GRADIENT DENSITY FILTER MEDIA FOR LIQUID APPLICATIONS

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ABSTRACT

Filtration applications normally require optimization of high filtration efficiency with low-pressure drop and high dust or dirt holding capacity. The structure of a filter medium plays a crucial role in achieving these product attributes. Controlled gradient density structures enhance this balanced performance. Filter media thickness and pore structure are engineered by controlling fiber characteristics and arrangement. A nonwoven media, used in liquid filtration, has been designed to provide such a gradient structure. The field studies described in this paper demonstrate that media with this balance of properties provide the user with filters that clean better, last longer, and are very cost effective.

This paper details critical parameters controlled for development of gradient structures with specific commercial applications and field study data.

INTRODUCTION

The ideal filter media for most applications will provide high filtration efficiency, low pressure drop and high dirt holding capacity. A filter media structure can accomplish all three of these attributes if it captures the desired particles, minimizes pressure drop, and requires infrequent filter changes. Filtration applications normally require a balance or optimization of these three attributes. Media with a density gradient structure can enhance this balanced performance. The filter medium thickness and pore structure are manipulated by controlling fiber characteristics and fiber arrangement. An optimized pore structure traps a broader range of particle sizes in the media. Thus, the media exhibits higher efficiencies and/or dirt holding capacity with minimal increase in pressure drop.

MECHANISMS

There are four types of mechanisms in filtration[1]. These mechanisms are briefly reviewed below.

> **Surface loading** is a mechanism where the pores are smaller than the particles collected on the surface of the filter (see Figure 1). As the surface loads, the differential pressure increases.
>
> **Cake Filtration** is a mechanism where a thick layer or cake of particles accumulates on the top of the medium. These particles are usually larger than the pores in the medium

(see Figure 2). This mechanism is effective in solids recovery because as the cake gets thicker, the efficiency can improve.

Figure 1: Filtration by Surface straining[2]

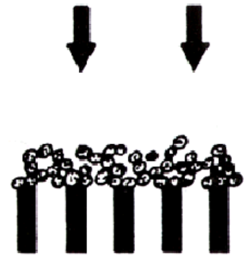


Figure 2: Cake filtration mechanism[2]

Depth Straining is a mechanism where the particles move through the medium and are physically entrapped in the web structure (see Figure 3). The pore sizes are smaller than the particles retained. Particles smaller than the pore structure will penetrate through the medium. This application is widely used in liquid applications and in less critical air applications.

Depth Filtration is a mechanism where particles smaller than the pore structure are trapped within the medium. This mechanism involves several complex forces, such as impaction, interception and diffusion, which act on the particles and result in high efficiency (see Figure 4). These forces all depend on the relationship between media construction and particle size to provide high efficiency.

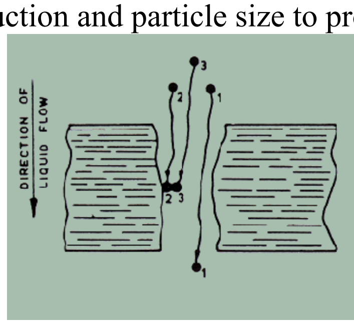


Figure 3: Filtration by depth straining[3]

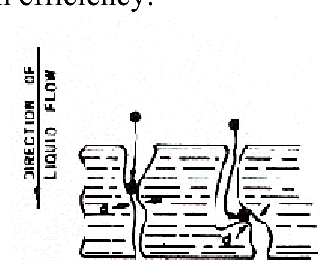


Figure 4: Depth filtration mechanism[3]

Depth straining and depth filtration are both mechanisms that work in gradient structure media. The pore structure is more open on the face of the filter, and the packing density of fibers and their diameters can change through the filter and result in more restrictive pores. This tortuous path results in improved efficiency and life with minimal pressure drop. Both of these filtration mechanisms allow greater utilization of the filter media in the direction of fluid flow.

GRADIENT DENSITY

Innovations in nonwoven technologies have propelled advancement in filtration media. Filter media, in general, provides some level of efficiency, pressure drop and dirt holding capacity. To improve the performance in one area, the functionality of the filter is sometimes compromised in another area. A nonwoven media has been designed to balance these three attributes. These structures are beneficial in both liquid and air filtration applications.

Figure 5 illustrates the gradient density structure provided by this particular nonwoven media. The media provides a coarse pre-filter layer upstream (Figure 6) to enhance holding capacity, of metal shavings and other debris, and a layer with finer pore structure downstream (Figure 7) for high particulate filtration efficiency. The media is one homogeneous nonwoven structure with continuous fibers that have been thermally bonded to prevent fiber shedding.

By manipulating the fiber arrangement, fiber diameters and other characteristics, the media can be tailored to filter fluids with a variety of contaminant size distributions.

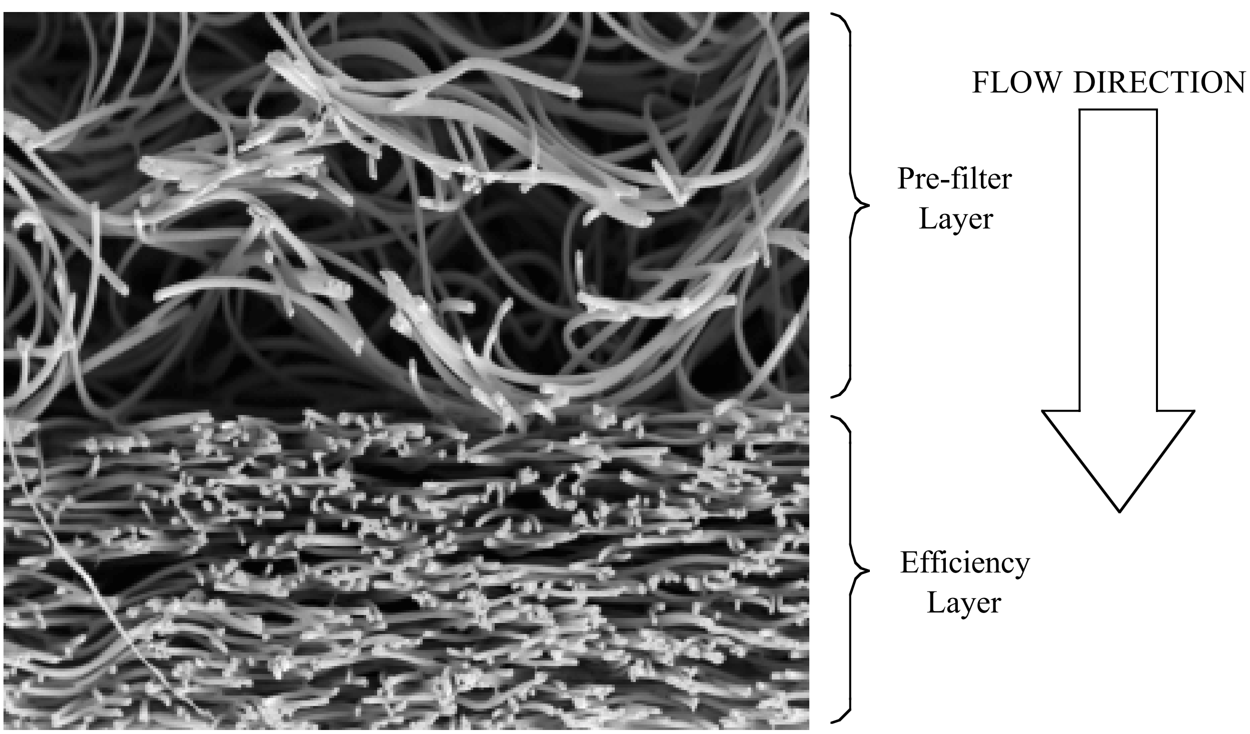


Figure 5: Gradient Density Structure (Media Cross Section)

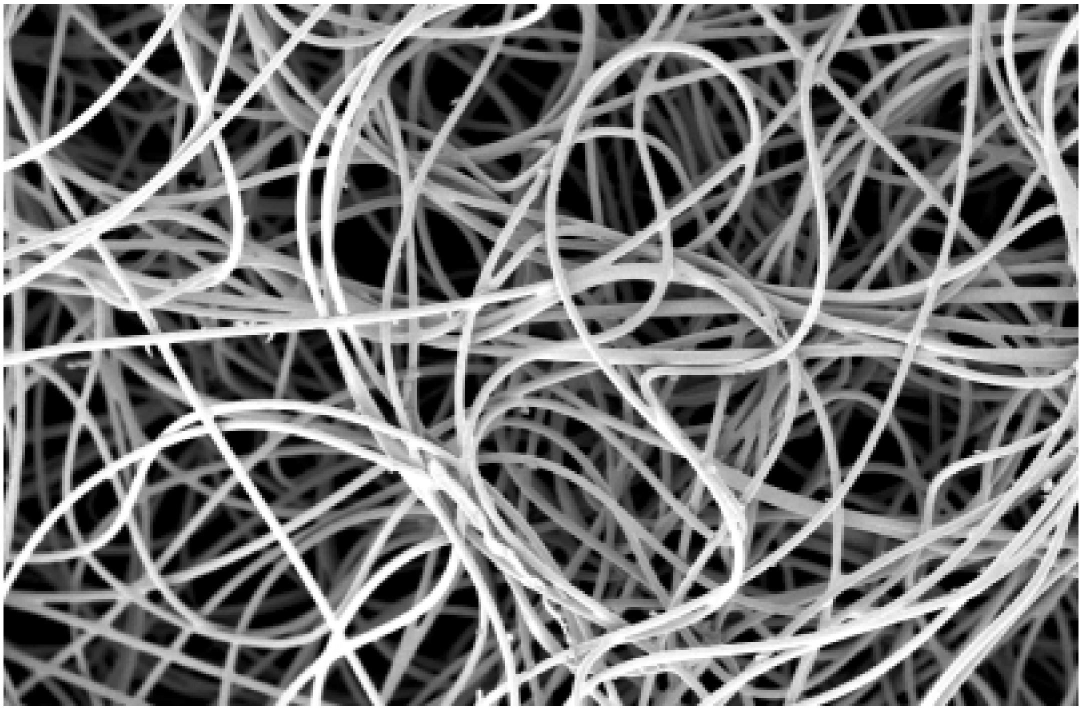


Figure 6: Upstream Dirt Holding Layer (Plan View)

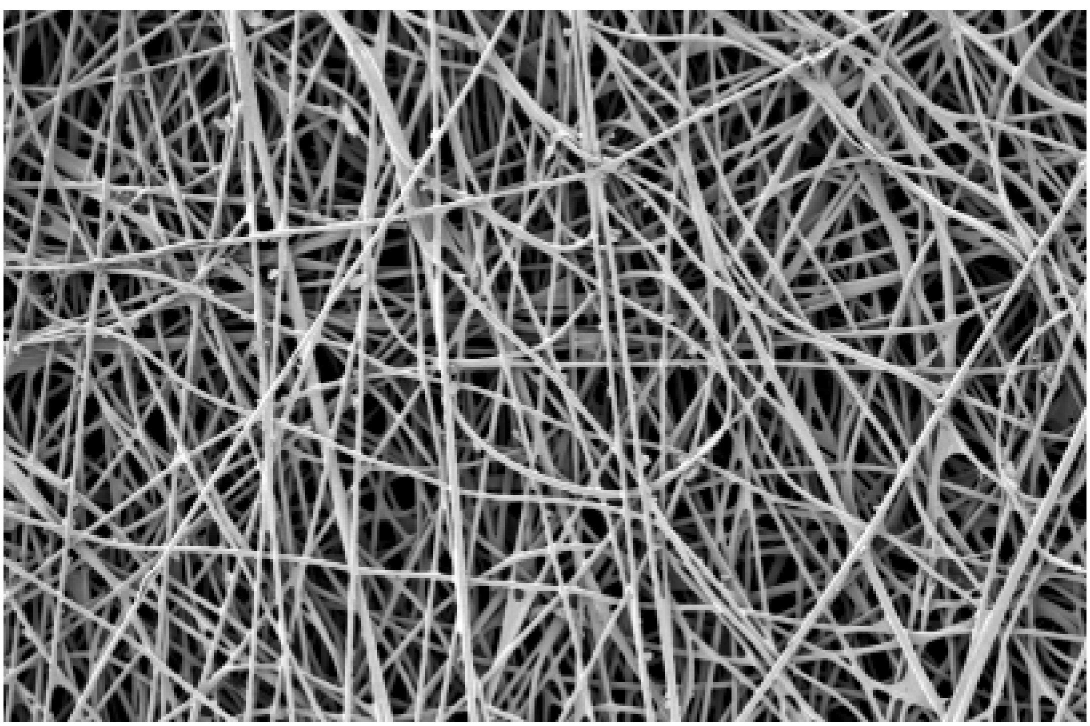


Figure 7: Downstream Efficiency Layer (Plan View)

This engineered gradient structure offers advantages in liquid filtration applications over typical felts. Standard felt media are typically comprised of non-continuous staple fibers, woven or mechanically entangled, that may have a tendency to surface load. Figure 8 illustrates the structure of a commonly available felt media. Table 1 compares holding capacity for a nonwoven gradient structure versus four commercially available felt products. This particular nonwoven gradient media can hold 20% to 70% more contaminants than typical felt products currently in use.

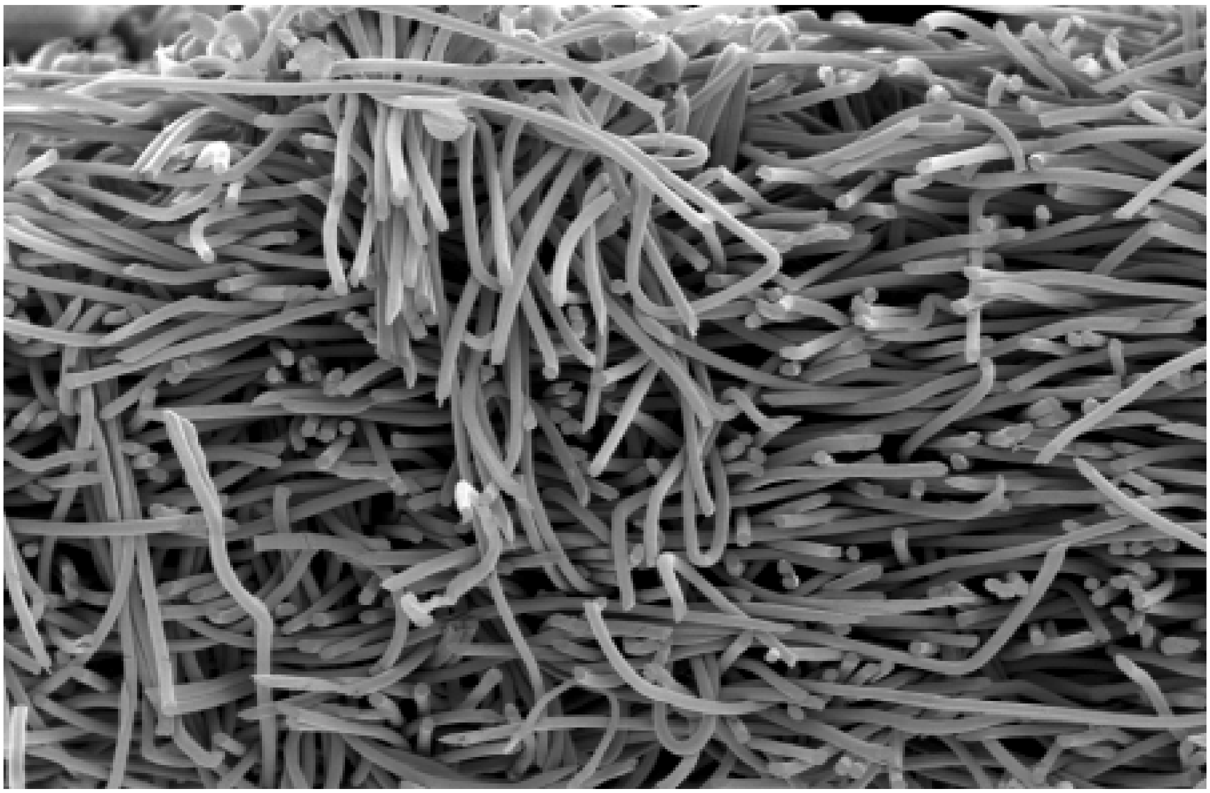


Figure 8: Typical Felt Cross Section

Table 1: Media Dirt Holding Capacity

Media	Dirt Holding Capacity (grams per sq. ft.)
Nonwoven Gradient Media	23.85
Felt #1	16.92
Felt #2	17.68
Felt #3	19.84
Felt #4	13.90

Average Felt Capacity is 17.08 g/sq. ft.

LIQUID CASE STUDY - FILTRATION MEDIA

Coolant filtration demands several major characteristics of the media, such as strength, chemical and temperature compatibility, dirt holding capacity, and efficiency. Each of these characteristics has a role and an order of importance in every filtration application. Gradient density depth filtration structures, presented here, optimize the pore structure and capacity of the media. The media design criteria and the four major characteristics are outlined below.

Strength

The media must be able to withstand the process conditions to which it is subjected. The media must allow for high liquid flow rates, heavy contaminant loads and provide the tensile strength to withstand indexing forces.

Chemical and Temperature Compatibility

Commonly used filter media are made from cellulose, polyester, and polyolefin raw materials. The media components must be compatible with the filtrate to provide maximum performance. Temperature, pH, and the fluid path are all parameters to consider. The media chosen should be chemically inert in the system to maintain strength and performance under the most stringent operating conditions. Note that some media can contain binders that can dissolve in the liquid, adversely affect the coolant chemistry and weaken the medium.

Dirt Holding Capacity

The dirt holding capacity indicates the amount of debris the filter media will trap and hold before the flow is restricted such that the media must be changed out in the filter press. The frequency at which the media is replaced with clean media is called the index time. Fewer indexes correlate to less frequent roll changes and a reduction in media consumption. Many filters index on pressure drop.

Efficiency

The filtration efficiency of the media should accommodate the range of particles in the application. This range includes a variety of shapes, such as spheres, chips and slivers, to be filtered as well as the size of the particles. By manipulating the fiber characteristics and fiber arrangement, the pore size distribution of the media can be tailored to the particle stream.

FIELD STUDY PROCEDURE

The process to qualify a gradient density media for a plant is similar at every location. A qualification plan must identify the amount and size of the dirt, index frequency, coolant chemistry and the process conditions of the system. A field study establishes the debris concentration (parts per million) in the coolant, the annual media usage, and the relative costs.

These evaluations take place over a period of one to six weeks, depending on the application and the regularity of the filter press operation. Data collection begins on the existing filter media and includes coolant sampling above and below the filter and the time of each index. The coolant is analyzed for the amount and size of debris in the system. Once the filter operating parameters are measured, a gradient density media is placed on the filter press. The system is allowed to equilibrate and comparative measurements begin. The objective of each trial is to improve filter performance and/or lower media usage costs.

Nonwoven gradient media and felts were placed in coolant filtration applications in the metal working industry. The case studies demonstrate how the nonwoven gradient structure improves coolant cleanliness and utilizes less media. The results from field tests at select automotive manufacturing and steel rolling plants in the United Kingdom and United States are cited below.[4]

Case 1: Cast Iron Grinding Operation Utilizing A Vacuum Filter Press In The U.K.

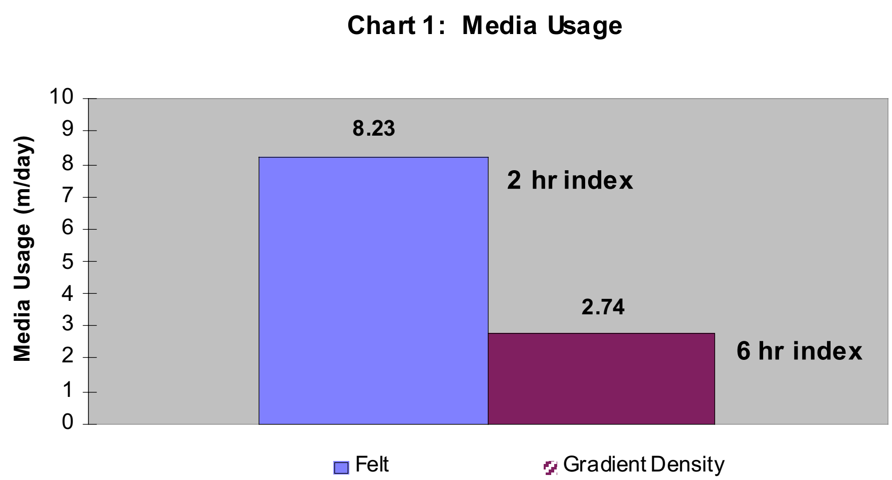
The objective of this plant trial was to reduce costs while providing the same or better performance using gradient density media. The felt media indexed every 2 hours and media usage averaged 8 meters per day. The debris concentration ranged from 40 to 58 ppm over the four-day period during which samples were collected. A gradient density media was selected to provide similar efficiency to the existing felt. Once the media indexed through the system the data collection began. The gradient density media usage averaged 2.74 meters per day and indexed every 6 hours. The debris concentration down stream of the filter ranged from 14 to 34 ppm over the four-day period during which samples were collected.

Charts 1 and 2 show that the gradient density media reduced media usage by 66%, and reduced the dirt concentration in the coolant by an average of 45%. The media offered an annual projected savings of £750, a 33% reduction in media cost, as shown in Chart 3.

Case 2: Cast Iron Broaching On A Vacuum Filter Press In The U.S.

The objective of this field study was to improve the filtration performance in this engine plant. The media on the filter press was a multi-layered spunbond laminate ranging in basis weight from 1.8 to 2.5 osy. The media usage over a two-week period averaged 38.4 feet per day collecting 7.24 ounces per square yard of dirt. The system contamination level during a 30 day period, ranged from 4 to 36 parts per million and averaged 16 ppm. The history indicated the operation ran five days a week at 20 hours per day. The gradient density media ran seven days on the filter press. During that period, the media consumption dropped by 72%, increased dirt collection 314% per square yard, and reduced system contamination by an average of 60%. Charts 4, 5, and 6 show the improved performance that density gradient media provided in this manufacturing application.

Case 1: Cast Iron Grinding Operation



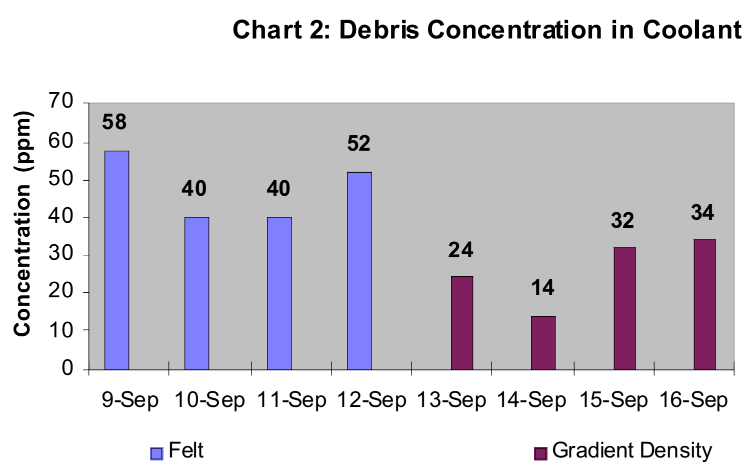
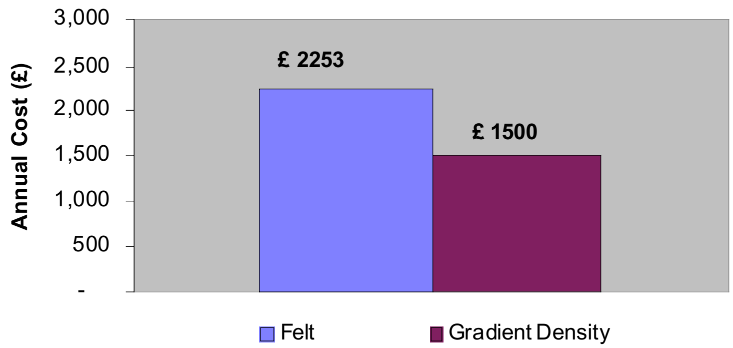


Chart 3: Projected Annual Cost



Case 2: Cast Iron Broaching Operation

Chart 4: Media Usage

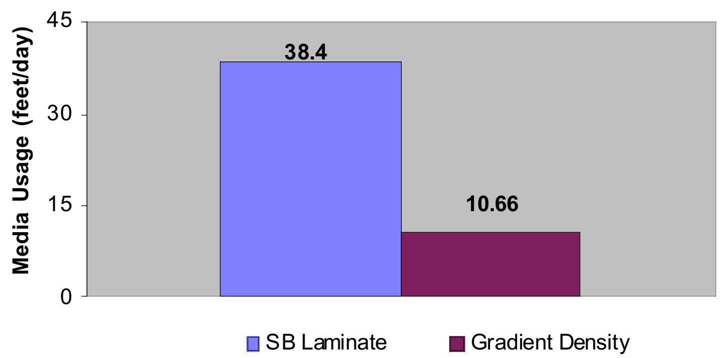
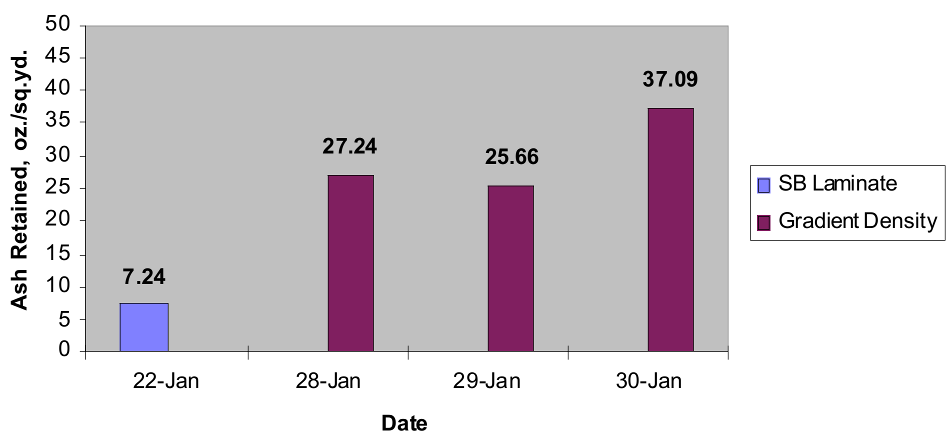


Chart 5: Dirt Retained



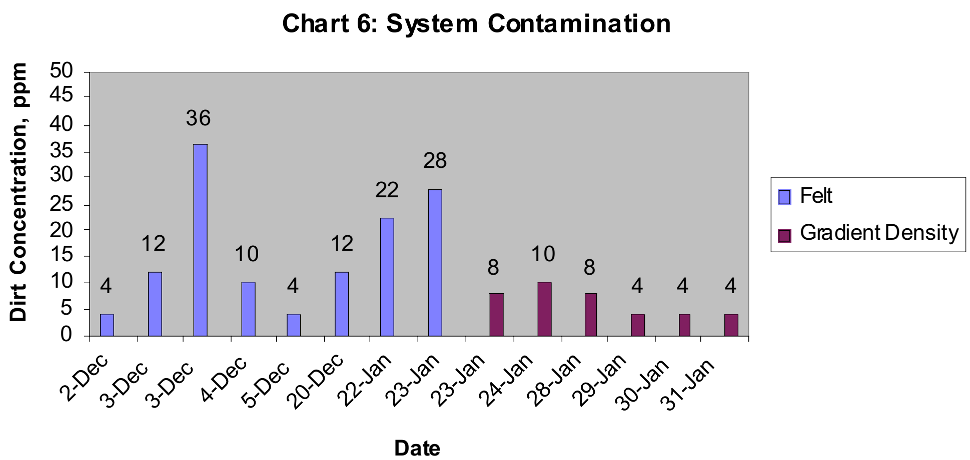


Chart 6: System Contamination
Dirt Concentration, ppm
50
45
40
35
30
25
20
15
10
5
0
4
12
36
10
4
12
22
28
8
10
8
4
4
4
2-Dec
3-Dec
3-Dec
4-Dec
5-Dec
20-Dec
22-Jan
23-Jan
23-Jan
24-Jan
28-Jan
29-Jan
30-Jan
31-Jan
Date
Felt
Gradient Density

Case 3: Steeling Rolling Application In The U.S.

The qualification plan for this application identified two gradient density media for consideration. The existing media was a 1.8 osy wet-laid nonwoven. The index cycle was every 1.75 hours and media usage averaged 47 yards per day. The dirt concentration in the coolant was 115 ppm and the media removed 21 pounds of dirt per day. These values correlated to an average capacity of 17 grams per square foot.

Charts 7, 8, 9, and 10 show that density gradient media #1 demonstrated a 40% reduction in usage, a 250% increase in capacity, a 110% increase in dirt removal (lb./day), and a 48% reduction in iron fines. This performance was outside the target cost range for this filter press, therefore a second gradient density media was evaluated. This gradient density media demonstrated a 58% reduction in media usage, a 282% increase in capacity, a 62% increase in dirt removal, and a 26% reduction in iron fines. The cost for the second media met the customer cost parameters for improved performance, as shown in Chart 11.

Case 3: Steel Rolling Operation

Chart 7: Media Usage

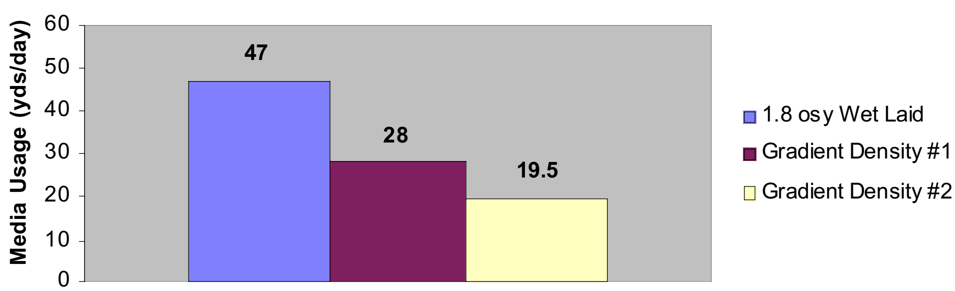
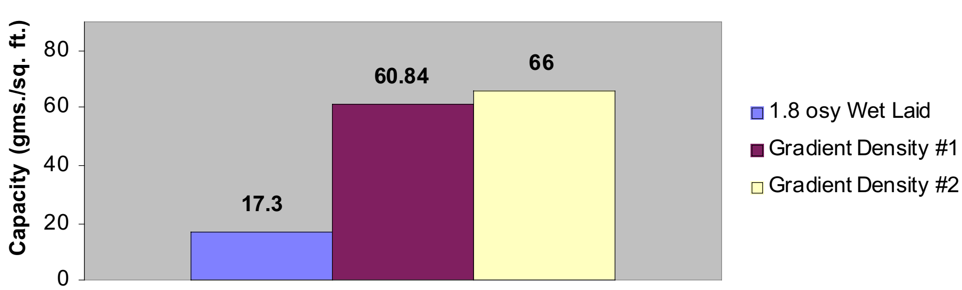
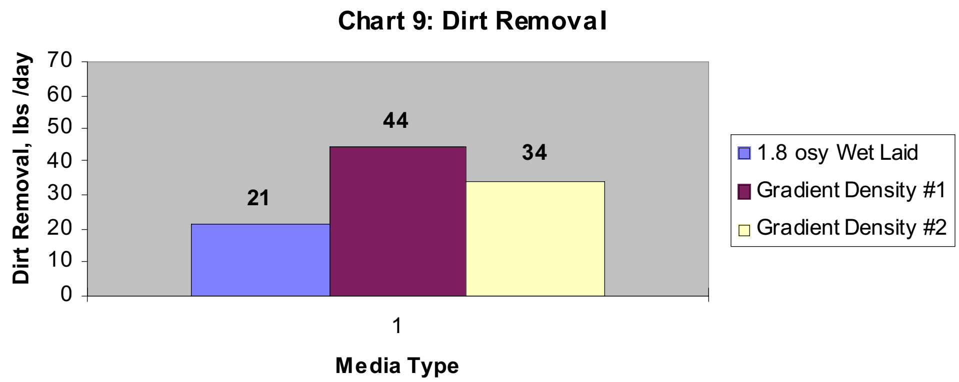
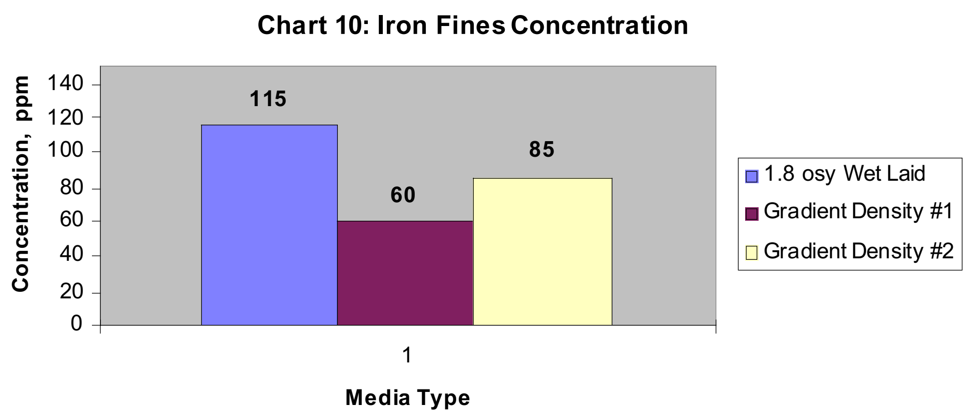
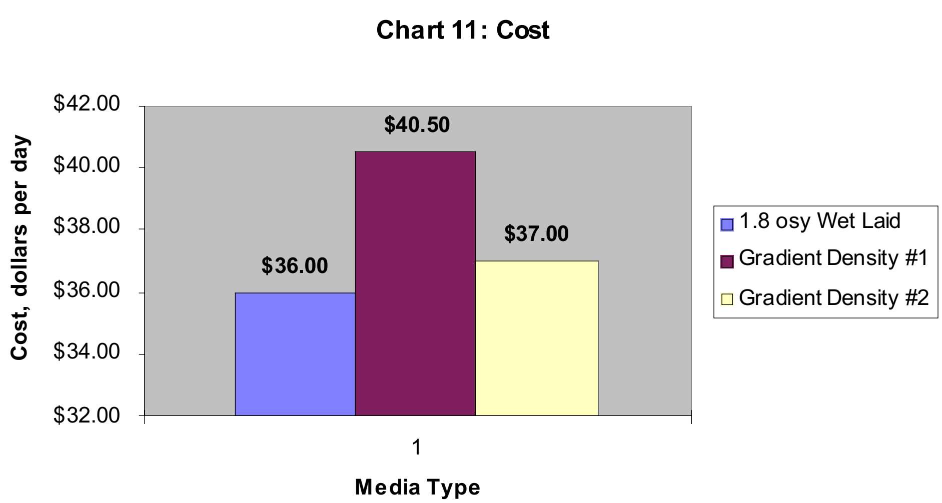


Chart 8: Capacity





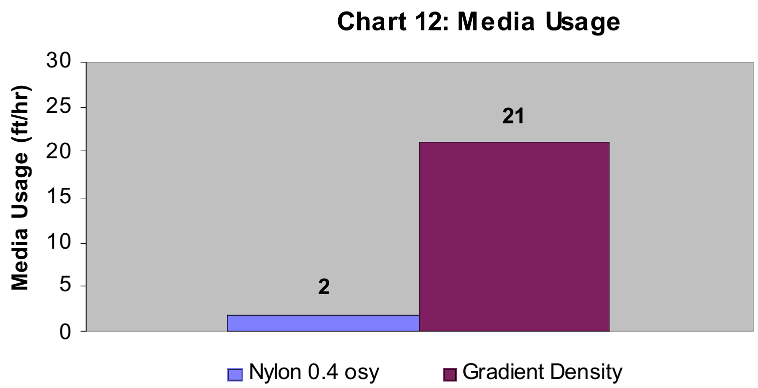


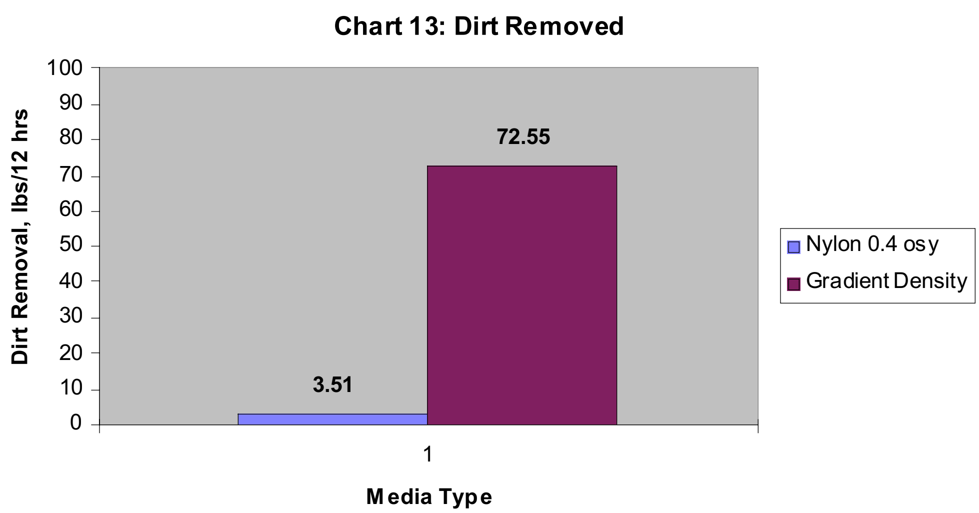


Case 4: Steel Rolling On A Gravity Filter Press

The objective of this field trial was to improve the cleanliness of the gravity filter press system. The existing product was a 0.4 osy nylon media. The filter media required manual indexing (slow pressure rise) because the medium was too open for the size particles in the system. The medium used was mismatched for this application. As a result, the coolant disposal costs were high. The nylon medium usage averaged 2 feet per hour and the dirt removal was 3.5 pounds in 12 hours. A gradient density media was selected for improved efficiency. Chart 12 shows the gradient density media usage increased 950% when the filter press ran to pressure index control. The particulate removal increased 1967% as shown in Chart 13. In this case, the increase in media usage was offset by reduced coolant consumption and disposal costs, resulting in lower total operating costs for the system.

Case 4: Steel Rolling Operation





CONCLUSIONS

These liquid cases demonstrate how gradient density structures can improve the filtration efficiency of a system. Gradient density media improved the filtration performance in each case and lowered the debris concentration in the systems. Gradient density structures can offer improved filtration for systems that already have good filtration.

In Cases 1, 2, and 3, using a nonwoven gradient structure reduced media usage and lowered costs for the end user. The nonwoven gradient structure held more dirt, had a longer service life, required less frequent roll changes and reduced disposal costs. In examples like Case 4, when the media is initially mismatched for the system, significant improvement in filtration performance can be achieved. Media usage may go up; however, the total cost of operating the system must be considered. In all cases, the end user benefits included a cleaner system and longer coolant circulation.

References

1. Purchas, Derek, Handbook of Filter Media, Elsevier Science LTD, 1996, pg. 27-30.

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3. Rushton, A & Griffiths, Chapter 3, "Filter Media" in *Filtration Principles and Practices*, Part I, (ed. Clyde Orr), Marcel Dekker Inc., 1977.

4. Selected Field Studies Data of Crystal Filtration Company, 1995-1998, (used with permission from Crystal Filtration Company). Individual results may vary.