. Consistency is an important aspect of many processes, and often the benefits of consistency outweigh the benefits of a more efficient filtration. Yet, it is important to be aware that all samples are different, especially when working with natural materials, and that no single method is perfect for every sample.

In the other sections in this eBook, we will delve deeper into various aspects of filtration and filter selection. Check out our Whatman Filter Selector Tool to guide you through finding the right filter for your application.

Properties of cellulose paper

Explore how different properties can influence the filter paper choice for your application.

In this section, we'll go through several properties of cellulose filter papers that can affect your filtration efficacy and efficiency. Taking these properties into account should help you select the most appropriate filter paper for your application.

Filter paper purity

One piece of filter paper looks much like another. But the way they affect your sample might be quite different. In the lab, you cannot afford to use filter paper that introduces significant impurities into the filtrate or has any other chemical or physical impact.

Impurities can affect sensitive analytical techniques, such as flame photometry and atomic absorption. If you're using these or similar techniques downstream of the filtration step, it makes sense to find and use the purest possible paper to minimize the chances of impurities affecting results.

Take Whatman™ filter papers, for example. These papers are all made from high-quality cotton linters, treated to maximize alpha cellulose and purity. But there will always potentially be some trace impurities, no matter how high the quality of source material. So, what can we do about this? In most cases, with known and consistent levels of trace elements, it's possible to apply a 'blank' correction in any analytical results, effectively cancelling out the impurities.

Should you remove organic impurities?

The majority of non-carbohydrate organic impurities come from the cotton waxes present during the manufacturing process. As these are insoluble in water, removing them from filter paper requires some aggressive reagents, making the whole process a little tricky. Even then, trace level might remain.

These aggressive reagents tend to oxidize, depolymerize, and degrade the cellulose. Hydroxyl groups, which usually help hold cellulose chains together, oxidize to aldehydes and carboxyl groups. As well as forming soluble carbohydrates, this process can weaken the filter paper.

So, there needs to be a pretty good reason to go to the trouble of removing these organic impurities.

Taking inorganic impurities into account

Filter papers can, depending on the raw materials and manufacturing processes, contain some inorganic impurities. Igniting filter paper at 900°C to leave just ash serves as a useful measure of general purity. This process burns off the cellulose and any volatile substances, leaving just the inorganic, non-volatile ones.

Qualitative filter papers have ash content in the region of 0.06%, which is good enough for general purpose filtration. In "ashless" paper, used for accurate residue measurements, processes employed by the manufacturer reduces the level of inorganic impurities. Quantitative "ashless" papers contain no more than 0.01% ash content, typically lower.

The impurities that do remain in ashless paper are usually inaccessible to normal reagents, and therefore don't affect the filtration process. For example, there might be traces of complex silicate incorporated into the structure of the cellulose fiber itself or associated with a small proportion of carboxyl groups.

For even higher purity, acid hardened filter papers, treated to reduce inorganic impurities further, can maximize the accuracy of any residue measurement.

If your process involves measuring volatile inorganic impurities, the normal ashing process can burn off your element of interest. Maximizing recovery in these cases requires some care.

Storing and handling filter paper

Care should be taken during storage, to minimize the potential for filter papers to pick up impurities from their environment. The absorptive and hydrophilic nature of cellulose means that this type of contamination is surprisingly common and can influence sensitive measurements.

Common contaminants picked up through general storage and handling include:

- Chlorides, sulfates, mineral acids, and ammonia from volatile components in the atmosphere or lab environment
- Sodium salts, iron, and other metal oxides and salts from airborne dust
- Amino acids from human skin or perspiration

Some simple precautions can minimize these contaminants. Always storing filter papers in closed boxes will minimize contamination from airborne dust and other work in the lab. Also, handling filter papers with forceps, especially for critical trace analyses, will minimize the risk of transferring contaminants from skin or gloves.

Chemical resistance of cellulose paper

The relatively open structure of cellulose filter papers weakens when wet. Measuring and comparing this chemical resistance across papers involves determining their tensile strength when wetted with reagents of known strength.

Organic solvents tend not to make cellulose fibers swell as much as aqueous reagents, though this does vary by polarity. So if you're using an organic solvent, an untreated filter will likely retain much of its strength and be sufficient, for most applications.

Working with aqueous reagents can be a little trickier. For some applications, the wet strength of standard cellulose filters is sufficient. But if you need the filter paper to maintain its strength, for example, with a large mass of retained material, then you can benefit from selecting a type of filter paper with improved wet strength.

How to improve wet strength for filter paper

On top of adjustments and controls during the paper making process, there are three methods manufacturers can use to increase wet strength:

- **Increasing paper thickness:** Improves strength, but very thick paper is highly absorbent and can be difficult to wash
- **Treating with mineral acid:** Removes trace metals (improving purity), producing a tough paper with a hard surface, as found in Whatman Grade 50 and 540 series
- **Adding a stable synthetic resin:** Suited for non-critical applications as the resin can affect critical analyses

If you need a strong filter paper, selecting acid-hardened or resin wet-strengthened papers is likely to give you a final strength well within practical limits.

Download our filter paper brochure for more information on the types of filter available, or try our Whatman filter selector tool, which can help you find the most appropriate filter paper for your application.

Folding

In this section we describe various filter paper cone folding techniques. Read on to see the options for getting a good seal over your conical funnel.

How to fold filter paper

As we've come across previously, paper filtration appears to be a simple technique. However, there are so many options, and different people often use different methods for the same purpose. Are some methods more suitable than others, or should you just go with what you know?

While you may already know some of the filter paper folding techniques, you might also learn a new technique that could improve your conical filtration.

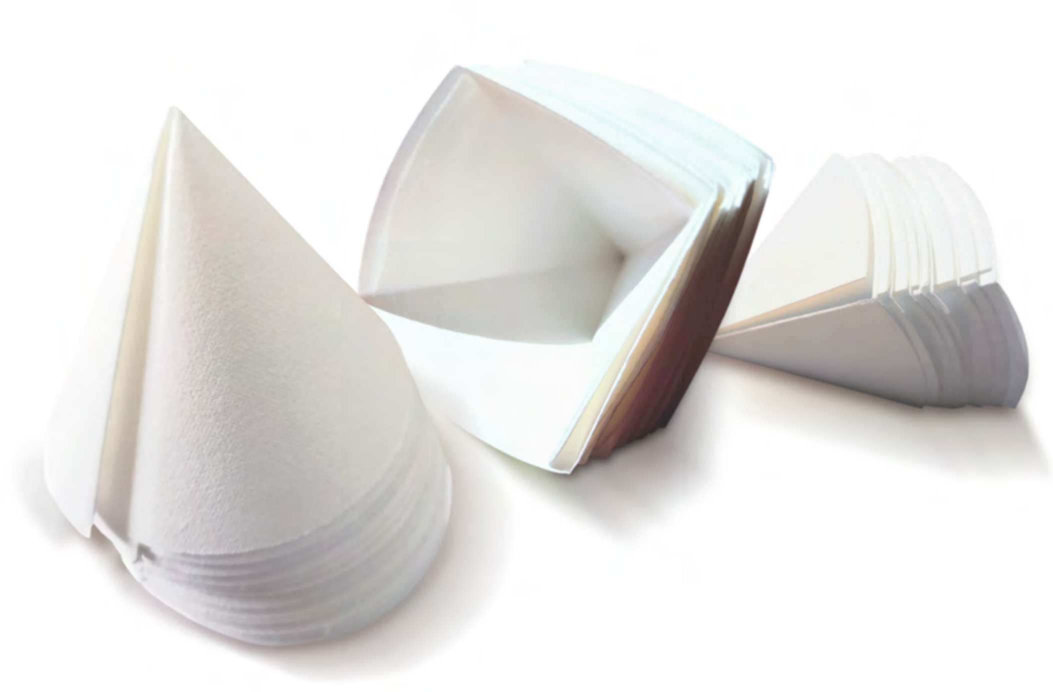
The 60° filter paper funnel

Many conical filter funnels have an angle of about 60°. Folding a filter paper cone so that it beds well down into the funnel, creating a good seal when wet, makes for an efficient filtration step. Very often users will fold the paper cone with the same 60° angle. You can achieve this by simply folding the filter paper into four quadrants, creating a 60° apex when the paper is folded out into a cone.

But is the simplest option suited to every user and situation? While the aim is consistent—a perfect seal when the paper is wet—and the technique is partly down to personal preference, you might find one of the alternatives below gives you a better seal.

Filtration paper folding techniques

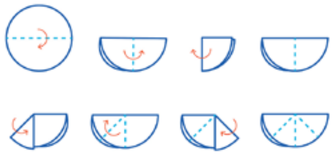
We've put together a table with some of the most common folding techniques. The choice might depend on your personal preferences, but one of these methods will hopefully help you create a paper filter cone for successful filtration.



Whatman folded filter papers

Whatman qualitative and quantitative grades are available prefolded. The prefolded paper is offered in the choice of format (cone, pyramid, and flat quadrant format), diameter, and grade to support your application needs.

Table 1. Different methods for folding a filter paper cone

	Quadrant folded				**Pleated/Fluted paper**
Folding method	Fold the paper into exact quadrants. 	Fold the paper into quadrants, then open to form a semicircle, identifying the center line. Next, make two further folds, either in the same or opposite direction. The result is a 60° cone when the paper is opened out. 	Fold the paper into quadrants. Make an extra fold at a slight angle from the center. The result is an angle at the apex of the cone slightly more than 60°. 	Fold the paper into quadrants, Tear off the corner of the outer fold 	Fold the paper into exact quadrants. Make a further two folds bringing the outer edges in two the center line. Open the folded circle and invert. Push alternate folds into the center, making a neatly pleated arrangement. 
Comments	Standard, very common technique	Allows the paper to filter in a more balanced manner than standard quadrant technique Has certain disadvantages, especially if the precipitate tends to creep	Can provide a better fit when wet and loaded with precipitate	Enables the rim of the filter paper cone to seal better against the glass funnel than a standard quadrant fold Tearing the corner is better than cutting as it tends to stagger the two thicknesses of paper.	Pleating filter papers is a very widely performed technique and offers improved flow characteristics compared to conventional quadrant folding

Back to the filtration funnels

Hopefully these folding techniques provide useful alternatives when you next come to conical filtration.

Coming back to funnels, just like the filters, there are several options that could suit your application. Each type of funnel will suit various techniques to a greater or lesser degree. Options include:

- Precision 60° funnel or similar with a smooth glass-like surface made from stainless steel or polymers, such as polythene
- Funnels with a fluted or grooved surface
- Funnels with long or short stems of varying bore

In the next section we'll continue looking at funnels, specifically those for vacuum filtration with flat disc filters. Read on for guidance on choosing the right funnel for your application.

Funnels

This section examines the different types of funnels for vacuum filtration—e.g. Büchner and Hartley funnels. Read on to see how to choose the right funnel and achieve the perfect seal.

Funnels for vacuum filtration

So far we've looked at some important considerations for paper filtration, the properties of filter papers, and how to fold filter paper cones for conical funnel use. Now let's take a look at other types of funnels that can be used with flat filter circles under suction or vacuum filtration.

There are several types of funnel available for vacuum filtration and it's important to select the right one for the job to maximize your filtration efficiency.

Here we list the different funnels you can choose from and talk in detail about Büchner and Hartley funnels, providing advice on Gooch crucibles. We've included some tips and advice to help your vacuum filtration run smoothly. So take a break, have a quick read, and see if you can make your filtration a bit easier.

Büchner and Hartley funnels

In Figure 1 (page 11), you can see the selection of funnels available for vacuum filtration.

Büchner and Hartley funnels are suitable for most vacuum filtration applications—e.g. filtering bulk solutions, suspended matter, pulp, and separating crystals. In fact, whenever you need rapid filtration or it's necessary to press filtered material, these are your go-to funnels.

The main advantage of these funnels is speed. Due to their shape, and if used correctly, you can make full use of the filter paper's surface area, allowing you to filter samples quickly and effectively. Vacuum filtration further accelerates washing of retained material.

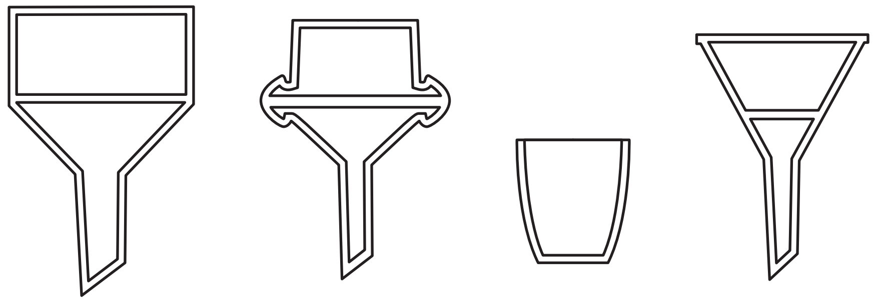


Figure 1. The different funnel types that are commercially available

What about filter supports?

Both Büchner and Hartley funnels contain filter supports. The type of support can vary from simple perforated discs to highly porous sintered discs.

If you intend to use a perforated disc, we'd generally recommend sticking to flat supports (not domed), and checking the perforations for slightly rounded upper edges, which will minimize damage to a wet filter under vacuum. In general, a funnel with a large number of small perforations is preferential to a funnel that has a support plate with fewer, larger openings.

When setting up the apparatus, also make sure you can position the filter to leave a clear, unperforated outer area to support and seal the edge of the filter paper in place.

Some advice if you use Gooch Crucibles

A Gooch Crucible can be made of sintered glass and can support cellulose or glass fiber discs. However, if these are used then extra care must be taken for efficient filtration.

Often, there isn't a flat area of non-porous material around the edge of the sintered disc, meaning that a paper disc may not seal completely. This can lead to leakage or bypass of the filter, so we'd recommend carefully checking that the paper makes a good seal before proceeding.

The importance of the perfect seal (and how to get it)

The most important point when performing vacuum filtration is making sure you have a complete seal between the filter paper and the funnel. Taking care over this step can be the key to successful, safe, and quick filtration.

Making sure that the filter paper is sealed all around the edge will minimize the risk of the paper being blown back by the sudden boiling of hot filtrates due to pressure change as they pass into the flask. This could otherwise result in contamination or loss of the sample.

In cases where the filtrate needs to be recovered, a complete seal also prevents reverse flow of the solvent when the vacuum is released.

Obtaining the perfect seal is not too difficult:

1. Apply a small amount of vacuum
2. Wet the paper with the appropriate solvent and allow to filter through

Alternatively, you could use a Hartley or Whatman 3-Piece Filter Funnel. These funnels are simple to set up and clean, and further reduce the risk of any leakage.

Lastly, don't forget that strong filter papers are essential in vacuum filtration, especially if you need to recover the precipitate afterwards.

For more advice on filtration and the different funnels, filters, and materials available, **contact Cytiva Scientific Support.**

Want to find out more about our filter papers? Take a look at the Whatman filter selector tool.

Considerations for quantitative analysis

This section discusses some practical considerations for successful paper filtration, especially for quantitative analysis.

The filter paper: practical considerations

If you've read sections 1 to 4, then you have had a great introduction to the basics.

Here we focus specifically on using cellulose filter papers, with some more practical considerations and advice that's particularly relevant for those of you performing quantitative methods.

What else should I consider for quantitative analysis?

In addition to thinking about the different filter paper options, their properties, the best method for folding a filter paper, and which funnel to use, there are a few last points to consider, including:

- Size of filter paper circle
- Preliminary wetting
- Filtering techniques

Each of these factors can contribute to the success or failure of quantitative analyses, so a little extra consideration here is time well spent.

Size of filter paper circle

The size of the filter paper circle is, unsurprisingly, one of the first and most vital considerations in quantitative procedures. Ash weight and volume of precipitate are the two factors at play here.

Ideally, the filtration surface area should balance against the overall ash weight per circle, if ash is of importance. The filter paper should not to be so large that it projects over the rim of the funnel or so small that it can be overloaded with precipitate.

For quantitative work that involves ignition, or small amounts of sample, the smaller the circle the better. As a general rule, you should look to use a filter paper circle that's just large enough so that the precipitate doesn't occupy more than half the volume of the cone (preferably less).

Preliminary wetting of the filter paper circle

While it's not often thought necessary, a preliminary wetting of the filter paper after placing it in the funnel is good practice and serves two purposes.

First, wetting can help with bedding the paper properly into the funnel, creating a good seal. This was discussed in section 4 of this series.

Second, wetting will help remove any minute traces of inorganic material, such as chlorides or ammonium salts, that could affect quantitation. Wetting will also help remove any loose fibers created from handling and manipulation of the paper.

Where experimental conditions allow, bedding the paper into the funnel with a little distilled water is preferable. If you need to use 'dry' organic solvents, the paper isn't wetted in the sense that it will adhere to the funnel, but it's still good practice.

Filtering techniques: washing and decanting

The choice of filtration technique, particularly the method of transferring or withholding the precipitate from the paper, depends on the final destination and use of the precipitate.

Your objective might be to collect the precipitate on the paper for subsequent ignition, or it might merely be a case of separating the solid and liquid phases so that one or both can be analyzed at a later stage.

Once you have this overall objective, you can consider the properties of the precipitate itself, which will help you adjust your filtering technique.

If the precipitate tends to cling to glassware, it can help to transfer to the filter paper quickly and wash *in situ*. Bear in mind that this will likely mean adding to the overall filtration time.

When working with an easily separated precipitate, or separating liquids from solids, you can reduce filtration time and improve washing efficiency by decanting. This is particularly suited to coarse, crystalline, or curdy precipitates that settle rapidly, leaving a distinct layer of supernatant for decanting.

Under normal circumstances, only a small fraction of the precipitate finds its way to the paper in the early stages—with the bulk transferring by the time washing is complete.

Filtering techniques: more options

Other adjustments to your filtering technique might include filtering hot, when possible. You might also have various useful pieces of equipment in your lab that could improve your workflow.

Glass rods, for example, are a simple but useful tool for decanting. They help break the surface tension between supernatant and glassware when pouring, reducing the risk of sample loss and therefore experimental error.

In section 6 ways to adjust your filtering technique will be discussed. We will look at precipitate creep (with some more washing tips and tricks), and how and when to use filter aids.

Precipitate

In this section we provide some tips on optimizing the filtration process. Here we examine precipitate creep and give you some hints for effective washing, and when to use filter aids.

Previously, we have looked at improving filtration protocols with some practical considerations and tips and tricks for paper folding and funnel choices. But there are also some useful points to consider relating to the precipitate.

This section focuses on the sample precipitate and the effect it has on some of the choices you might make to optimize filtration. In particular, it discusses the use of filter aids, precipitate creep—what it is and what you can do about it—as well as some advice on washing.

Dealing with difficult precipitate

Certain types of precipitate might initially filter rapidly but then settle into a semi-impermeable jelly on the filter paper. It then becomes increasingly difficult to penetrate through this jelly-like layer with each wash.

Sometimes, this effect is due to hydrated aggregates that are separated/free floating in suspension, but then collapse into a film on the paper.

It can be possible to overcome this issue through washing by decanting, but this type of precipitate often has an affinity for glassware. So, it's usually easier if you get the precipitate into a filter paper cone as early as possible for washing *in situ*.

Difficult-to-filter samples like these can substantially add to filtration time, especially when handling multiple samples. So, it's worth taking advantage of all time-saving options.

Filter aids to aid filtration

Using filter aids is one option for minimizing flow rate issues with challenging suspensions like aggregated jelly-like layers. These filter aids are inert materials, a typical example being ashless filter paper clippings, though other materials like diatomaceous earth or perlite are also used.

In the case of cellulose filter aids, these can either be added directly to the suspension to be filtered or used to create a thick retentive prefilter layer prepared *in situ* from mechanically disintegrated ashless filter paper clippings.

These types of filter aids are widely used to enhance filtration speed. The open structure of the filter mass also contributes to these time-savings (Figure 1).

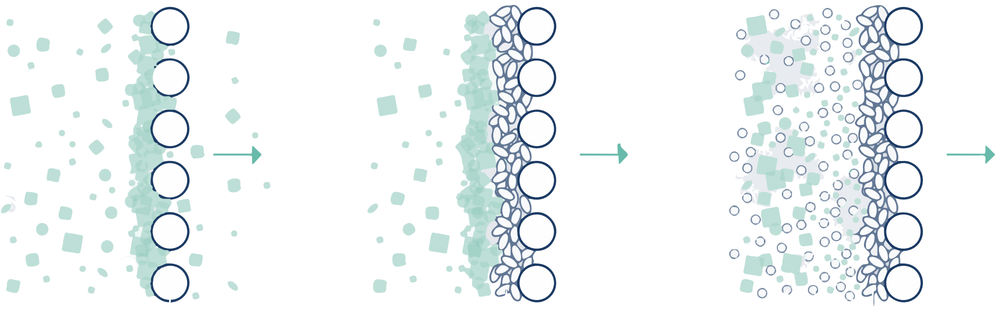


Figure 1. Effect of having a filter aid as a precoat and in suspension on filtration ease and efficiency.

What about precipitate creep?

In some cases, precipitate can creep up the sides of the filter paper cone and become stuck. Any downstream quantitative analysis you perform might not then take this into account, affecting the accuracy of results.

If there is already a tendency for precipitate creep, the effect can be made worse in some situations:

- Surface tension effects might encourage precipitate creep if the folds of the filter paper are not flattened properly against the funnel
- During the transfer of precipitate to the filter paper cone, or as a result of washing steps, films of liquid can sometimes rise too high above the level of liquid in the filter paper cone, resulting in the loss of traces of precipitate

So, making sure that the filter paper cone is flat against the funnel and keeping an eye on the liquid level in the funnel are two ways to help minimize precipitate creep.

Cleaning up the wash

There are a few factors that affect washing in any filtration step:

- Solubility of a precipitate (and/or it's tendency to decompose)
- Specific surface area of the precipitate particles
- Adsorption of impurities during precipitate formation
- Diminishing effectiveness of each successive wash
- Temperature

The surface area of the precipitate can affect the rate of filtration. Suspensions with a higher proportion of larger particulate matter filter more slowly than those with smaller particles and are more likely to clog the filter paper. Sometimes, impurities can be adsorbed to the surface of a precipitate and become weakly bound, increasing the surface area and affecting the rate of filtration.

It's useful to match the filter paper grade to the sample precipitate and perform extra washing steps to maximize filtration efficiency.

In general, completing numerous small washes is the most efficient tactic, making sure that the precipitate is left to drain thoroughly through the filter media after each wash. Though there might be a decrease in effectiveness with each, it's still useful to perform several successive washes for complete filtration.

The filter paper works most efficiently when pliable and 'wettable', which gives it the best fit possible in the funnel. Using a comparatively low wet-strength paper and carrying out a preliminary wetting step can help achieve this good fit.

However, there are circumstances where a higher strength hardened filter paper is more appropriate. For example, when there are heavy, bulky precipitates involved, there is a need to remove the recovered precipitate by scraping, or hot, corrosive suspensions are being filtered.

It's worth keeping an eye on jets of water during your washing. They can easily damage the filter paper, with high pressure jets piercing holes and affecting the filtration accuracy and efficiency. Managing the power of the water stream and directing the flow at an angle, rather than perpendicular to the surface, can help minimize any damage to the filter paper.

During washing, it can also help to move the stream smoothly to minimize splashing. Where desirable, it's also possible to maneuver the stream such that you bring the bulk of precipitate into suspension again. Though take care to avoid overfilling the filter paper cone at the same time!

The roundup

While it's easy to think of paper filtration as a simple technique, there are always opportunities to improve the efficiency and reproducibility of your method and workflow.

So far this eBook has covered some of the key considerations for choosing the most appropriate laboratory filter papers and funnels for your filtration needs, and examined some of the options available for folding filter paper cones for a conical funnel and practical considerations for quantitative analyses.

This final section will focus on papers specially treated for high wet-strength and the benefits of using pre-folded filter paper, and summarize some of the key topics covered in previous sections to help you keep your filtration step on track.

Find the right filter for your application with with the Whatman filter selector tool

Using wet strengthened and hardened filter papers

During filtration, an exceptionally heavy demand is placed on the filter paper in certain situations; for example, if you are applying a vacuum, or need to use hot solutions. In these cases, using a wet strengthened or a hardened filter paper can make a significant difference. In comparison to normal filter paper material, wet strengthened and harded papers are designed to withstand extra stress, without the use of additives or synthetic resins Although these filter papers were primarily designed for use under vacuum, they can also be used in ordinary conical filter funnels. You should consider using a high wet strength paper if you:

- Use reagents that could disintegrate an untreated paper
- Need to scrape off precipitate or suspended matter
- Are expecting a large bulk of precipitate
- Need to remove the paper and precipitate intact from the funnel

Time to stop folding filter papers?

Both wet strengthened and standard papers are available in 'pre-pleated' and "pre-folded" formats, that is, folded and ready to use. One of our filtration product managers discusses the pros and cons of using specifically folded filter paper in a blog where quadrant and flutet filter paper are compared.

Sometimes, depending on your specific needs and applications, it makes more sense to purchase ready-to-use papers. These papers eliminates the time spent folding papers and, therefore, minimizes your overall filtration time (Figure 1).

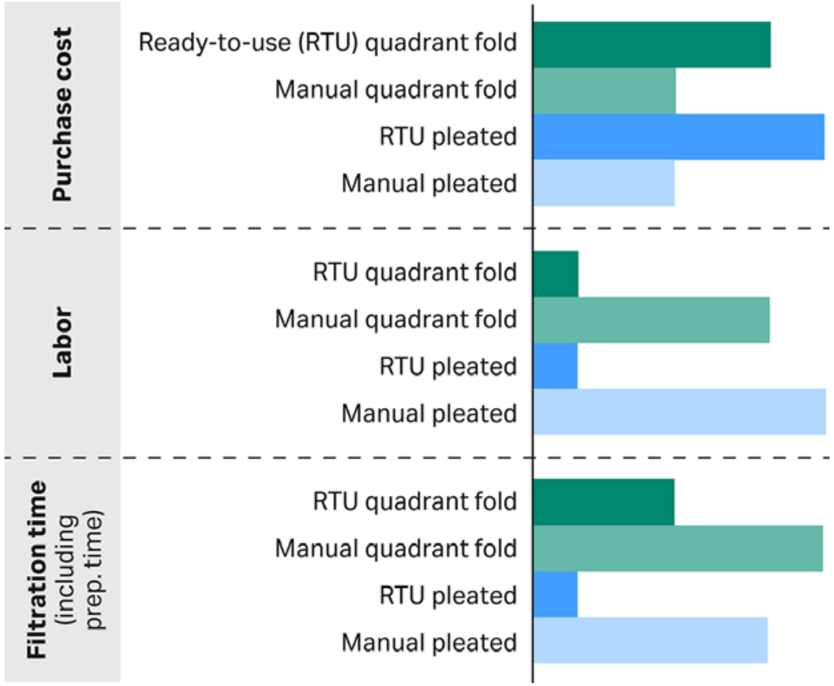


Figure 1. Relative comparison of cost, labor, and time for manually quadrant folded or pleated and pre-folded filter papers

'Dry' organic solvents don't generally affect the wet-strength of cellulose fiber filter paper, therefore you may need to combine hardened properties with pre-pleating. A standard non-strengthened folded paper can be used for large-scale work, however if your solution 'wets' the paper strengthened folded papers are the recommend option.

View our range of wet strengthened prepleated filter paper

A roundup

Over the course of this eBook, we have examined several aspects of laboratory filtration, from basic considerations to folding techniques. Take a look at the highlights below and see if there's anything you might have missed:

The introduction

Summarizes some of the key considerations when planning your filtration workflows, discussing the importance of being aware that each type of sample is different, and that no single method is necessarily the best option in all cases.

So, consider, for example, whether you'll be performing quantitative analysis, or if you need to do any purification or other preparative work. Vacuum filtration might be necessary and it might be that the liquids you use can react with or affect the filter paper in other ways. These are all things that you can think about when working out the best way to set up your filtration.

Properties of cellulose filters

Examines cellulose filter papers and how different properties can influence your filter paper choice.

This section discusses the effect of organic impurities and why you might *not* want to remove them under normal circumstances, as well as how to deal with inorganic impurities. Care must be taken during storage to minimize the possibility of filter papers accumulating impurities from their environment.

Folding filter papers

There are many ways to fold a filter paper circle, with each lab often having their own style. Some of these methods—using diagrams and instructions—explains how you can achieve the perfect seal in a conical filter funnel.

Using funnels

The perfect seal (and how to get it), with a particular focus on Büchner and Hartley funnels, the filter support options they have, and why it's worth paying attention to the type that you use.

Improving efficiency

The final sections cover the filtration workflow, with some top tips for boosting efficiency and results. Section 5 focuses more on the filter paper itself, with some tips for optimizing quantitative analysis whereas part 6, highlights considerations based on the sample and precipitate.

We hope this eBook provides you with tips and tricks for getting the most out of your paper filtration. Whatever your needs, we have the experience and expertise in laboratory filtration to help. You can find more tips and tricks in our laboratory filtration blogs and our knowledge center.

However, if you would like direct support with your filtration workflow, or are interested in finding out more about the filter paper options available, please contact our Scientific Support or your local Cytiva representative. You can also use the Whatman filter selector tool to help guide you through finding the right Whatman filter paper for your application.

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