Engineering Principles of Precoating

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Since the first diatomaceous earth filter aids made their appearance, clearer filtrates have been obtained than was ever possible using filter cloths or screens by themselves. The art of precoating, because of the tremendous variety of filter aids and filter designs, requires an understanding of some fundamentals before satisfactory filter performance can be attained.

Precoating is an operation designed to deposit a layer of diatomaceous earth (or some suitable material) on the filter media. The filter media can be a fabric cloth, wire screen, porous stone, sintered metal or almost any permeable material. It should be noted that this manual applies mainly to pressure leaf filters or candle filters. Primarily, the purpose of the precoat is to prevent blinding or plugging of the media and to provide clean cake discharge. Precoat also produces clarities superior to that provided by the media alone and helps prolong the useful life of the media.

In addition to diatomaceous earth, paper fibers, perlites, activated or natural clays, carbons and metallic salts have specific uses when applied as precoat material. Commercial grades of diatomaceous earth may be obtained to provide particle retentions from 2 microns down to sub-micron range.

Selection of a precoat material is dependent upon the nature of the solids to be removed in a commercial scale filtration. Factors to be considered are:

1. Apparent micron size of the haze, turbidity or precipitate
2. Settling rate of the solids
3. Solids %/Wt. of the feed liquor
4. Solids density
5. Solids characteristics, i.e., granular, slimy, coarse, fine, etc.

Some of these factors are not as critical for the selection of the precoating material as they are for filter design and fluid flow. However, all are important as design criteria for the overall filtering operation.

Important physical properties of filter aids, which must be considered in selecting a precoat material, are:

1. Relative inertness
2. Proper micron retention
3. Uniform particle size distribution
4. Adequate porosity
5. Ample void volume
6. Normal settling rate
7. Low bulk density
8. Moderate material cost

Two common filtering materials, which cannot be used as precoat materials in leaf filters, due to their rapid settling rates, are sand and anthracite.

In any unknown liquid-solid separation problem, where the nature of the solids is unknown, a simple vacuum funnel or bomb filtration test will supply most of the data required. It may be necessary to evaluate the solids in the laboratory to determine a firm basis for pilot runs or full-scale operations.

Filter cloths up to 50-micron retention are not critical of slurry concentrations to produce a desired precoat thickness and rapid clarity. However, more open weaves and wire cloths above 50 to an absolute maximum of 250 microns are very critical of the slurry concentrations employed to bridge the interstices. The maximum reliable width of an aperture, which can be bridged by diatomite with a minimum slurry concentration, is 0.005".

Commonly employed wire screen meshes, which are recognized as standards in the filtration industry are:

- 24 x 110 Plain Dutch Weave (0.016"/0.11" wire diameters)
- 70 x 80 Mesh (0.007"wire diameter)*
- 60 Mesh twilled (0.011" wire diameter)*
- Various grades of "PZ" wire mesh (also known as Reverse Dutch Weave)

It should be noted that these two grades are not as commonly used as in the past.

Where corrosion is not a factor, the selection of screening having the largest wire diameter provides the longest screen life. Enlargement of the apertures by the abrasive action of the silica

TABLE I

WIRE SCREEN PRECOAT AMOUNT AND SLURRY CONCENTRATIONS REQUIRED

MATERIAL GRADE or EQUIVALENT	(1) WET DENSITY LBS/CU.FT.*	(2) 1/16"DEPTH LBS/100 SQ.FT.	(3) MIN GALS LIQUOR/LBS	(4) CONCENTRATION PPM
ALL SOLKA FLOC GRADES	12-16	8	20	6000
PERLITES	12-14	8	20	6000
STANDARD SUPER CEL	14-16	8	20	6000
HYFLO SUPER CEL	17-19	10	17	7000
CELITE 501	18-20	10	16	7500
CELITE 503	20-21	11	15	8000
CELITE 535	20-22	11	14	8600
CELITE 545	21-23	12	14	8600

A minimum slurry volume per 100 square foot of filter area for precoat circulation is the product of columns 2 and 3.

diatoms (which are constantly shifting position from pressure stresses during the rise of cake resistance) is the cause of eventual wire failure. A predictable life of 5 years or more is not uncommon (in the absence of corrosion) for stainless screening in these meshes.

Table I is useful for determining precoat amounts and concentrations for filters equipped with heavy duty screening described previously. The table provides norms for ultimately safe values.

**Wet Density of a filter aid is the volume produced in a centrifuge tube from a weighed amount of slurried in water and centrifuged to a constant level. Specific Gravity produced time 62.4 is the wet density.*

In some cases, a system engineered to this data, may permit 10-15% dilutions if experimenting proves it to be feasible.

Media with smaller micronic retention capabilities than those described above can economize on precoat amounts proportional to the reduction and concentrations. The gallons per pound of precoat can be inversely increased, provided the required protection from progressive blinding is not impaired (see Table II). Precoats of less than 3 lbs. per 100 square foot on fabric cloths are not generally practical. However, reductions to 1 lb. per 100 square feet can be made with high density liquors and very tight media in applications requiring low rates of flow per unit area and great filter size to produce commercial volumes (i.e., cane sugar liquors or beet sugar thick juice).

It may be noted here that refinements of precoating amounts and concentrations to achieve the ultimate economy of operation can be undertaken. These refinements should be based upon pilot tests, laboratory evaluation or prior experience.

SETTLING RATES

Only brief mention has been made of the raw feed solids as a factor influencing precoat operations. Some solids, such as colloids, slimy organics, gypsum or gelatinous materials do not have commercial settling rates, which lead to clarification by this means. Also, even when assisted by flocculating agents plus costly pH adjustments, settling rates are cumbersomely slow. The use of filter aids effectively solves this problem by containing the solids as the slurry passes through the media. This is much like floc settling in a tank, clarifying the liquid in the process.

The process engineer must be aware of and recognize the importance of the settling rates of filtering materials in the feed liquor at process temperatures. This vital data usually escapes notice or is even ignored. But, it is the criteria, which can spell success or failure with full-scale filters.

Settling rates may be determined by sedimentation. A 1000 ml. graduate is a convenient means of measuring the feet per minute rate of settling by timing the settled volume. The filter aid material is thoroughly agitated with precoat liquor at the proper temperature in the graduate and allowed to settle. By measuring the settled depth against elapsed time, a curve can be drawn establishing the % settled solids against time in minutes. Since this settling or sedimentation is not typical of the conditions encountered when filling a tank or pumping prefilt feed during actual production, a practical solution is required to maintain uniform suspension. This may be solved using the time required to settle 10% of the filtering materials in the following method:

HEIGHT OF LIQUID SUSPENSION IN FEET = FEET TIME IN MIN. TO SETTLE 10@ x 2 MEAN MIN.

A properly designed precoat system has two major requirements:

1. It must prevent withdrawal of any portion of the contents of the system until the filter tank is full.
2. It requires a filling rate or flow velocity, which produces a rate of rise within the filter in excess

TABLE II

CORRECTIONS TO TABLE I FOR RETENTIVE MEDIA LESS THAN 250 MICRONS

MEDIA MEAN MICRON RETENTION	MULTIPLES FOR MATERIALS TABLE I LBS/100 Square Feet	PERMISSABLE GALS/LB. MATERIAL
10-50 Microns	0.25	4.0
50-100 Microns	0.38	2.7
100-150 Microns	0.63	1.6
150-200 Microns	0.75	1.3
200-250 Microns	1.0	1.0

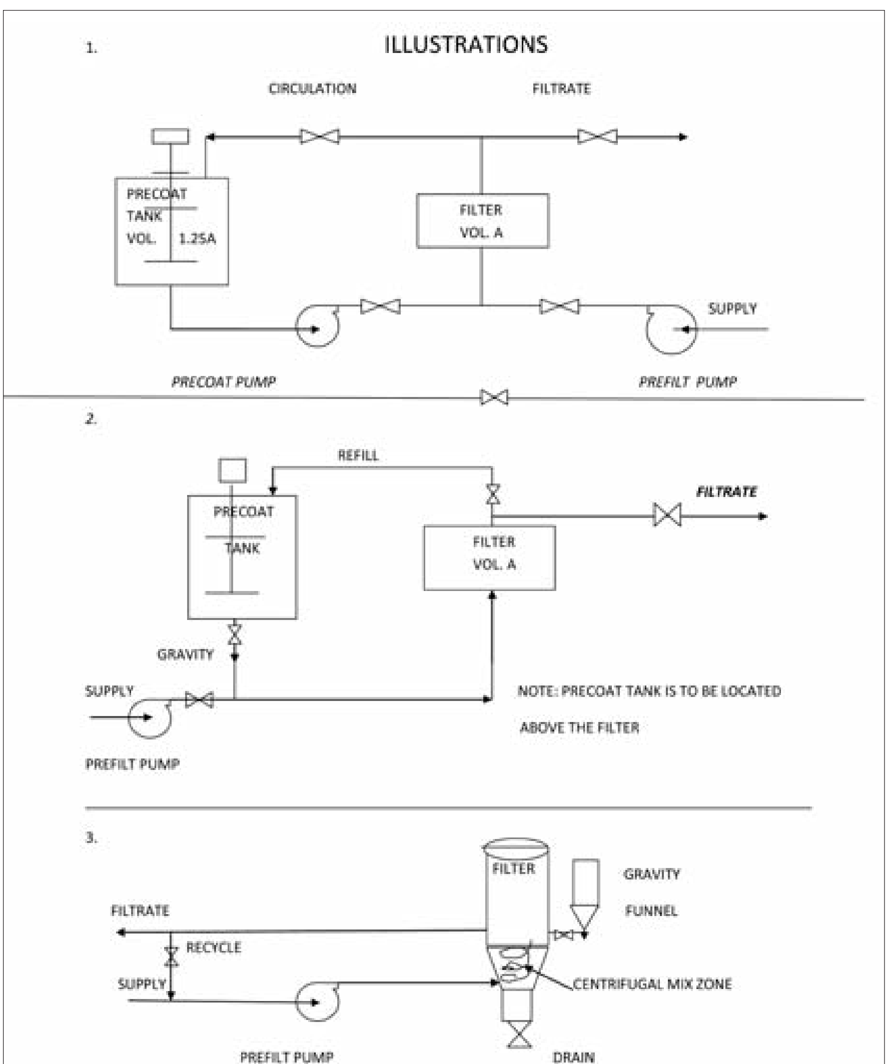
of the settling rate of the filtering materials (as determined previously). This must be calculated for the maximum cross section of the filter tank to produce an even precoat layer.

While it is evident that the precoat rate may be one-half the filtering rate, all conditions being equal, since at mid-leaf during filtration, one half the flow has been removed as filtrate; precoats should be applied at maximum rates for minimum time. However, an accurate determination of the filtering material settling rate, directly concerns Body Feed or Admix operations. The proportional feed of filter-aids during production operations (Body Feed or Admix) will be discussed in a supplement.

In almost all precoat applications, a given precoat thickness is an unnecessary precaution. Filter aid precoats, due to the fact that they are so low in applied wet density and contain billions of particles, will provide an ample thickness with the amounts shown in Table I with corrections shown in Table II for tighter media.

In many cases with tight media, rapid clarity and good cake release (at completion of the filter cycle) are obtained with only a film layer. Greater precoat amounts are many times unavoidable when:

1. Slurry volumes are excessively large when using open media.
2. Pumping rates are not adequate to uniformly suspend filtering materials at all levels in the filter tank.
3. Precoat slurry is not evenly distributed in all parts of the vessel, causing sparse concentrations in portions of long, horizontal, small diameter tanks.
4. Flow through the media is more rapid in some areas than others, such as areas nearest the leaf outlets from lack of proper hydraulic balance.
5. Filtrate piping dropping directly to lower level preparation tanks, causing a siphon and premature flow through the leaves. This may occur during filling as soon as the leaf outlets are covered and before the vessel is full of slurry.



METHODS OF PRECOATING

Selection of the precoat slurry liquid is primarily a process consideration, but is generally the process liquor as raw feed or clarified liquor from a prior filtration cycle. Water is acceptable for aqueous solutions or a solvent in non-polar fluids when dilutions can be tolerated. When, due to process considerations or if dilution is impractical or costly, the precoat fluid must be drained before the prefilt feed is started.

Please refer to illustrations 1-3 on page 42:

1. Most clarifications use a precoat tank, having enough volume to fill the filter and inter-connecting piping, with sufficient volume remaining in the tank to continue agitation. The precoat tank is normally sized to contain a volume of liquor 1-1/4 the amount contained in the filter and precoat piping. Precoat tanks should be designed with a bottom outlet to the precoat pump suction with enough depth or baffled to avoid a vortex. Agitation, either with a mixer or by recirculation flow, must be adequate enough to suspend the filter powder and provide enough roll to thoroughly wet the dry material without manual assistance. Vent lines from the filter to the precoat tank, should be approximately 1/3 the size of circulating flow piping to promote air displacement and rapid filling. The precoat pump may be a separate unit designed and powdered to provide adequate performance. Or, the main prefilt (system) pump can be used with a throttling valve adjusted to the desired flow. In this latter case, selection of the proper characteristics for all conditions is very critical. Centrifugal pumps are commonly used because of their universal applications, but other types of pumps are used for precoating in many industries.

When the wet density of solids in the prefilt feed are above a specific gravity of 1 and relatively low in ppm, prefilt feeds can be utilized for precoating with good economy and simplification rather than filtrate or other cumbersome multipurpose procedures. When it is understood that an average precoat concentration containing 1 lb. of filter powder in 20 gallons of water represents a slurry of 6000 ppm, the volume of the powder–compared to 1 specific gravity solids id 2–1/2 to 4 times the contamination. But, of most significance is the void volume available for envelopment of the colloids. While the useable voids for filtration varies with each grade or class of material, the range of voids will be from 60 to 75%.

This phenomenon provides a workable rule that may be stated: When solids are 1/10 or less the precoat concentrations in PPM–use the feed liquor for precoating. This, as inspection will show, is a safe ratio, and can be refined by preliminary tests to produce the greatest benefit without sacrificing the purpose of the precoat.

Following are examples of practical methods, which use this principle:

2. GRAVITY FILL

A precoat tank with sufficient volume to serve the filter is located overhead. Powder is introduced to the precoat tank, suspended to uniformity, and then dropped to the filter tank in conjunction with starting the prefilt feed. Filtrate, whether cloudy or not, is returned to the precoat tank for the next fill.

The success of this method depends upon the filter to develop mixing and uniform distribution of the prepared slurry to the diluted concentration. In this instance, the gravity precoat tank may be of less volume than the filter.

3. PRECOAT FUNNEL

A funnel, generally used on Vertical Leaf Filters up to 150 square feet of area, provides substantially the same results where filter aid quantity is less than 50 lbs. A prerequisite to this method is an efficient internal mixing and baffling of the feed to achieve the uniform distribution throughout the tank, which is required for precoating.

The funnel may be charged with prepared slurry or by bucketing in several gallons of liquor to a dry powder. The funnel valve is opened and the slurry allowed to gravity flow to the tank. The funnel valve is closed and the prefilt pump started.

Cloth dressed filters are most adaptable to this method of precoating as smaller quantities of filter aid, with re-

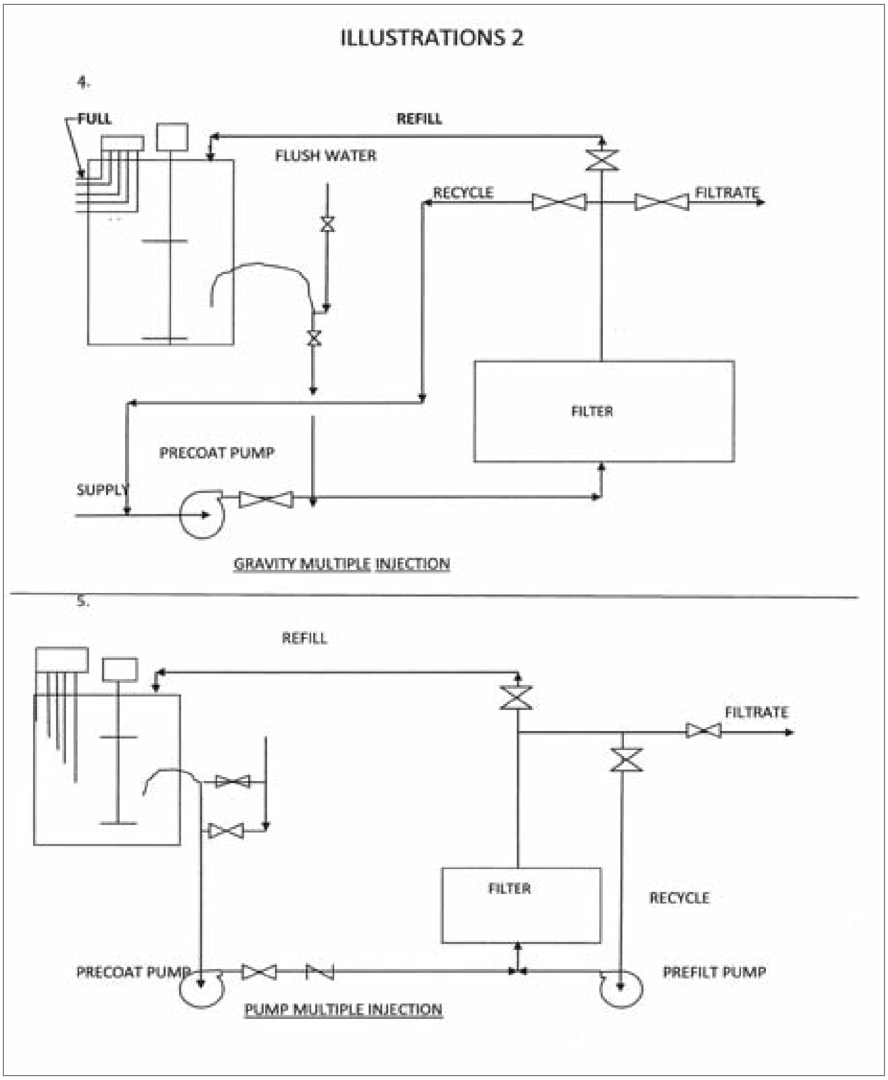


TABLE III

RATE OF PRECOAT DEPOSITION RELATED TO PRECOAT VOLUME

PRECOAT VOLUME N PASSED THRU MEDIA AT ANY RATE	PRECOAT FRACTION PERCENT APPLIED	IN SLURRY
0.5	39.0	61.0
1.0	62.5	37.5
1.5	77.5	22.5
2.0	86.2	13.8
2.5	91.5	28.5
3.0	94.7	5.3
4.0	98.1	1.9

Two circulations will deposit about 90% of the precoat charge. A gain will be obtained when the precoat vehicle is clean liquor, as some additional precoat will be deposited before contamination becomes a factor.

sulting economies, may be used. This is illustrated in Tables I and II.

4. INJECTED PRECOATS

If a gravity set-up is inconvenient, it is obvious a pump can be substituted in 2 to make the same delivery of suitable slurry to be combined with prefilt feed.

The frequent charging of precoat tanks by use of instrumentation, rather than manual operation, implements much of the objectives desired to reduce labor and provide instrument reliability for positive quality control. Proportional admix injection (known also as body feed) of concentrated slurries combined with the prefilt feed liquor may be used upon start up of the filter to provide a suitable precoat.

Concentrations of up to 1 lb. per gallon may be used as the slurry for injection. For gravity introduction, a series of probes, each positioned for the amount of charge, are programmed to open and close the drain valve at the appointed time. This drain valve should not be located at the bottom of the tank where settled powder will accumulate, but should enter the tank at a low level with a drop pipe to the interior near the bottom. A clean, timed, fluid back flush above the valve will purge the line of powder slurry. A pumped slurry introduction, based on this principle, provides a combination pump start with valve opening using the same side-entering outlet described for gravity proportioning. But flushing the siphon line is combined with simultaneously flushing the pump and the discharge lines to prevent resulting failures from powder settling. Otherwise, probe levels, tank sizes and calculated powder mixtures remain constant.

RATE OF PRECOAT DEPOSITION

There is some value in predicting the time required to deposit a given amount of precoat layer. Clarity must be produced rather promptly with a sufficient precoat layer established to provide good cake release at completion of the cycle. Minimal precoats will fail if the volume turnover is not sufficient to reach the desired layer. As all precoats are applied by flow in a given volume, the rate of deposition is a function of the rate of slurry reduction within the system. The following table illustrates the rate of change in which time of the circulation volume N divided by the rate, and percent deposition is the fraction of amount Cf/Co to the original.

Two circulations will deposit about 90% of the precoat charge. A gain will be obtained when the precoat vehicle is clean liquor, as some additional precoat will be deposited before contamination becomes a factor.

A filter feed rate at the mayor cross section of the filter vessel, no less than twice the observed settling rate, assures building uniform cake over the entire height of the immersed leaf. As the cake grows, it displaces volume in the leaf zone and rate of rise increases. It is important to maintain distribution in the early portion of the production period at low-pressure drop. By sustaining permeability, filtrate volume may be increased by as much as 10%.

Clarity-Time Relation: Clarity produced from a given precoat mix, when using a powder of proven efficiency is a function of the rate per unit area, concentration of the slurry and retention of the media.

Refer to Table II for other media. Multiply above mean times by column (1) for the type of media employed. Dense media will give almost instantaneous clarity. Caution is suggested to employ sufficient time to produce a full-scale use of the precoat charged for additional protection to the media and satisfactory cake discharge. See Table III.

FILTRATION

While the preceding deals primarily with Precoating, we want to add some observations on Filtration and Proper Filter Selection.

In an article in the June 26, 1972, CHEMICAL ENGINEERING, Dereck B. Purchas, consultant chemical engineer, goes into full details about "FILTRATION". Here is an extract of his comments from that article where he states: Achieving truly trouble free filtration in industrial installations requires a lot of attention to five major areas:

- Definition of the filtration problem
- Selection of the appropriate filter or filters
- Selection of the filter medium or media
- Selection of auxiliary equipment
- Control of operating conditions

TABLE IV

RELATIVE SETTLING RATES FOR 10% MATERIALS IN WATER (70° F)

Material Grade or Equivalent	Feet/Minute	Inches/Minute
Filter-Cel	0.25	3
Standard Super-Cel	0.42	5
BW-200 Solka-Floc	0.50	6
Hyflo Super-Cel	0.66	8
BW-100 Solka-Floc	0.92	11
Celite 501	1.00	12
BW-40 Solka-Floc	1.20	14
Celite 503	1.33	16
Celite 535	1.66	20
Celite 545	2.50	30

TABLE V

PRESSURE LEAF CLARITY-TIME RELATIONS AT VARIOUS PRECOAT RATES

CONCENTRATIONS TABLE I

PRECOAT RATE GPH/Sq.Ft.	FROM WHEN FLOW STARTS MEAN TIME TO CLARIFY (Minutes)
10	10
15	7
20	5
30	3.5
40	2.5
50	2.0
60	1.6
70	1.3

Precoating | Filters

In defining the filtration problem there are so many factors in a typical filtration problem, it is often difficult to think that a problem has been fully defined before a specific type of filtering equipment can be recommended or considered. It is because of this that many manufacturers or consultants have their own questionnaire to be filled out by the prospective client. The person or persons that must fill-in these que- stionnaires must be as complete as possible in listing the process conditions and answering the questions in these forms. Unfortunately, in some cases, the required data to complete these forms may not be available or known sufficiently by the person completing the form and sometimes it is recommended to try to prepare a representative sample of the process liquor to be furnished to perform bench scale testing so that the results may be scaled up to the determine the actual production units. The questionnaire resolves the possibility of not asking the right questions when discussing the application with a client. Such test also determines the filterability of the process liquor and in a small scale helps determine what pretreatment if any is necessary or what filter media and filter aid is best for the application.

It is important to define the degree of clarity required in the application and not vague expectations such as "good clarity". Equally important is providing an accurate percentage of suspended solids and particle analysis. It is important to know if all of the suspended solids are to be removed and how the removed solids are to be disposed or if further processing is required.

Full understanding of the filtration duty is a prerequisite in the selection of the filter equipment. Pretreatment of the process liquor is very important because that will determine how it will filter. The shape, size and particle distribution of the suspended solids is an important factor. In the selection of filter, the various types must be considered such as centrifuges, gravity filters, compression filters, pressure filters and vacuum filters.

Following filter selection – it is equality important to select the type of filter media – such as filter cloths, wire mesh, sintered wire mesh, and membranes. Consideration must be given to the porosity, particle retention, filter cake release and cleaning of the media. In the case of the filter cloths, the compatibility with the process liquor must be considered. Whether it should be woven or non-woven, temperature limitations and performance of the cloth are to be given consideration.

The selection of auxiliary equipment is to be considered also – the size and features of the precoat mixing tank, type of mixer, type and capacity of the precoat pump and the feed pump, body feed mixing tank, and mixer and pump.

Last but not least is the recommendation to read published articles on processing magazines and those published by the filter aid manufacturers and filter cloth and wire mesh suppliers – all provide a lot of helpful information in considering filters and filtration systems.

The writer has compiled this manual from various sources that he has read and compiled in over 49 years in the field of filtration. The similarity of comments or notes in this manual with published information is simply the fact that those sources have been consulted in the compiling of notes and comments in this manual. The writer does not claim any or all in part to be originally his. FN

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