CONCENTRIC FIBER BED FILTER ASSEMBLIES

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ABSTRACT

Fiber bed filters are used in a wide variety of chemical processes and environmental applications where coalescence of aerosol mists are required. Fiber beds are particularly applicable where aerodynamic diameters are 5μ or less.

At times, capacity requirements for processes increase, necessitating the addition of fiber bed filter surface area to avoid pressure drop and power requirement increases. However, filter containment vessels are often not constructed with potential future expansion in mind. So generally, adding more filters to an existing vessel is not an option. The remedy has been to add a second containment vessel, in parallel, containing the additional required filtration surface area.

An alternative, developed by The CECO Group, is to use concentric filters, trademarked as TWIN-PAK™. In this construct, no additional projected area is required, yet the filter surface increase is on the order of 50%, with commensurate increase in capacity or reduction in pressure drop.

Fiber bed filtration is primarily used for enhancement of air quality thru removal of fine aerosol particulate, both liquid and solid, that has aerodynamic diameters in the low micron and sum-micron range. Particulate in the 0.4-0.7µ range, the wavelength span of visible light, are especially effective in creation of stack plumes.

Fiber beds operate thru the process of diffusion as contrasted with interception or impaction, which would be the more typical filtration modality. In diffusion the flow thru the fiber bed is laminar, thus the pressure drop is linear with velocity. Since the commercial applicability of fiber beds is generally confined to near micron and sub micron sized particulate, these particles at low velocity have little momentum. As such, they track the streamlines of flow effectively and readily pass around obstacles in the flow path. The most challenging particle size for fiber beds is about 0.3µ aerodynamic diameter. For particles nominally less than and greater than that size, the efficiency increases.

The efficiency of a fiber bed is directly proportional to thickness and density and inversely proportional to velocity. To assure contact with a fiber of the filter body, which is required for coalescence, fiber bed filter walls are generally between 1.5 and 3 inches in thickness. This thickness presents a balance between ultimate efficiency and reasonable pressure drop. Inasmuch as compromises in either of these criteria can be made, the construction of the filter can be adjusted. Filter efficiency also increases with finer filter fiber diameter and in order for filters to be nominally 2 inches thick and achieve submicron efficiencies greater than 99% the fiber needs to be about 8-10µ in diameter.

The ability to drain coalesced liquid is important to the efficiency of the filter. Fiber beds have a void fraction of 0.89 to 0.96, which is to say they are mostly open volume. This open structure facilitates draining. In operation, a liquid mist particle will adhere to a fiber locality. At that instant drag forces from the flowing gas and gravity forces are insufficient to overcome the local attractive force holding the particle to the filter fiber. However, as subsequent mist particles coalesce at the same location the mass of the drop increases to the point where gravity and drag forces predominate. The net effect is the draining of the particle toward the bottom downstream surface of the filter where ultimately the coalesced stream disengages from the filter.

Fiber beds are typically cylindrical in shape and can assume a variety of diameters and lengths. The filter media can be composed of several different materials; fiberglass (various grades and types), polyester fiber, nylon, Teflon, graphite, polypropylene and others, either alone or in combination. The cylindrical filter is constrained between and inlet flange and end plate and inner and outer cages. These serve to compress and support the filter media and achieve a desired level of compaction or density. Both the filter media and hardware are chosen for both efficiency and longevity in the desired application.

One is brought to fiber beds because a high level of particulate removal is required. Designs focus on the current need. To do otherwise would increase the capital investment in excess vessel and filter capacity than current need dictates, or anticipating less capacity in the future, would result in higher power costs at the outset due to greater pressure drop thru the filter system.

In a typical design the fiber bed filters are installed in a vessel and either sit on a tube sheet or are suspended from the vessel top plate. The tube sheet is typically 2-4 feet above the bottom of the vessel, depending on the capacity of the system. The tube sheet contains holes which have a diameter equal to the inside diameter of the fiber bed filter. A gasket and bolting secure the filter candle to the tube sheet with a leak tight seal. In such an installation the flow is thru the interior of the candle to the outside: inside-out flow. The surface area for filtration is calculated based on the inner diameter of the filter. Obviously greater surface area is achieved for each foot of filter height the larger the diameter of the candle. A size is reached, however, where issues of fabrication, field handling and installation and vessel support become predominant, and work against large diameter candles.

Most fiber bed candles are less than 4 feet in diameter. The larger the diameter of a candle, the more the interior volume is wasted. Often a second filter can be inserted in the interior volume to increase the overall surface area of the assembly with minimal additional complexity. In such a configuration, for a sitting filter assembly, mist laden gas enters the annular volume between the filters (Fig. 1). The gas flows outward thru the outer filter as would be the conventional case, and inward thru the inner filter. The top plate of the TWIN-PAK™ assembly is open over the ID of the inner filter to allow the gas to exit from the filter core into the vessel interior. The additional effective surface area is calculated on the ID of the inner filter. In the case of a hanging filter candle the mist laden gas flows from the outside of the outer filter into the annular volume and from the core of the inner filter into the annular space. From the annular volume between the filters, the mist free flow is into the vessel head area above the supporting tube sheet.

As an example of the flow for a sitting concentric filter consider the following examples. Assume a facial velocity though the filter wall of 30 ft/minute for a TWIN-PAK of 10 foot length.

ID" outer	ft^2/ft	$ft^3/min.$	OD"inner	ft/min. annu	ft^2/ft	$ft^3/min.$	%incr.
20	5.24	1572	16	3203	3.14	942	60
32	8.38	2514	28	3359	6.28	1884	75
38	9.95	2985	34	3400	7.85	2355	79
44	11.5	3450	40	3424	9.42	2826	82

For a 20 foot long filter assembly at the same facial velocity.

20	5.24	3144	16	6400	3.14	1884	60
32	8.38	5028	16	1650	3.14	1884	37
32	8.38	5028	24	3343	5.24	3141	63

In the design and application of fiber bed filters there are limiting velocities that need to be considered. On the upstream side of the filter we generally design to limit the velocity of flow, parallel to the surface of the filter wall, to less than 3600 ft/minute. This limit is imposed to aid uniform draining of coalesced mists from the filter. Recognizing that larger mist particles will coalesce early in their travel through the filter wall, and smaller particles deeper within the filter, high velocities across the upstream surface, through drag force, will inhibit the draining on the upstream filter surface. This will have the effect of reducing the effective filter draining volume. Additionally, structural pressure drop within the annular volume will increase. On the downstream side of the filter, velocity parallel to the filter surface is limited to 1200 ft/minute in most cases. This limitation is to prevent re-entrainment of the coalesced liquid into the out flowing gas stream.

Consider the first example again, but in this case as a hanging filter (Fig. 2). In such a configuration the annular volume between the filters is now on the downstream side. The velocity in the annular volume is 3203ft/minute, much higher than the limitation of 1200ft/minute. In order to make this work a smaller diameter inner filter will be required. The effective capacity increase, however, will not be as significant. Again looking at example one.

ID" outer	ft^2/ft	$ft^3/min.$	OD"inner	ft/min. annu	ft^2/ft	$ft^3/min.$	%incr.
20	5.24	1572	12	1575	2.62	628	40
20	5.24	1572	10	1248	1.57	471	30

In the second case a 30% increase in capacity, or commensurate decrease in pressure drop is achieved at an annular velocity slightly above the established re-entrainment velocity.

The TWIN-PAK fiber bed filter construction increases the options for a manufacturer to significantly increase volumetric capacity with only minor containment vessel modifications or to achieve corresponding pressure drop reductions.

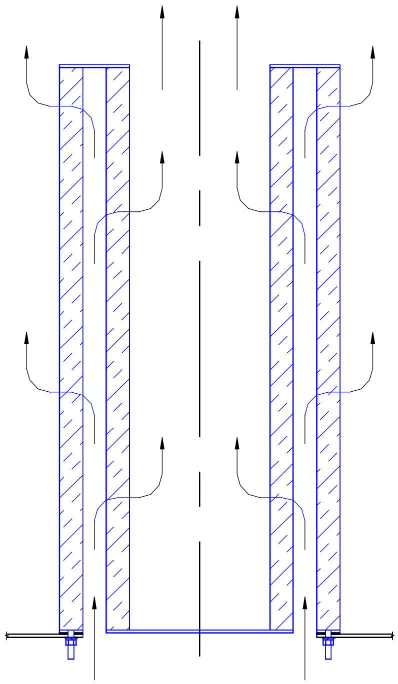

FIG. 1

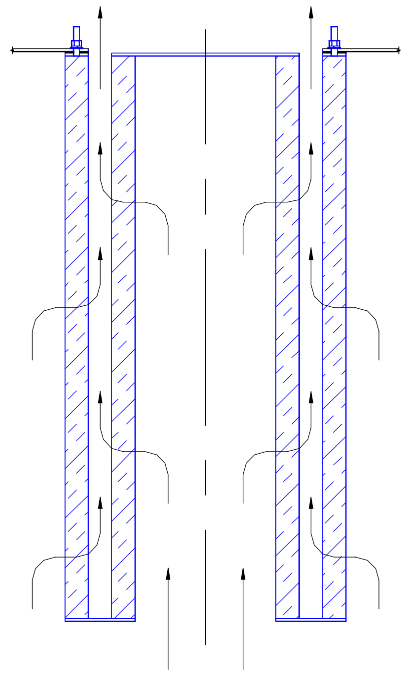

FIG. 2