Evaluation of Recycled Crushed Glass Sand Media for High-Rate Sand Filtration

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EVALUATION OF RECYCLED CRUSHED GLASS SAND MEDIA FOR HIGH-RATE SAND FILTRATION

FINAL REPORT

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CWC is a nonprofit organization providing recycling market development services to both businesses and governments, including tools and technologies to help manufacturers use recycled materials. CWC is an affiliate of the national Manufacturing Extension Partnership (MEP) – a program of the US Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller US manufacturers improve their performance and become more competitive. CWC also acknowledges support from the US Environmental Protection Agency and other organizations.

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1. Specification Sheet

EXECUTIVE SUMMARY

A field test was performed to examine the efficiency of finely processed recycled glass sand used as a filtration medium in high rate sand filtration. . Previous CWC studies and lab tests at Pennsylvania State and San Jose State Universities have demonstrated that, when properly processed, recycled glass is an effective filtration medium as a substitute for natural sand in many applications. This field test at an athletic club swimming pool was designed to determine if glass sand was indeed able to attain or exceed the clarity achieved with conventional sand and to establish whether glass sand media could be cleaned less frequently and with less water. Confirming previous research in this field application was intended to provide the filtration industry with enough information to allow for economic evaluations to be made regarding the market potential for recycled glass sand as a filtration medium.

The test was run from July 1997 to March, 1998 at the Bally Total Fitness Center in Federal Way, Washington. Three filters were used, for a total of 21.18 square feet of filter surface area. The maximum flow for the filter system, at 15 gallons per minute per square foot of filter area, was 327 gallons per minute.   Each filter contained 275 pounds of 1/8" x 1/4" pea gravel and 650 pounds of #20 silica sand. Control data on turbidity, operating pressures and backwash efficiency was developed by observing and testing the filters' operation through four complete filter runs with conventional silica sand media (US Sieve Standard #20 x 30).

The conventional media was removed and replaced with the *VitroClean*^{TM} crushed glass sand media manufactured by TriVitro Corporation in Seattle, WA. Again, data was collected during repeated filter runs with the recycled glass media. This data was then compared to the control data for silica sand.

The field evaluation revealed the following trends that illustrate the improved performance of recycled glass sand media compared to conventional sand media:

1. Improved water clarity shown by a 25% reduction in National Turbidity Unit readings
2. Increased backwash efficency shown by a 23%+ reduction in water used for backwashing
3. Approximately 20% less glass sand (by weight) is required for filtration

Due to problems in filter operations and changes beyond the control of this project, an anomaly in filter pressure differentials was noted. While it is unfortunate that the data on influent pressure and flow was inconsistent, other

critical and positive information regarding improved water clarity and increased backwash efficiency remains unaffected.

The data supports findings that indicate strong performance advantages in using recycled glass in high rate sand filtration. Glass is able to catch more turbid particles, thereby cleaning water more effectively and efficiently. This may allow pool filters to be operated for fewer hours to achieve desired water clarity, thereby saving energy and equipment life. More efficient backwashing uses less pool water that has already been chemically treated, heated and filtered and requires less operational and staff time..

Of particular interest is the fact that these results were achieved by using 20% less filter media by weight. In economic terms, filter media is measured and purchased by weight; costs for filter media are incurred in both the acquisition and disposal of media. Simply by the fact that glass is 20% less dense than silica sand, real savings in pool operating costs can be achieved, especially when improved water clarity and increased backwash efficiency are added considerations.

1.0 BACKGROUND

This study compares the performance of a recycled glass filtration medium with a conventional sand medium in high-rate recirculating sand filters. Previous studies sponsored by the CWC have tested glass as a filtration medium in slow sand filtration for municipal water treatment, septic treatment sand filtration, and monitoring well filtration. Those studies demonstrated that, when properly processed, recycled glass is an effective filtration medium as a substitute for natural sand in many applications. This study extends the knowledge base of effective filtration uses of recycled glass.

The water treatment and swimming pool industries have used slow-rate sand filtration for over a century. In slow rate filtration, water is driven by gravity through a filter bed. Because the only driving force is gravity, slow rate filters require large amounts of filtration media and large facilities. In addition, flocculants (broad-based polymer filtration aids) are often needed to cause particles to agglomerate for physical removal in the filter. In order to reduce the size of filtration facilities while maintaining filtration efficiency, gravity sand filters evolved into pressurized "rapid-sand" filters, with flow rates designed for three to five gallons per minute per square foot (gpm/sq ft). These filters use more tightly graded filtration media.

In the 1950's, sand filters with filtration rates of up to 20 gpm/sq ft were introduced. These “high-rate” sand filters did not use flocculants. The lack of flocculants, along with the higher flow rates, made the need for high quality filtration media even more critical. These filters require very tightly graded media, typically U.S. Standard Sieve #20 x #30 (ASTM E11 – .850mm x .600mm) silica sand, with high uniformity of size, no clays or non-silica soils, and sub-angular grain shape.

The Northwest United States (especially Oregon and Washington) does not have natural sources of high quality sand media for high-rate filters. This has resulted in higher costs for media, because the material must be shipped from other parts of the country. Compared with the other research on glass filtration media sponsored by the CWC, high-rate filtration media has a greater potential to support the costs of high quality private-sector processing and wholesale distribution.

TriVitro Corporation of Seattle, Washington, processes glass for a variety of uses, including tile manufacturing, paint additives, and media for abrasive blasting. *TriVitro* manufactures VitroClean™, a filter medium that has been processed specifically to meet swimming pool filter specifications. As a result of *TriVitro*'s process, VitroClean™ glass sand particles have the sub-angular grain shape required by the filter industry.

The glass used in this project was post-industrial plate glass scrap from window and door manufacturers. The glass is processed through a series of crushers, dryers, and screens to remove contaminants and to produce a range of uniformly sized filtration media. Post-industrial glass was chosen for this test because it is completely free of the potential organic (sugars, labels, etc.) and inorganic (aluminum rings, steel caps, etc.) contamination that can be slightly present in post-consumer glass. The potential for these types of contamination would introduce another variable in the analysis, and it was beyond the scope of this project to test methods for cleaning post-consumer glass.

Other studies involving crushed glass have been completed with slow sand or rapid sand filters mostly involving domestic drinking water filters. These included: "Crushed, Recycled Glass as a Water Filter Media", Richard Huebner, Ph.D 1994 and "Recycled Glass: Development of Market Potential", R. Guna Selvaduray, San Jose State University, 1994 These studies have proven very successful and have shown crushed plate glass media filters to have consistently removed smaller turbid particles than their sand media counterparts.

Our challenge was to examine the performance of recycled glass sand media against quality conventional sand media in high-rate sand filters in actual field conditions.

Our goals were:

1. to determine if the glass sand was indeed able to attain or exceed the clarity achieved with conventional sand.

2. to determine if the glass sand could indeed be cleaned less frequently and with less water.

2.0 PLAN AND SET UP

This study examined and compared the performance of recycled glass sand media with conventional sand medium in high-rate sand filters during actual operating conditions. Data was first collected on the operating characteristics of conventional sand media, then that data was compared with recycled crushed glass sand media. The original parameters for evaluation of the two media included:

- Visual inspection of the pool water
- Recirculation flow rate
- Backwash flow rate
- Turbidometer readings
- Influent and effluent filter pressures

The visual inspection (by photo) was eliminated early in the evaluation since the range of changes seen in tubidity was not observable through visual or photographic inspection. , and Unforeseen field conditions affected the recirculation flow rate and influent pressure readings and would later present a problem that resulted in limiting our expanded evaluation.

The Pacific West Health Club (Federal Way, WA) was chosen as the test site, even though this facility's mechanical room required some additional work. Upgrades required at the facility included upsizing of a backwash pit by adding an auxiliary backwash tank with a gravity drain to an approved sewer connection, as well as installation of upgraded digital flow meters, sight glasses, pressure gauges, and a turbidometer.

3.0 FILTER EQUIPMENT

Filters used for this evaluation were "Triton" TR series filters manufactured by PacFab, Inc. These filters are common in the swimming pool industry, with an estimated 5,000 to 7,000 filter vessels located on the West Coast of the United States. Each filter contained 7.06 square feet of

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cross-sectional filter area. Three filters were on one manifold, for a total of 21.18 square feet of filter surface area. The maximum flow for the filter system, at 15 gallons per minute per square foot of filter area, was 327 gallons per minute. These filters are designed for flow rates between 5 and 20 gallons per minute (gpm) per square foot.

Each filter contained 275 pounds of 1/8" x 1/4" pea gravel and 650 pounds of #20 silica sand. The sand depth from surface to bottom drain lateral was 13.5 inches. The bottom drain laterals were grooved to prevent sand particles larger than #30 silica from leaving the filter. Each filter was fitted with manual air relief valves.

The backwash sight glass was not sufficient for this study, so an additional in-line sight glass was installed on the backwash discharge line between the filters and the backwash holding tank. This sight glass was fitted with two parallel lines, allowing a technician to evaluate the clarity of the backwash water to determine when the filter had been sufficiently backwashed.

The size of the existing backwash holding tank was unable to hold a complete backwash discharge from even one filter. An additional backwash holding tank with a capacity of 300 gallons was installed. This allowed a complete backwash of three minutes per tank. The holding tank water gravity-flowed into the sewer pit.

4.0   ADDITIONAL EQUIPMENT

The recirculation flow rate and the backwash flow rate were monitored by Signet Model 5100 digital flow meters. One was placed on the effluent recirculation line downstream of the filter, prior to chemical injection points; measuring recirculation flow. The other flow meter was placed in the backwash discharge line. To assure accuracy, the devices were installed in locations providing laminar flow (10 pipe diameters prior to measuring device and 5 pipe diameters downstream of the device of clear pipe: no fittings, elbows, etc.).

Pressure readings were taken with stainless steel pressure gauges manufactured by Ashcroft with oil filled cases for vibration dampening. They were located on the filter cap and the effluent filter line; six gauges were used, two on each filter. Since the filters were manifolded, the gauge readings were averaged to achieve consistency The gauges chosen were 0-60 psi as we were not sure what pressures would be encountered. As it turned out, a 0-30 psi gauge would have suited the project better. Pressure gauge readings of influent and effluent pressures were used for the calculation of pressure differential. Differential pressure measurements provide the best evaluation of filter bed performance with respect to collection of suspended particles, reflected by resistance created across the filter.

The most important criteria for measurement was water clarity. Turbidity units were measured by a Hach Turbidometer, model 1720A. Measurements were recorded in National Turbidity Units (NTU's). According to standards established by the National Sanitation Foundation, pool water that is rated "excellent" maintains a NTU reading of .5 or less.

Data collection sheets and procedures were developed in-house. Two National Swimming Pool Foundation Certified Pool Operators were employed as primary and secondary technicians. Training in data collection and backwashing procedures was completed and data collection began on July 1, 1997.

The swimming pool was intended to be the primary test site. However, since a spa system was located in the same room, both systems were fitted with the equipment described above and comparative evaluations were conducted. A system of valves were installed so that the Hach Turbidometer could measure either the pool or the spa. After switching the water source , a waiting period of ten minutes was established to allow the Turbidometer to adjust to the new water. The spa water often provided skewed turbidity readings because the spa air jets introduced air bubbles that were not entirely dissipated or removed by filtration. The air bubbles appeared as turbid particles to the turbidometer.

5.0 ESTABLISHING THE CONTROL DATA

The original silica sand in the filters was tested by an independent test lab and rated "very good." The sieve size was primarily U.S. Standard #20 x 30, with a size coefficient (D_{60}/D_{10}) of 1.4. The size coefficient is the ratio of the screen size through which 60% of the medium passes, divided by the screen size through which 10% of the medium passes. The plan was to operate with the conventional sand for no less than four complete filter runs (period between backwashes) to establish a "control database" to which the crushed glass sand media would be compared.

There was difficulty with the backwash flow meter because debris continued to foul the transducer paddle wheel. An in-line oversized strainer basket was installed to capture large debris and the problem was partially solved. Data collection was resumed the following week, however, small particles continued to clog the flow meter too often to provide reliable flow data. As a data back-up, backwash duration (in time) was noted. While this was not as accurate as flow, it did provide a backwash standard that could be measured and evaluated against the glass sand media.

The pool water clarity was excellent with the original conventional sand. Due to inadequate lighting for quality photos and the subtle differences expected, the visual evaluations and recordings originally planned were not conducted.

Collected data was consistent each day, with expected increases and decreases in pressures, flow and turbidity readings corresponding to filter performance as they filled with turbid particles. The control data phase was completed in eight weeks (see Appendix A for Figures 1 through 6).

The data was an average of the pressure and flow characteristics recorded each week. However, sometimes because of staff scheduling, data was not collected and some days were interpolated from adjacent data. According Washington State Health and Safety Regulations, after the recirculation flow drops 10% (approximately 25 to 30 gallons per minute), backwashes must be scheduled to clean the filters and reestablish the desired flow. During the analysis of the baseline sand and glass sand media, the time between filter backwashes was seven days in all but two cases during the 17 weeks of data collection. Seven days was a convenient schedule for backwashing, so scheduling and data charting were established on a seven-day cycle. Figures one through five, therefore, reflect pressure and turbidity averages for each successive day following a backwash.

The backwash flow rate measurements were somewhat skewed by flow meter problems. The average duration (in minutes) of backwash (total of six backwashes recorded) of the conventional sand was three minutes, twenty-one seconds. Although this was somewhat subjective, the backwash sight glass was fitted with two black parallel lines that were to be viewed through the backwash water. When the edges of the lines were clear, the backwash was deemed complete.

6.0 MEDIA CHANGE

The conventional media was removed and replaced with the *TriVitro* crushed glass sand media. The sand replacement took approximately one day. The 1/8" x 1/4" rounded pea gravel was left in place. The underdrain laterals were surrounded and covered with gravel to a height of approximately one-inch above the laterals. This gravel allowed the filter to better distribute the backwash flow to the sand bed and is required by the National Sanitation Foundation (NSF) for the filter's approval at filter rates of 15 gpm (and higher) per square foot of filter area.

The filter manufacturer's specifications required 6.5 cubic feet of medium for each filter (a total of 19.5 cubic feet for the system). This would have required 1,950 pounds of silica sand. However, glass is less dense than silica sand, so only 1,560 pounds were needed, demonstrating a 20% savings in filtration media by weight. This savings would be reflected in both raw material and shipping costs. This difference is derived from two factors . First, the specific

gravity of glass is 2.53, compared with approximately 2.75 for sand, a 10% difference. In addition, the newly fractured [please check page or line break]
glass particles appear to not pack as tightly as the sand grains. Therefore, the interstitial spaces between the glass particles are, on average, larger and have less rounded edges than sand grains. This confirmed research at San Jose State and Pennsylvania State Universities.

7.0 FLOW METER PROBLEMS

Upon installation of the glass medium, the Signet flow meter equipment failed on a regular basis. Evaluation of the recirculation flow meter transducer revealed that glass particles (estimated to be 40 micron and smaller) were passing through the filter underdrain laterals, causing the rotor to jam. After evaluation of the glass filtration medium, it was determined that there were too many "fines" left in the first batch of VitroClean™ sand after processing. The problem began to lessen as repeated backwash procedures eventually removed the smaller sand particles. However, at this point there was a question of whether the glass filtration medium as delivered in the first batch would meet most pool owners' satisfaction.

During the same period, *TriVitro* had improved its glass processing to the extent that *TriVitro's* engineers were confident that their process improvements had almost totally eliminated the fines carryover. Therefore, it was recommended that the original glass sand be replaced and additional data collected using this improved media product. The CWC agreed to a project extension and an additional six weeks of testing was undertaken.

The final *TriVitro* product tested was VitroClean™ 25N, with a coefficient of uniformity of 1.40 and effective size of .50mm. A specification sheet is included in Appendix B.

8.0 GLASS SAND PERFORMANCE

With the exception of the backwash duration data, the glass sand media data was collected from the second sand media load. In fact, after four weeks of operation and backwashing and most of the "fines" removed, the media characteristics of the "cleaned" glass sand (the first medium after

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being subjected to multiple backwashes) and the new "improved" glass sand were virtually identical. The glass sand media data is illustrated in Figures 1 through 6.

Recirculation Flow

After switching to the glass sand media, the most immediate and surprising change was the measurable increase in recirculation flow (figure 1). This was even more disturbing in light of the increased influent pressure readings (figure 2). The characteristics of flow with increasing pressure usually results in a decrease in gallons per minute. The effluent pressure, however, was constant, as illustrated in Figure 3. The pressure differentials (figure 4) differed by only three pounds per square inch and remained constant throughout the filter run. Explaining the strange and conflicting data in this field test is difficult. It is likely that a reduction in the pump suction head (possibly stemming from a change in the pump strainer basket and/or its maintenance)allowed for higher flow and resulted in higher influent pressures. The pressure increase in the influent pressure readings did not confirm an earlier filter "ripening" advantage as reported by the Pennsylvania State study.

Water Clarity

NTU readings actually dropped a full 25% (figure 5). This significant drop in NTU readings indicates the glass sand media traps finer turbid particles than conventional sand and results in clearer water.

Backwash

The average duration of backwash (in minutes) was two minutes, thirty-four seconds based upon ten backwashes, compared to three minutes, twenty-one seconds for silica sand based on six backwashes. There was a reduction of 23% for water used for backwashing glass sand media compared to conventional sand. This is a result of the glass sand having less density; the lighter material would tend to fluidize quicker and thus require less water for a complete backwash. Glass particles have a more angular shape and relatively flatter fractured sides. The noteworthy improvements in the backwash results in this field test were consistent with trends identified in the San Jose State University study (Selvaduray) where measurements of the sand bed expansion were greater with the glass sand media than conventional sand.

Consumption

In all cases, the amount of media required by weight was substantially less (approximately 20%) for the recycled glass sand than for silica sand. In pool operations this difference would be noted twice – first in the purchase of filter media and second in the disposal of spent media. Both are measured in economic terms by weight.

Summary

The field evaluation revealed the following trends. These trends illustrate the improved performance of recycled glass sand media compared to conventional sand media:

1. a 25% reduction in National Turbidity Unit readings
2. a 23%+ reduction in water used for backwashing
3. approximately 20% less glass sand (by weight) is required for filtration.

It is worthy to note that items 1, 2, and 3 were mirrored in the spa test data.

Applicability to other filter systems

Industries and governments use high rate filtration systems in a variety of settings. Findings from this and preceding studies show strong potential for glass to be used in commercial and municipal filtration. It is likely that the benefits concluded from this swimming pool field evaluation would be seen in other types of filtration applications, such as stormwater, agricultural and industrial filtration.

9.0 CONCLUSIONS

This project was intended to be a full scale “field test” of recycled glass for high-rate sand filtration. The work done at San Jose State University and Pennsylvania State University showed that, in laboratory scale, recycled glass had equal or better turbidity removal and better efficiency. True to findings in prior research, recycled glass sand media performed or better than conventional filter sand in swimming pool filtration.

The data supports findings that indicate there are strong performance advantages in using recycled glass in high rate filtration. The main advantages of recycled glass sand over conventional sand are:

1. Improved Water Quality. Finer particles were removed in the filter more efficiently, Reflected by the 25% decrease in NTU’s. The findings showed repeatedly that recycled glass sand cleaned water more effectively. Clearer water is always desired. Being able to catch smaller turbid particles makes high-rate filtration sand even more efficient and therefore attractive over other types of filtration media. This advantage may allow for recirculation systems to be operated fewer hours in those locations that allow for pool systems to be turned off during non-use periods. This saves electrical energy and extends equipment longevity.
2. More Efficient Backwashing. Less backwash water was required to clean the filter medium. As these test results are duplicated in repeated future usage, the ability to backwash with over 20% less water is a major advantage that can prove very valuable both in construction and in operation. The cost of sewer lines and holding tanks can be reduced. Most importantly, water has been saved. Beyond the value of the water resource, pool water has an added economic value when it has been chlorinated, pH adjusted, alkalinity adjusted, hardness adjusted, heated and filtered. The savings through more efficient backwashing are measured both in the cost of the water consumed and then disposed (some facilities that are charged per 100 cubic feet of water that is treated by sewage plants). Costs for chemicals and for heating water are also reduced.

3. Less Media. Glass sand media is less dense and therefore lighter than conventional sand filter media. Less media by weight is required. Shipping, handling and disposal costs would be saved proportionately to the ratio of density of glass vs. silica sand media., approximately 20%.

The benefits described in 1) and 2) above, i.e., savings in pool operating costs, energy, water usage, etc., are achieved with 20% less material by weight.

It cannot be emphasized strongly enough that these results reflect a test of a specific glass filtration medium produced by a specific processor. Although they confirm the efficacy of properly processed glass as a recirculating water filtration medium, they do not support the use of glass for this application from any other processor, unless that processor is able to produce media that meets industry specifications for consistency in particle shape, size distribution, cleanliness and uniformity.

10 RECOMMENDATIONS FOR FURTHER STUDY

This field evaluation clearly shows improved water clarity and a reduction of backwash water usage. The data confirms the research work of others (Pennsylvania State and San Jose State Universities). Recycled glass sand media is an exciting alternative to conventional sand and should hold an important place in the water filtration industry.

The following recommendations are provided to those who may wish to undertake further testing in swimming pool operations:

1. The use of ultra-sonic flow measurement devices with totalizers will allow for a more precise measurement of filter media backwash flow and water usage. The paddle wheel units, though

very accurate, have tolerances that do not allow for particulate matter in the water and can become clogged.

2. The ability to record data 7 days per week every week is important in order to monitor trends.
3. Controlling pool operating conditions at the field test facility is important. Filtration equipment repairs or modifications and staffing changes can interfere with data collection and skew results.
4. Care must be taken to isolate and monitor changes in operating pressures due to the use of recycled glass media. Using gauges that more accurately reflect the actual pressure conditions, (see Section 4 above), careful evaluation of suction and discharge head condition on the recirculation pump during the baseline evaluation and new media evaluation is important. This can be accomplished with vacuum and pressure gauges on the suction and discharge lines of the pump.
5. Test designs should track filter ripening and run times. Reports from the Pennsylvania State and San Jose State University studies showed faster ripening and longer run times. It would be valuable to determine if these trends are readily observed in field test conditions.

10.0 REFERENCES

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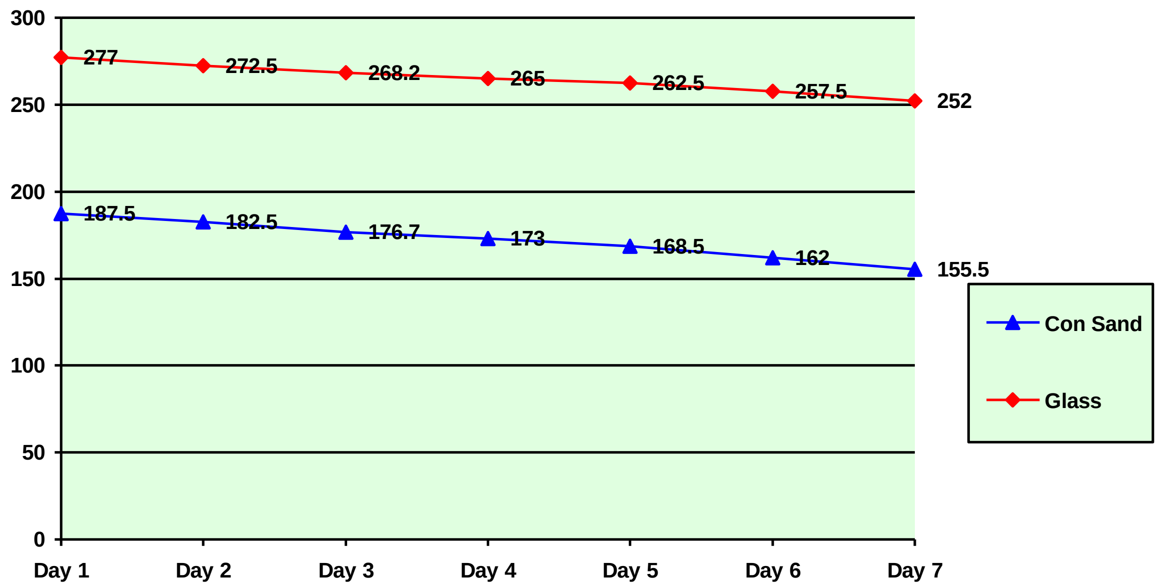
APPENDIX A: FIGURES 1 THROUGH 5

APPENDIX B

1. Specification Sheet

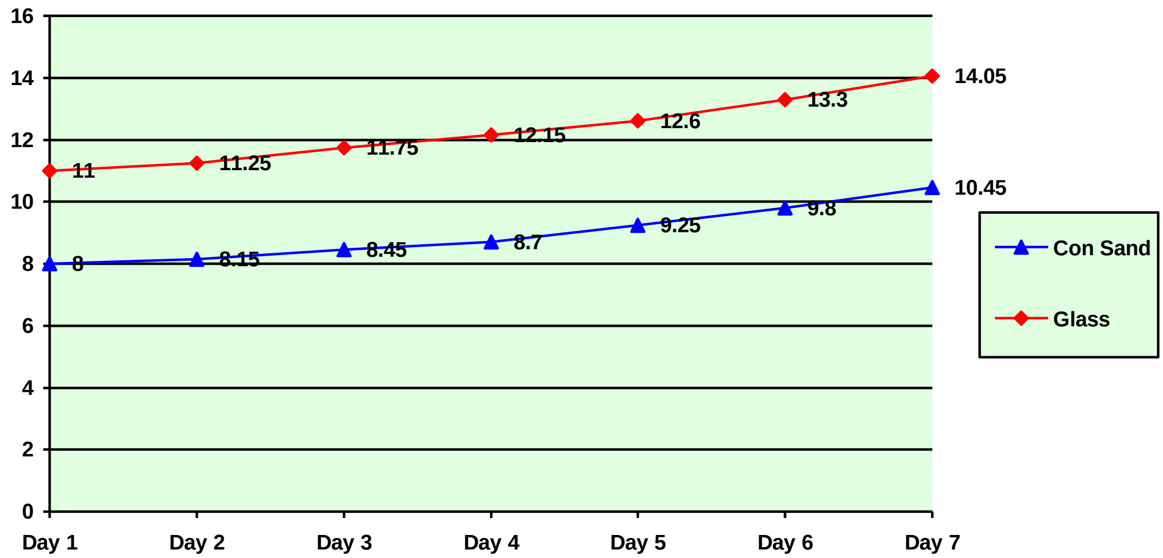
Recirculation Flow Rate (Gallons per minute)



Comparison of Average Recirculation Flow Rates

Figure 1

Influent Pressure (Pounds Per Square Inch)



Comparison of Average Influent Pressures

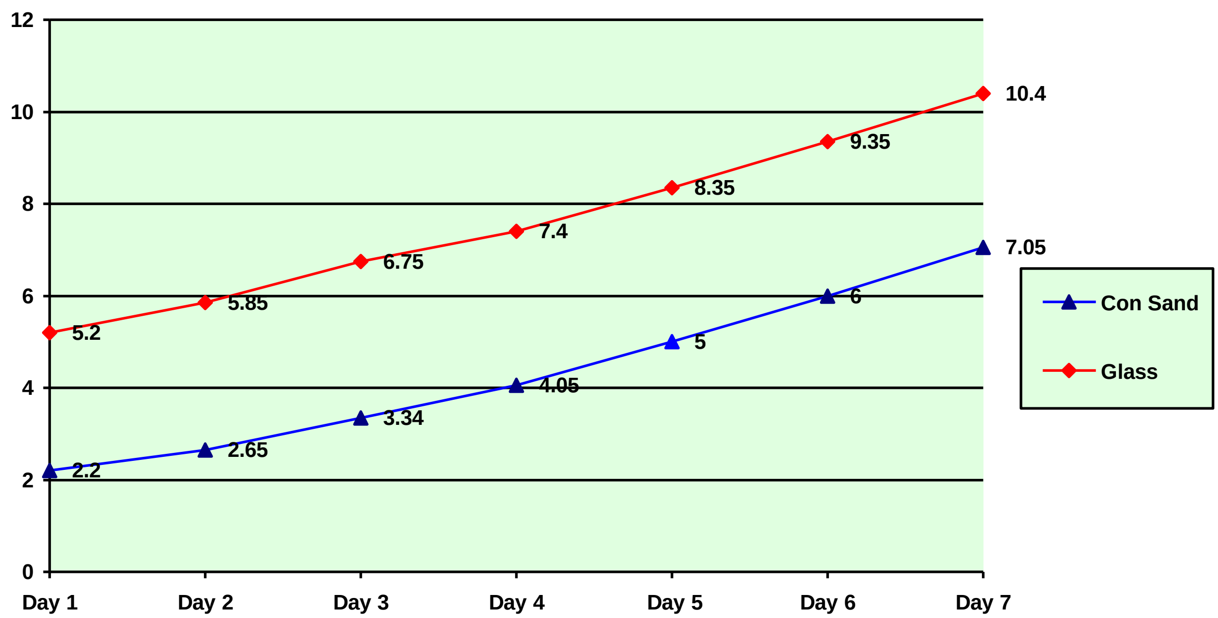
Figure 2

Effluent Pressure (Pounds Per Square Inch)

Comparison of Average Effluent Filter Pressures

Figure 3

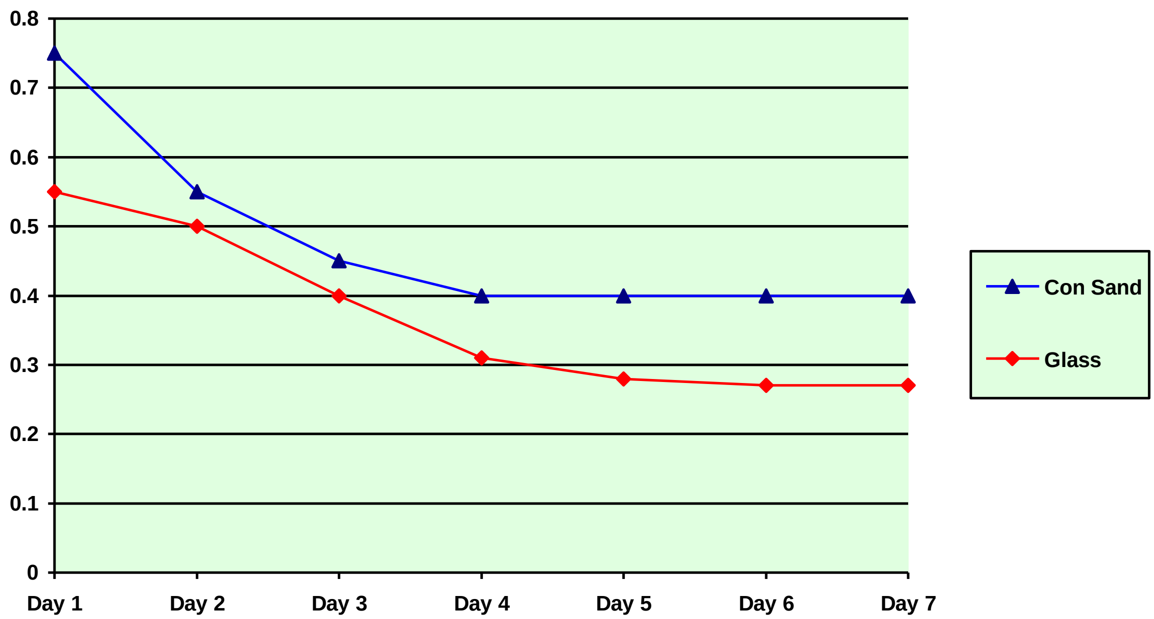
Differential Pressure (Pounds Per Square Inch)



Comparison of Average Differential Filter Pressures

Figure 4

Turbidity in National Turbidity Units (NTUs)



Comparison of Average Turbidity Units

Figure 5