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FINAL REPORT

FOG Interceptor Design and Operation (FOGIDO) Guidance Manual

(Supplemental Report to 03-CTS-16T)

Co-published by

IWA
Publishing

03-CTS-16TB

FOG INTERCEPTOR DESIGN AND OPERATION (FOGIDO) GUIDANCE MANUAL

Supplemental Report to 03-CTS-16T

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2008

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This report was co-published by the following organization. For non-subscriber sales information, contact:

IWA Publishing
Alliance House, 12 Caxton Street
London SW1H 0QS, United Kingdom
Tel: +44 (0) 20 7654 5500
Fax: +44 (0) 20 7654 5555
www.iwapublishing.com
publications@iwap.co.uk

Library of Congress Catalog Card Number: 2008934929
Printed in the United States of America
IWAP ISBN: 978-1-84339-527-0/1-84339-527-4

North Carolina State University

ACKNOWLEDGMENTS

The authors of this report are indebted to the following water utilities, companies, and individuals for their cooperation and participation in this project:

- Town of Cary, North Carolina
- Oxford Tobacco Research Station, North Carolina
- Carolina Classic Manufacturing, Inc.
- Wilkes Enterprise, Inc
- Duke Roots, Inc.
- RootX Root Control Corp
- Solutions-IES

Research performed at North Carolina State University could not have been accomplished without the help of students and lab technicians. Tarek Aziz, a Ph.D. candidate at the time of this research, was responsible for a significant portion of the lab work. The principal investigators (PIs) would also like to thank Barbara Oslund and Heather Markell from Solutions-IES for the development, administration, and analysis of the FOG and roots survey.

The root study research carried out at Oxford Tobacco Research Station could not have been possible without the help of students and laboratory staff. Students that have worked to setup the roots control pilot system include Colleen Bowker, Liz Dinatale, Ojochide Idichaba, Akinawale Omofoye, and Justin Woods. The PIs are indebted to Dennis Metcalf from North Carolina State University, and Fred Smith and his team at the Oxford Tobacco Research Station, for the construction of the pilot system and maintaining the green house for proper tree growth. The PIs would also like to thank Donald Smith from the Town of Cary in the development of the grease interceptor design Microsoft Excel® spreadsheet.

The principal investigators would like to thank Mike Hogan and Duke Roots Inc. for the treatment chemicals and for sending a treatment team to apply their product to the roots at the pilot system. Many thanks to also Pat Monaghan of RootX Root Control Corp. for donating their chemical treatment product for the root control study in this research project.

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ABSTRACT AND BENEFITS

Abstract:

Fat, oil, and grease (FOG) is generated every day by food preparation and cleaning activities conducted at commercial establishments and, on a smaller scale, by residential sewer usage. FOG accumulations in the sanitary sewer collection system result in reduced capacity that may lead to sanitary sewer overflows (SSO) if not periodically cleaned. As the accumulation commences, the effect of slowed wastewater flow exacerbates the rate of accumulation and deposit of FOG materials onto the pipe walls, thereby reducing capacity.

The primary means of controlling FOG blockages is to capture and retain FOG materials through passive grease interception devices. Limited scientific studies have evaluated these devices. Many claims of enhanced performance made by manufacturers of grease and oil interception devices need to be verified by objective and unbiased research protocols. A companion report, *Assessment of Grease Interceptor Performance,* has conducted such a study. The FOGIDO report outlines the recommendation for the sizing and configuration of grease interceptors (GI) using research information from the companion report. In addition, a Microsoft Excel® spreadsheet GI size calculator has been developed to compute flows and FOG loading to size the GI for a specific food service establishment.

Benefits:

- Provides an alternative approach for sizing GIs for food service establishments.
- Improves process performance of GIs, with a higher percent grease removal, based on alternative design configurations.
- Provides more efficient sizing of GIs.
- Provides more transparency in computation of GI sizing.

Keywords: Fats, oils, grease, FOG, grease interceptor design, GI, SSO, FSE, food service establishment.

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EXECUTIVE SUMMARY

Objectives:

- Describe the current state of understanding of gravity grease interceptor (GI) design and sizing and how it relates to the current experimental and computational research.
- Establish a new, transparent method for the calculation of flow rate into GIs.
- Develop a new equation for GI sizing, taking into consideration expected FOG and solids accumulation.
- Discuss potential factors that could decrease the FOG removal effectiveness of a gravity GI.

Current Situation

Several proposed equations exist in the literature for the sizing of grease interceptors. Typically, these equations lack transparency (i.e., very little background information is provided about their development) and may not take into account established knowledge of gravity separators. Often times, these interceptors are oversized, resulting in added cost to the food service establishment (FSE) owner as well as the negative impact associated with hydrogen sulfide production. The present research aims to utilize the extensive field, laboratory, and numerical observations of GI performance completed in a companion report to establish tools to design grease interceptors.

Grease Interceptor Configuration

The literature is full of opinions about grease interceptor design; most requiring compartmentalization and inlet and outlet tees near the GI bed without any scientific basis for the suggested design configuration. Field, experimental, and computational experience with such designs performed in this research study has enabled the research team to develop more effective configurations and make recommendations that have been shown to improve the FOG removal performance.

These design enhancements generally involve better distribution of the flow within the GIs to allow for quiescent conditions that enhance gravity separation. In addition, design suggestions for alternative inlet and outlet tees are based on extensive laboratory and pilot experimental tests, field observations, and numerical simulations. Simulation of these alternative designs indicated approximately 90% removal of influent fats, oil, and grease (FOG) in the free globule range (150 μm) with as little as 20 minutes hydraulic residence time.

Estimation of Food Service Establishment Flow and Sizing of Grease Interceptors

The current design methodology proposes that the design flow into a grease interceptor be derived from the maximum flow from the kitchen. In order to calculate this maximum flow, the research team has developed a classification of kitchen fixtures that enables the user to assign an appropriate flow based on the fixture in use and in terms of typical flow rate units such as gallons per minute (gpm).

According to common kitchen practice, some kitchen sinks are drained from a filled state, while others are never drained and only experience the flow contribution from their associated faucet. The potential contribution of the filled sinks is determined through the use of Manning's Equation in conjunction with various plumbing characteristics. Faucet flow contributions are calculated based on known peak discharge limitations for the various fixtures in a kitchen.

Two methods are proposed for the use of these flow characterizations. The first, and preferred method, is a spreadsheet calculator where the various parameters is entered and the maximum flow is then determined for the specific food service establishment. The alternative method is a table built from the basic calculations embedded in the spreadsheet, with some assumptions that may not be consistent across all food service establishment kitchens. The tabular method should only be used if these assumptions are applicable for the specific food service establishment kitchen configuration.

After determining the calculation of the maximum flow rate, a 1/3 factor is proposed based on observation of field grease interceptor hydraulic operations. The modified flow rate then becomes the design flow for the grease interceptor. A sample calculation using the proposed approach in this study is provided. This calculation displays the maximum flow rate, the design flow rate, and collected field data that depicts the actual flow through the GI.

After establishing the GI design flow, the GI storage space is determined to account for the FOG and solids loading. The FOG and storage space is based not only on the FOG and solids loading into the GI but also the amount of FOG and solids removed by the GI, the sludge volume index of the solids, and the pump-out frequency.

Need for Future Research

The design methodology proposed in this study utilizes some assumptions related to the state of the FOG and solids entering the GI. However, these assumptions may not be consistent across all food service establishments. Future research needs to include a methodology to characterize the food service establishment waste stream. This detailed characterization would provide better guidance into the extent of FOG and solids that can be removed within the GI and possibly offer alternative recommendations into improving the GI removal. In addition, more GI field observations need to be performed across different types of food service establishments that have retrofitted the GI based on the recommendations in this report. This additional field data would validate the proposed design configurations and increase the much needed transparency in the entire GI design process.

CHAPTER 1.0

INTRODUCTION

1.1 Background

Researchers reviewed the literature regarding the design, operation and maintenance of grease interceptors (GIs). Discussed in this section are excerpts from three documents: 1) UPC guidelines (IAMPO, 2004); 2) a GI guide developed by the plumbing and drainage institute (PDI) (PDI, 1998); and 3) a design considerations document put together by the National Precast Concrete Association (NPCA) (NPCA, 2007). Though several of the points discussed by these documents are valid in the performance of GIs, they generally underestimate the complexity of FOG removal. All of these documents suggest some claims or assumptions that are now in question due to the results of this research (mentioned in the companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*). Below is an analysis of those documents. Table 1-1 provides a critique of the initial IAMPO 2004 GI design guidelines. An updated document is discussed in the following section.

Table 1-1. Recommended Procedures for Design, Construction, and Installation of Commercial Kitchen Grease Interceptors (IAMPO, 2003, Uniform Plumbing Code Appendix H).

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H 103.1 Interceptors shall be constructed in accordance with the design approved by the Authority Having Jurisdiction and shall have a minimum of two compartments with fittings designed for grease retention.	According to laboratory and pilot scale GI tests, the use of two compartments has not generally lead to an improved GI performance (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*). As shown in this companion report, the use of a mid-baffle wall seems to enhance only those GI designs with a distributed inlet/outlet configuration. With the traditional inlet designs, there is the possibility of short circuiting from the inlet pipe to the mid-baffle pipe. Conversely, with the distributive inlet configuration used in this study, the mid–baffle wall prevents the bypass of the central region of the reactor that would allow a large fraction of the inlet flow directly into the outlet pipe. In addition, the statement, "…fittings designed for grease retention." is unclear and would likely depend on the uniqueness of the GI design and whether it can enhance process performance.

H 106.1 Parameters. The parameters for sizing a grease interceptor for one or more fixtures are hydraulic loading and grease storage capacity.	As discussed in the companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*, the sizing of a grease interceptor is a complex function of residence time, initial FOG droplet size, and internal GI configuration. According to the 3D CFD simulation for one given hydraulic loading and the same influent oil concentration, a change in the inlet droplet size can result in a significant reduction in performance (i.e., from ~80% to 10% removal for the 150 and 80 micron size, respectively). The literature has also demonstrated the importance of inlet FOG condition on the removal effectiveness of a GI (Hee et al., 2006). The results of this study seem to suggest that the development of a universal GI design that can be sized solely on the hydraulic loading and the FOG storage capacity is too simplistic. It is possible that analysis of the FOG influent characteristics will have to be assessed prior to the selection of the most appropriate GI size and design.
H 106.2 Sizing Formula. The size of the interceptor shall be determined by using the method outlined in Table H-1.	Table H-1 (Table 1-2) attempts to quantify the size required of an interceptor as a result of the flow and cleaning demands for a given FSE. This table does not take into account: the characteristics of the influent FOG (i.e., temperature, oil droplet size, use of emulsifiers) or GI configuration, albeit, these parameters are difficult to include in a simple sizing relationship. The use of such formulas may oversize or undersize the GI needed to achieve at least 90% removal from the influent. Results from this study suggest that increasing the size of the GI will only provide nominal improvement in the percent removal for FOG droplet sizes of 150 microns (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*). Further, the GI internal configuration, GI cleaning cycle, and temperature or buoyancy driven flows as seen with field measurements may significantly impact the removal efficiency (*Assessment of Grease Interceptor Performance*).

IAMPO, UPC- 2006 – Revised Procedures for Design, Construction, and Installation of Commercial Kitchen Grease Interceptors

Recently, the UPC code was revised to change their grease interceptor design structure from Equation 1.1 and Table 1-2 to the use of drainage fixture units (DFU) (Table 1-3). DFUs are assigned to different fixtures and equipment that can potentially discharge FOG into the grease interceptor. The assigned DFUs for a given type of fixture or equipment are a function of whether it is used in a public or private setting or if it is part of an assembly (i.e., larger facilities). No explanation was provided into the derivation of these values albeit, they seem to be related to the maximum flow capacity for the specific equipment and connected pipe size. Food service establishment items that do not fall into one of the items are computed using a separate table. The final grease interceptor size is based on a 30 minute residence time. However, no information is provided on recommendations for alternative GI geometry configurations.

$$\text{Number of meals per peak hour} \times \text{Waste Flow Rate} \times \text{Retention Time} \times \text{Storage Factor} = \text{GI Size} \quad (1.1)$$

Table 1-2. UPC Table for Sizing of GI (IAMPO, 2004).
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Waste Flow Rate	
a. With dishwasher	6 gallon (22.7 L) flow
b. Without Dishwasher	5 gallon (18.9 L) flow
c. Single Service Kitchen	2 gallon (7.6 L) flow
d. Food Waste disposer	1 gallon (3.8 L) flow
Retention Times	
Commercial Kitchen Waste	
Dishwasher	2.5 hours
Single Service Kitchen	
Single Serving	1.5 hours
Storage Factors	
Fully Equipped Commercial Kitchen	8 hours operation: 1 16 hours operation: 2 24 hour operation: 3
Single Service Kitchen	1.5

Table 1-3. Gravity Grease Interceptor Sizing (IAMPO UPC, 2006).
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DFUs (1)	Interceptor Volume (2)
8	500
21 (3)	750
35	1000
90 (3)	1250
172	1500
216	2000
307 (3)	2500
342	3000
428	4000
576	5000
720	7500
2112	10000
2640	15000

(1): The maximum allowable DFUs plumbed to the kitchen drain lines that will be connected to the grease interceptor
(2): This size is based on: DFUs, the pipe size from Nayar, 1992
(3): Based on 30 minute retention time

PDI – Guide to Grease Interceptors – Eliminating the Mystery (PDI, 1998)

The Plumbing and Drainage Institute (PDI) validates small in-kitchen grease interceptors through their own procedure (PDI-G101), which describes a method for quantifying the performance of a given interceptor. In general, this document describes the advantages of the small-scale interceptors and indicates the flaws and challenges of large scale interceptors. Although the PDI is attempting to create a standard for performance regarding FOG removal efficiency, several of the performance claims and concepts presented by the PDI document are also in question as a result of the present research. These claims and possible concerns are described in Table 1-4.

Table 1-4. PDI Claims and Concerns Based on Design Procedure.
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FOG removal process (pg. 1, paragraph 5): "To separate [FOG] from the FSE wastewater stream, an interceptor provides separation chambers, which allow FOG to rise to the surface. FOG free water then exits from the separation chamber at the low point farthest from the inlet end."	The PDI document does not consider the characteristic of the influent FOG (i.e, droplet size, temperature, oil type) or mention the effluent discharge concentration that is considered to be FOG free. This research has revealed performance changes as a result of GI residence time (albeit, there seems to be a limiting size that does not produce significant % removal for 150 micron FOG globule diameter), internal GI configuration, and influent FOG characteristics.
The factors of FOG removal (pg. 1, paragraph 6): "To simplify the influences which affect separation one could say there are only three major factors which must be considered. They are the design of the interceptor, the installation of the interceptor, and the maintenance of the interceptor."	While this statement does seem consistent with part of the research study, it does leave out the influent conditions of the FOG (i.e., FOG globule size and stability and influent temperature). Once characterized, an appropriate design could be selected to achieve at least 90% removal assuming cleaning maintenance is performed in a timely manner.
The uses of baffles in a reactor (pg.3, paragraph 2): "The baffles serve to lengthen the flow path of the effluent to increase the time of separation while providing a non-turbulent environment for separation to take place."	Research indicates that certain baffle designs may result in high velocity zones that may transport FOG globules through the system and reduce the time for proper gravity separation. However, the present research has shown that the impact of the mid baffle wall will depend on the inlet/outlet configurations.
Maintenance of a PDI certified interceptor (pg. 8, paragraph 2): "A PDI certified interceptor has a rated retention capacity equal to twice its flow rate expressed in pounds. For example, a 35 GPM interceptor is rated to retain at least 70 lbs of grease. A user may determine the cleaning schedule by determining how much grease has been trapped over a period of time."	The claim suggests that, regardless of influent condition, the GI will remove FOG until this parameter (double the flow rating) is met. Again, this performance criterion does not address the influent condition since the performance of a GI does change with the influent FOG globule size (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*).
Regarding the cleaning frequency and meeting code requirements of discharge < 100 ppm (pg. 8, paragraph	The claim suggests that the required discharge will be met within the required cleaning cycle. This claim is unrealistic as it does not incorporate the configuration of a given interceptor or the influent characteristics.

NPCA - Design Considerations and Discussion of Large Outdoor Grease Interceptors (NPCA, 2007)

As a leading source of GI construction materials, the National Precast Concrete Association (NPCA) naturally has a vested interest in informing individuals about grease interceptors. Table 1-5 discusses several of the statements made in this document that are now in question as a result of the research performed to date.

Table 1-5. NPCA Claims and Concerns Based on Design Procedure (NPCA, 2007).
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(pg. 4, paragraph 3): "Actual wastewater usually contains various emulsifying chemicals, and the mixture is agitated before discharge to the trap or interceptor. While it would be impractical to evaluate all the variables that make up wastewater, it is important to remember that increasing the retention time (by increasing size) allows time for the FOG's to separate."	The results of this study suggest that retention time is an important parameter up to a certain value. However, beyond this value, the benefits of increasing the GI size are diminished (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*). As the results have shown in this companion report, a tripling of the residence time only resulted in a 10% increase in FOG removal consisting of 150 micron FOG globule sizes. An additional factor that is also important is the composition of the influent. As documents citing the API oil-water gravity separators note, oil droplet sizes below 150 microns are no longer considered removable by gravity separation (Hee et al., 2006). A numerical simulation of FOG globules performed during this study confirmed that only 10% removal of 80 microns is expected simply from gravity separation (*Assessment of Grease Interceptor Performance*). In addition, the selection of the GI configuration for the same retention time can significantly impact the FOG removal efficiency. As shown in the companion report, the inclusion of the mid baffle wall improved the removal efficiency of the distributed inlet configuration while reduced the removal efficiency for the standard GI configuration. Hence a more comprehensive approach must be taken when sizing and selecting the GI for efficient FOG separation.
(pg. 4, paragraph 4): "Regulatory bodies set different effluent discharge limits all around the country. Presently there is no one recognized maximum allowable level of [Animal, Vegetable FOG] discharge, although the different values are relatively similar."	Discharge regulation at this point is somewhat arbitrary as research is needed to understand the conditions that FOG deposits form in the sewer collection systems. This study was able to determine the basic constituents of a FOG deposit but did not determine their rate of formation and the conditions that influence their formation rate. In addition, current CFD simulations of the GI separation process indicate that GI removal performance may be independent of the influent FOG concentration. In this study, CFD simulations have reported 80% removal of the influent FOG concentration whether it was 1000 mg/L or 3000 mg/L. Preliminary experiments have confirmed these results and further suggest that standard interceptors may not be able to maintain discharge limits for high influent FOG concentrations.

Regarding Factors Effecting GI Sizing (pg. 5, paragraph 2, # 1-5). The document list 5 factors effecting sizing: 1. Retention Time, 2. Flow Rate, 3. Concentration, 4. Pumping Frequency, 5. Chemistry	This research has indicated performance changes as a result of: Retention time (which also incorporates #2 (Flow Rate)), and Chemistry. CFD simulations have shown a significant difference in percent removal due to influent globule size. The concept, however, that enough residence time will significantly improve the removal of any FOG globule size is somewhat unrealistic as shown in this study and in the literature (Hee et al, 2006) (i.e., below the free globule size (<150 micron), gravity separation will not provide significant removal). In addition there is a point of diminishing returns where increasing the size of the GI to achieve longer residence times does not significantly improve the FOG separation process. As stated previously, several CFD simulations performed with varying influent concentrations (#3) displayed no significant performance changes. This does, however, relate to point #4 that eventually a threshold will be reached in the FOG capacity. Point #4 also refers to the interceptor acting as a heat sink to cool the influent stream. The effect of a hot influent (relative to a cooler tank) has been investigated and shows that a buoyancy driven flow will occur that has the potential for scouring already separated FOG if carried out for an extended period.
(pg. 6, paragraph 2) Regarding the physical sizing of an Interceptor. This document goes into detail comparing municipalities' variation on the sizing of grease interceptors. The document performs calculations for commonly utilized GI sizing and compares the results (pg. 9).	The table indicates that for a given restaurant type, municipalities can vary as much as 400 gallons for smaller restaurants to 11,000 gallons for larger restaurant flows. Research indicates minor improvements (i.e.10% increase in FOG removal) by tripling the residence time. Moreover, the benefits observed with more effective GI design configurations displayed even smaller percent improvements in performance with increasing residence time. Bottom line, residence time is only one of a complex array of factors that must be incorporated in a design strategy for effective removal of FOG from an FSE or high density residential complex.

Currently, empirical formulas are utilized for sizing grease interceptors. In addition, manufacturer claims that a specific design will remove influent FOG are often taken at face value. Experimental tests and CFD simulations described in the companion report. 03CTS16TA, *Assessment of Grease Interceptor Performance,* have shown that FOG removal from the influent stream varies with GI design and influent characteristics (i.e., average droplet size, droplet distribution, and velocity distribution). The data in this research further suggests that a well designed GI will only remove so much FOG regardless of the influent concentration., representing a significant shift in the standard accepted practice for assessing FOG removal.

Standard practice is based on the precept that the FOG level in the GI effluent will depend on the influent concentration. Consequently, an effluent discharge limit of 100 ppm can only be achieved if the influent is not much higher than 1000 ppm, given 90% removal efficiency.

While the data collected in this study has primarily been performed with oils that are mono- or poly-unsaturated, it is likely that largely saturated FOG will not be significantly removed at higher percentages. In addition, there is an increasing usage of unsaturated FOG in restaurants due to the high concern that saturated FOG have on human health (Garza, 2005). Consequently, the results of the tests performed in this study may be more indicative of the type of FOG being discharged by current food service establishments.

While more sophisticated design changes could be made to the standard GI (i.e., addition of tube/plate settlers or non traditional baffle wall shapes), one must be careful about the potential impact of these design changes on the ease of cleaning the accumulated material within the GI. GI clean out is still an important part of the maintenance process as shown in field evaluations discussed in the companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*.

In this study, a few design configurations seemed to produce similar removal results ranging from 84-87% (based on the 20-minute residence time). These include the standard no-baffle configuration, distributive configuration, flared inlet/outlet, and the short inlet-standard outlet-no baffle configuration. Interceptors designed in these configurations may be expected to remove approximately 85% of non-emulsified or non-dispersed influent FOG (i.e., FOG greater than or equal to 150 microns globule size). Each of these design configurations are unique and not interchangeable due to the flow pattern that is produced. Moreover, these alternative designs allow for clean out maintenance that is currently performed by third party companies for the food service establishments (FSEs). Bottom-line, a pre-treatment strategy must include at minimum an optimized GI design (i.e., one of the suggested configurations in this chapter) to help reduce the FOG concentration using gravitational separation.

CHAPTER 2.0

DESIGN METHODOLOGY FOR GREASE INTERCEPTORS

Grease interceptors work to remove FOG and other materials primarily through gravity separation. Consequently, it is important to provide conditions that will allow FOG globules or solids to separate from the liquid stream with minimal disruption that may be caused by local fluid velocities. These local velocities can interact with the separated FOG or solids layer, cause breakup of FOG globules and reduce their terminal migration velocities, or cause reactor short circuiting and reduce the separation time necessary for efficient removal of FOG globules or food solids. Moreover, as mentioned earlier, the accumulation of FOG and solids ultimately means that the grease interceptor must be cleaned periodically. Hence, sophisticated grease interceptor designs that impact required cleanout maintenance cannot be encouraged. Therefore, the designs presented in this section are based on modifications that still provide ease of access and maintenance to grease interceptors.

2.1 Inlet/Outlet GI Configurations

Fluid velocities near the inlet and outlet should not exceed 0.015 m/s as results from experimental tests and numerical simulations revealed poorer separation performance at higher velocities. Local fluid velocities can be reduced by distributing the influent/effluent flow across a larger cross-sectional area. Ideally, the cross-sectional area would occupy the entire cross section of the of the grease interceptor (i.e., depth times height) as this setup would provide the lowest fluid velocities. A proposed design with this configuration would require a perforated baffle to distribute the influent flow. However, due to the potential for fast settling solids present in FSE waste streams, an additional compartment with a perforated baffle close to the inlet may cause significant deposition upstream from this baffle and reduce its effectiveness.

The current suggested design involves the distributed plane jet (DPJ) inlet/outlet described in the companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*. A detailed schematic with dimensions for the DPJ is provided in Figure 2-1. The dimensions have been normalized to coordinate implementation with any size rectangular grease interceptor. Important features in the DPJ design include straightening vanes to quickly distribute the local velocities within the expansion joint and the length of the rectangular portion (Figure 2-2). The straightening vanes are only used with the inlet version of the DPJ design.

An alternative to the DPJ design configuration is the distributed pipe configuration displayed in Figure 2-3. This design is considered easier to install and requires less space than the DPJ. As discussed in the companion report *Assessment of Grease Interceptor Performance*, the distributed pipe configuration in Figure 2-3 produces a circulation flow pattern that places higher local velocities near the grease interceptor wall and provides an upward motion in the central region that seems to enhance separation. When utilized with a mid-baffle wall, the results are better than the standard grease interceptor configuration.

A final alternative inlet/outlet design consists of utilizing a shorter standard inlet pipe with a standard outlet pipe configuration and no mid-baffle wall configuration (Figure 2-4). Results with this configuration produced comparable FOG removal performance with both the DPJ and the distributed inlet with mid-baffle wall results. As with the distributed inlet design, this shorter standard inlet pipe configuration is easier to install than the DPJ design but would require significant modifications to the overall GI configuration to remove the mid baffle wall.

2.2 Baffle Wall Configurations

This study demonstrated that grease interceptor designs should only include baffle walls with specific inlet/outlet configurations. Overall, the mid-baffle wall should be designed to distribute the flow and minimize the occurrence of high local fluid velocities. However, for simple retrofits of existing grease interceptors, the standard mid-baffle wall configuration could be used since field observations, experimental and numerical tests have revealed improved performance with simply changing the influent pipe configuration.

Two particular designs that have worked well are shown in Figures 2-5 and 2-6. These mid-baffle walls can be used with the DPJ and distributed influent configurations. The mid-baffle wall is still located in the same position as in the standard GI configuration since computer models did not reveal any enhanced performance with the relocation of the mid-baffle wall. However, as mentioned in the previous section, the mid-baffle wall should not be used if a shorter standard inlet pipe with a standard outlet pipe configuration is selected.

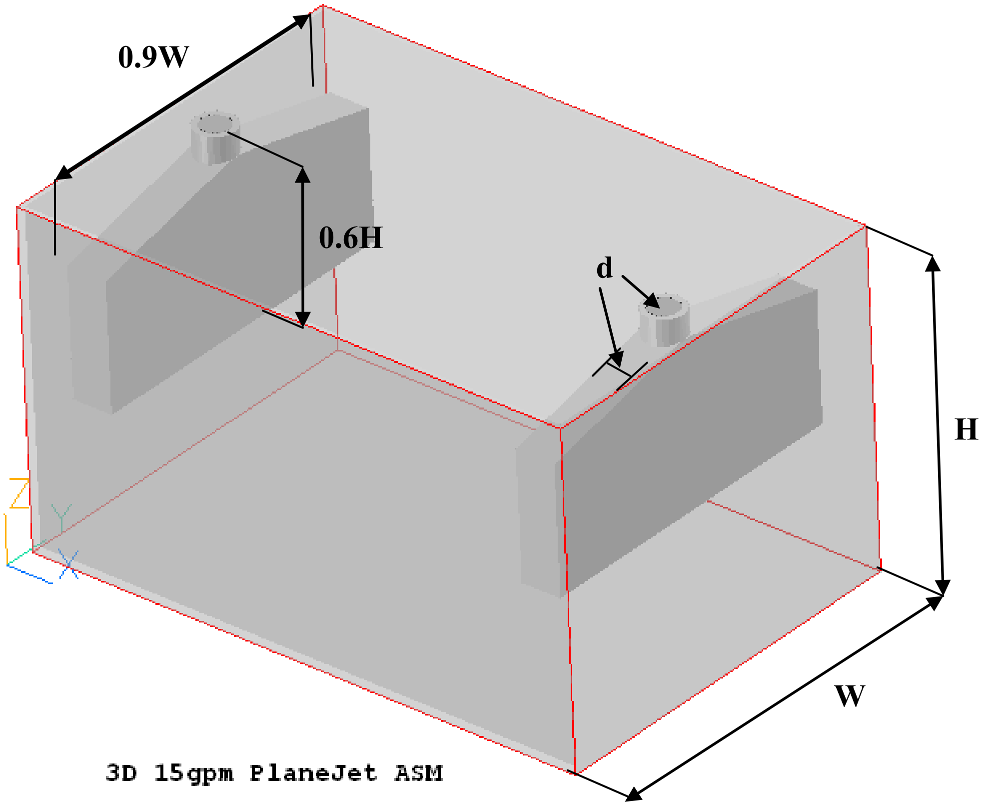


Figure 2-1. Design of Distributed Plane Jet Grease Interceptor.

H = Height of WSE

W = Internal Width of Tank

D = Pipe Diameter

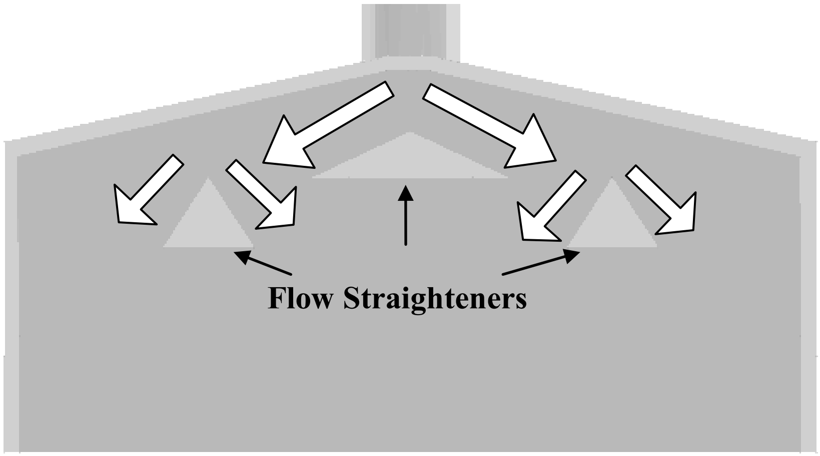


Figure 2-2. Flow Straightening Vanes of Distributed Plane Jet Grease Interceptor.

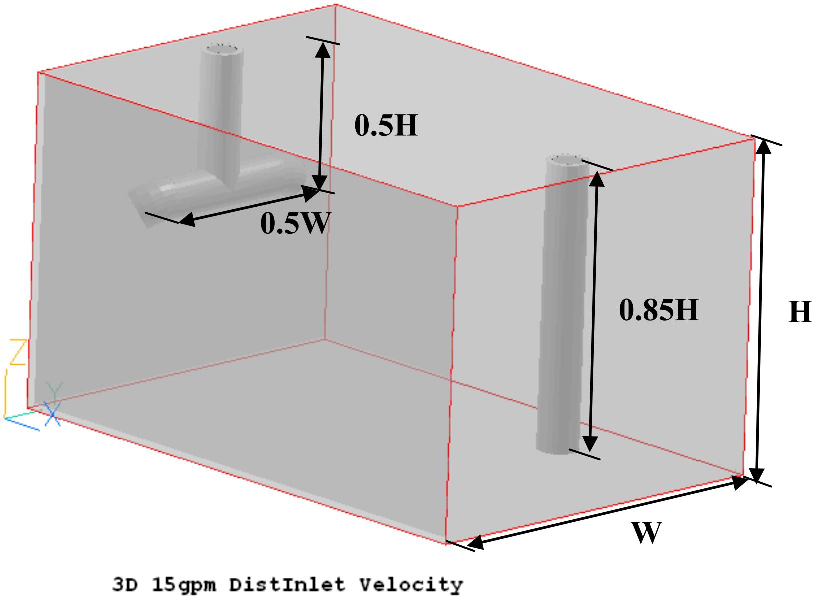


Figure 2-3. Distributed Grease Interceptor.

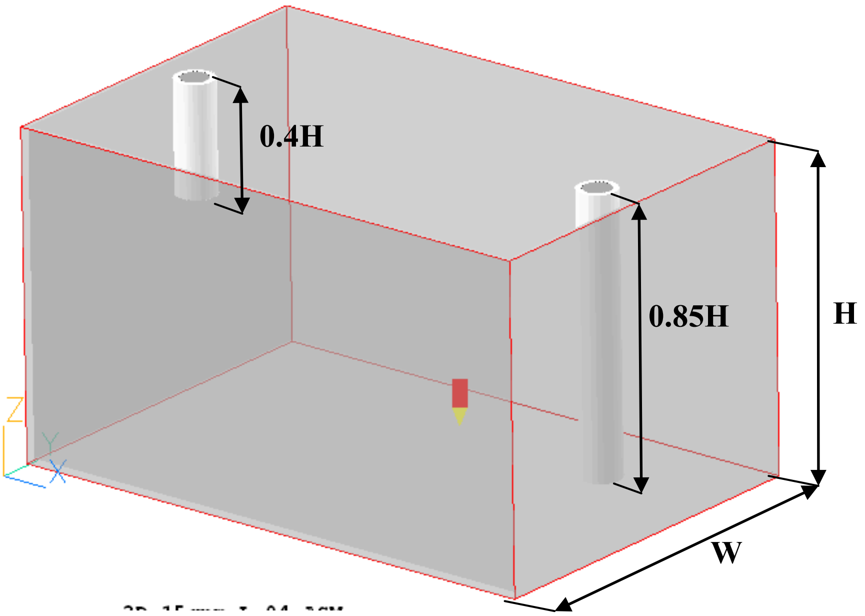


Figure 2-4. Short Inlet Grease Interceptor.

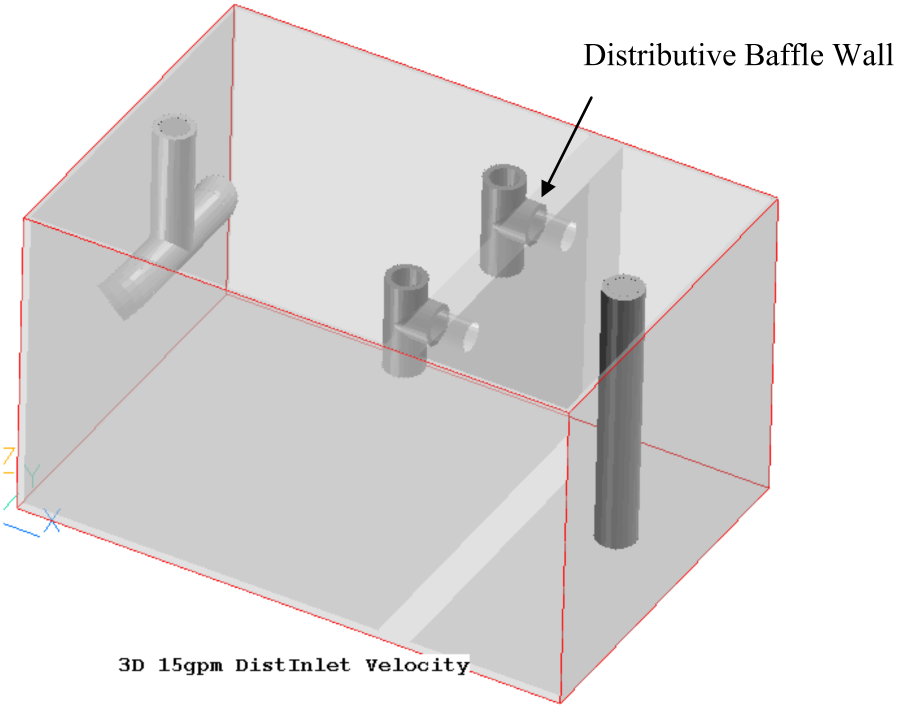


Figure 2-5. Distributed Baffle Wall Design.

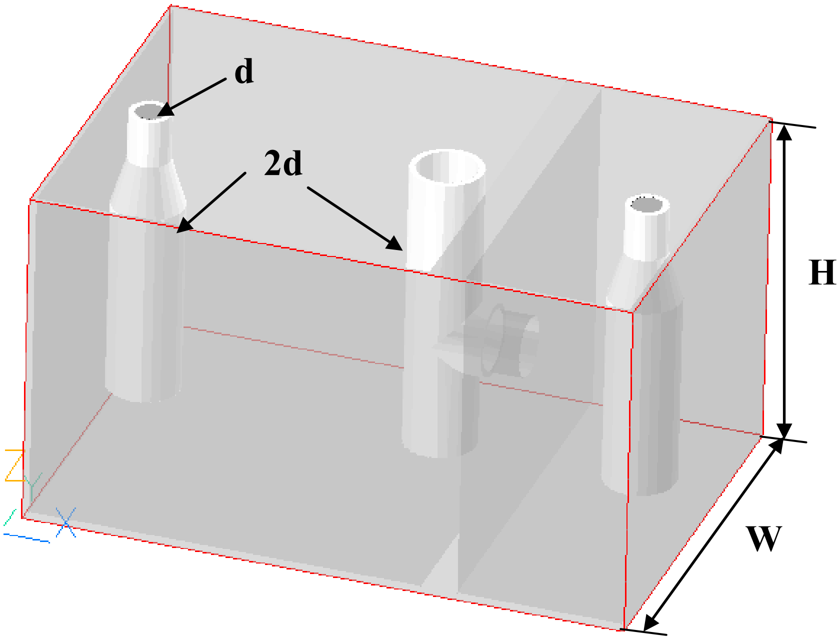


Figure 2-6. Flared Baffle Configuration.

CHAPTER 3.0

GREASE INTERCEPTOR SIZING CONSIDERATIONS

3.1 Premise

Several challenges arise in the sizing of grease interceptors. From the standpoint of the FSE owner, large interceptors require greater installation costs, higher maintenance costs, and run the risk of foul odors as a result of hydrogen-sulfide production. From the standpoint of municipalities, GIs must be sized to protect the operation of the sewer collection system. The fact that each FSE operates differently and have a wide variety of waste stream characteristics makes this a challenging task. It is, therefore, necessary to utilize defensible standards for the sizing of GIs.

The flow contribution of a FSE kitchen to a GI is based on the available plumbing fixtures utilized within the kitchen. The project team, in conjunction with the Town of Cary, North Carolina, characterized plumbing fixtures common to a FSE kitchen. Table 3-1 provides a description of common fixtures.

In Table 3-1, kitchen fixtures are divided into eight different groups. Observation of typical kitchen practices indicate that, based on the use of a fixture, the flow contribution from the sink can either be quantified by draining a filled sink or by direct faucet flow. In the case where the fixture does not drain from a filled sink, the flow contribution of the given fixture should be the maximum allowable faucet flow. This value is commonly regulated for a given pressure (1992 Energy Act). When the kitchen fixture practice dictates that the sink will drain from a filled state, a more appropriate alternative of quantifying the flow to the GI would be to use Manning’s Equation in comparison with the volume of the sink to determine the peak allowable flow.

Table 3-1. Summary of FSE Fixtures.

Fixtures	Description	Flow Contribution
Ware Washing Fixtures	Fixtures in which kitchen pots, pans, and other kitchen utensils are washed. These fixtures often feature three compartments where the dishware is washed. After each cleaning process the three sinks are then drained.	Manning's Equation
Food Preparation Fixtures	Food preparation fixtures are sink fixtures primarily involved in the preparation of meats, vegetables, and seafood. Flow rate contributions from these fixtures are calculated based on the primary activity of cleaning and de-thawing food by means of running water from the faucet.	Faucet Flow
Pre-Rinse Fixtures	Pre-rinse fixtures include those sinks involved in the rinsing of ware prior to washing. Flow rate contributions from these fixtures are calculated based on the primary activity of rinsing ware by means of water flow through a spray nozzle. Note: If a pre-rinse spray nozzle is associated with a sink that has a combination faucet and spray nozzle, a discharge flow rate should be entered for the pre-rinse fixture and the ware washing or prep sink faucet fixture.	Faucet Flow
Dishwasher Units	The dishwasher units are devices used in the automated washing of ware. Dishwasher units include, but are not limited to rack type, under counter, conveyor, and plate washing machines. Flow rates from these units are determined by manufactures specifications on peak wastewater discharges. Clothes washers used for the cleaning of soiled clothes, linens, and towels associated with food service establishments operation shall be entered as a dishwasher unit.	Discharge Flow
Cooking Equipment	Cooking equipment fixtures are those apparatuses that have a connection to the plumbing system for the disposal of wastes associated with cooking or preparing food. Equipment that typically utilizes the plumbing system for waste disposal include, but are not limited to tilt skillets, tilt kettles, brazing pans, rotisserie ovens, and Chinese stoves (woks)	Manning's Equation
Equipment Cleaning Fixtures	Equipment cleaning fixtures are those apparatuses that are utilized for the rinsing and cleaning of equipment associated with cooking or preparing food. Equipment cleaning fixtures may include, but are not limited to can washes, mop sinks, automated hood cleaning systems, and washing stations. Enter the maximum water discharge for the equipment cleaning fixture	Faucet Flow
Waste Food Disposal	Enter the peak discharge rate of the waste food grinder, garbage disposal, pulper, etc. per the manufacturer specifications.	Faucet Flow
Washable Kitchen Floor Area	Washable floor areas include all drains located in food preparation and serving areas. The washable floor area contributions toward the grease interceptor flow rate are based on the maximum water supply discharge rate(s).	Faucet Flow

3.1.1 General Equations

When considering a sink draining from a filled initial state, the use of Manning's Equation (3.1) provides an approach to assess the magnitude of flow expected from such a fixture.

$$\text{Q(gpm)} = 669\frac{AR^{2/3}S^{1/2}}{n} \qquad (3.1)$$

where,

$$R = \frac{P_w}{A} \qquad (3.2)$$

In Equation 3.1 and Equation 3.2, Q is the flow rate given in gallons per minute, A is the flow area within the pipe (in^2), R is the hydraulic radius of flow (in), S is the pipe slope, P_w is the wetted perimeter of flow (in), and n is the Manning's coefficient value, which depends on the piping material.

For pipe flow, the calculations of area and wetted perimeter depend on how full the pipe is flowing. Figure 3-1 depicts a partially filled pipe.

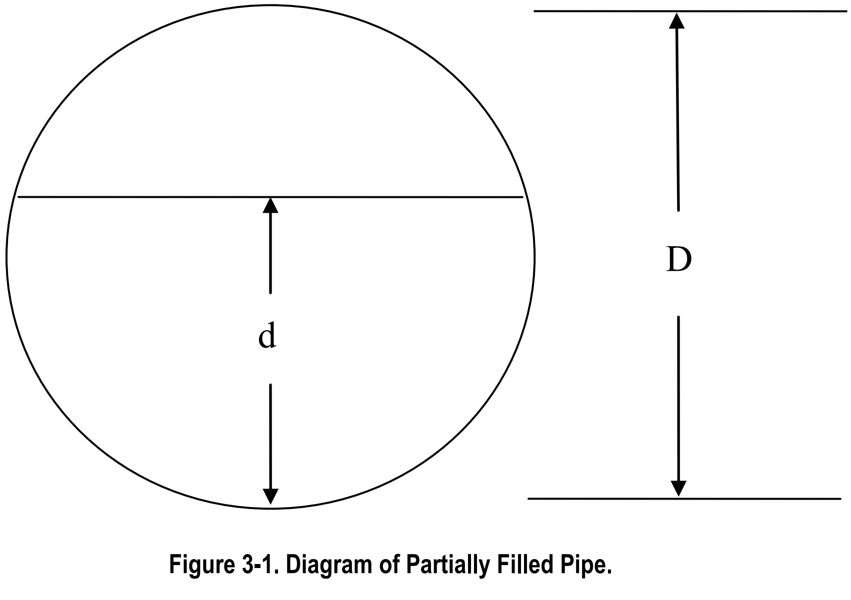


Figure 3-1. Diagram of Partially Filled Pipe.

Observation of the geometric equations describing the flow area and wetted perimeter of a partially filled pipe indicate that flow calculations depend on whether the height of fluid in the pipe is below or above the half filled point (Figure 3-2).

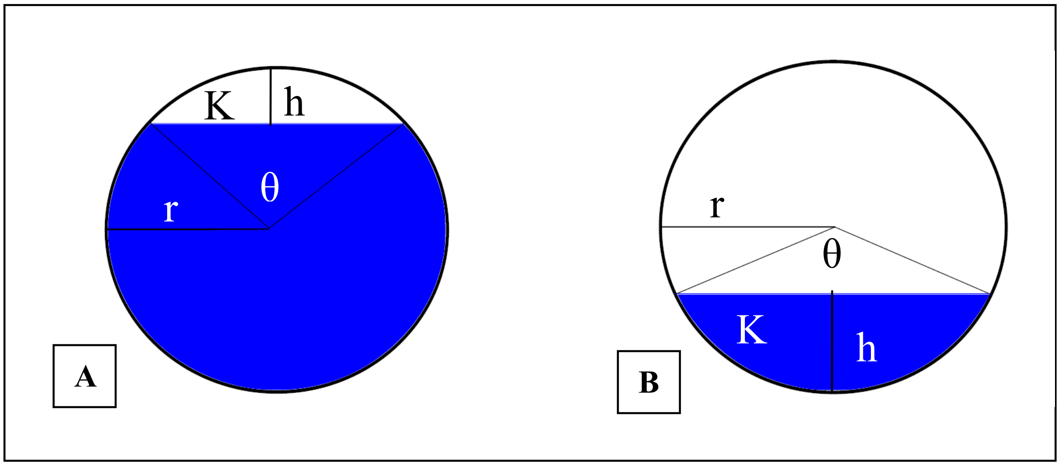


Figure 3-2. Definition of Variables for Calculation of Area and Wetted Perimeter of Partially Filled Pipes.

Table 3-2 details the equations required for the calculation of the flow area and wetted perimeter for partially filled pipes.

Table 3-2. Summary of Calculations for Partially Filled Pipes Shown in Figures 3-1 and 3-2.

Variable	**(A)** $d \geq r$	**(B)** $d < r$
h	d	$2r - d$
θ	$2\arccos\left(\frac{r-h}{r}\right)$	$2\arccos\left(\frac{r-h}{r}\right)$
K	$\frac{r^2(\theta - \sin\theta)}{2}$	$\frac{r^2(\theta - \sin\theta)}{2}$
$s(\text{arc length})$	$r \times \theta$	$r \times \theta$
$A(\text{Flow Area})$	K	$\pi r^2 - K$
$P_w(\text{Wetted Perimeter})$	s	$2\pi r - s$

If the equations in Table 3-2 are combined with Manning's Equation (Equation 3.1) with a given slope and 'n' coefficient and plotted for a variety of pipe fill fractions (${}^{d}\!/_{D}$), the resulting flow rate in Figure 3-3 as a function of the pipe filled fraction would develop.

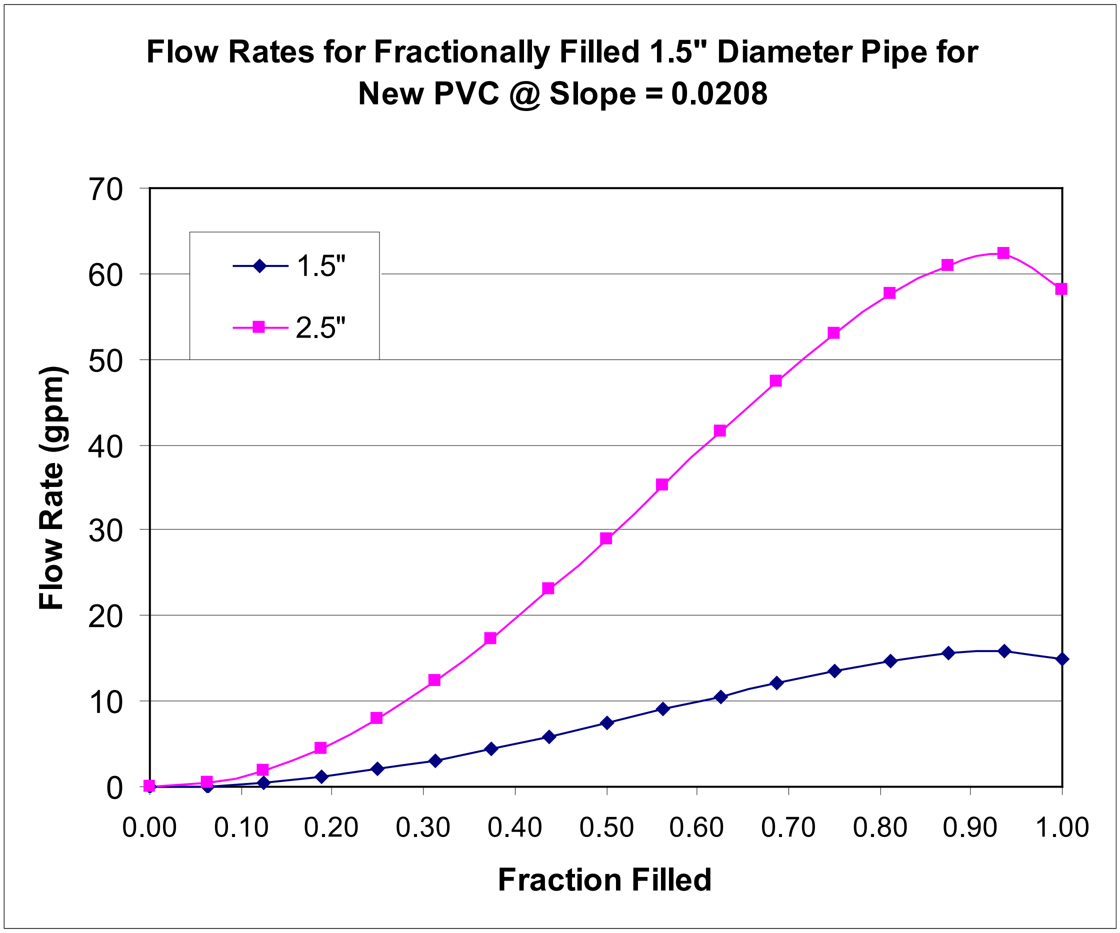


Figure 3-3. Manning's Equation Flow vs. Fraction Filled.

Figure 3-3 displays a flow rate comparison of 1.5" and 2.5" diameter PVC pipe at a slope of 0.0208, which is the slope required by this North Carolina state regulatory agency. As would be expected, the flow rates under these conditions are substantially different. The implication of this graph is that a 1.5" pipe will never exceed approximately 16 gpm under gravity flow, at the slope and pipe material described. Alternatively, with a 2.5" diameter pipe, the peak flow would be substantially greater (>60gpm).

Under the condition where a filled sink is draining, the use of the Manning's Equation, applied under a conservative filled fraction (~90%) allows for an estimate of the potential flow. When combined with the information regarding approximate sink dimensions, a conservative and yet appropriate description of flow contribution from a draining sink can be attained (i.e. a flow greater than the sink volume should not be allowed).

In summary, the contributions of the kitchen fixtures to the total flow observed into a grease interceptor are complex. The proposed flow contribution methodology employs the use of common practices and kitchen plumbing in order to quantify a total flow into the grease interceptor.

Fixtures within a kitchen are broken into two primary categories: drained sink fixtures and faucet flow fixtures. The large bursts of flow into an interceptor are likely to come from the draining of sinks and cooking equipment in the kitchen, while the sustained, lower flow rate may come from fixtures that never achieve a filled sink. Figure 3-4 summarizes these statements in a graphical representation.

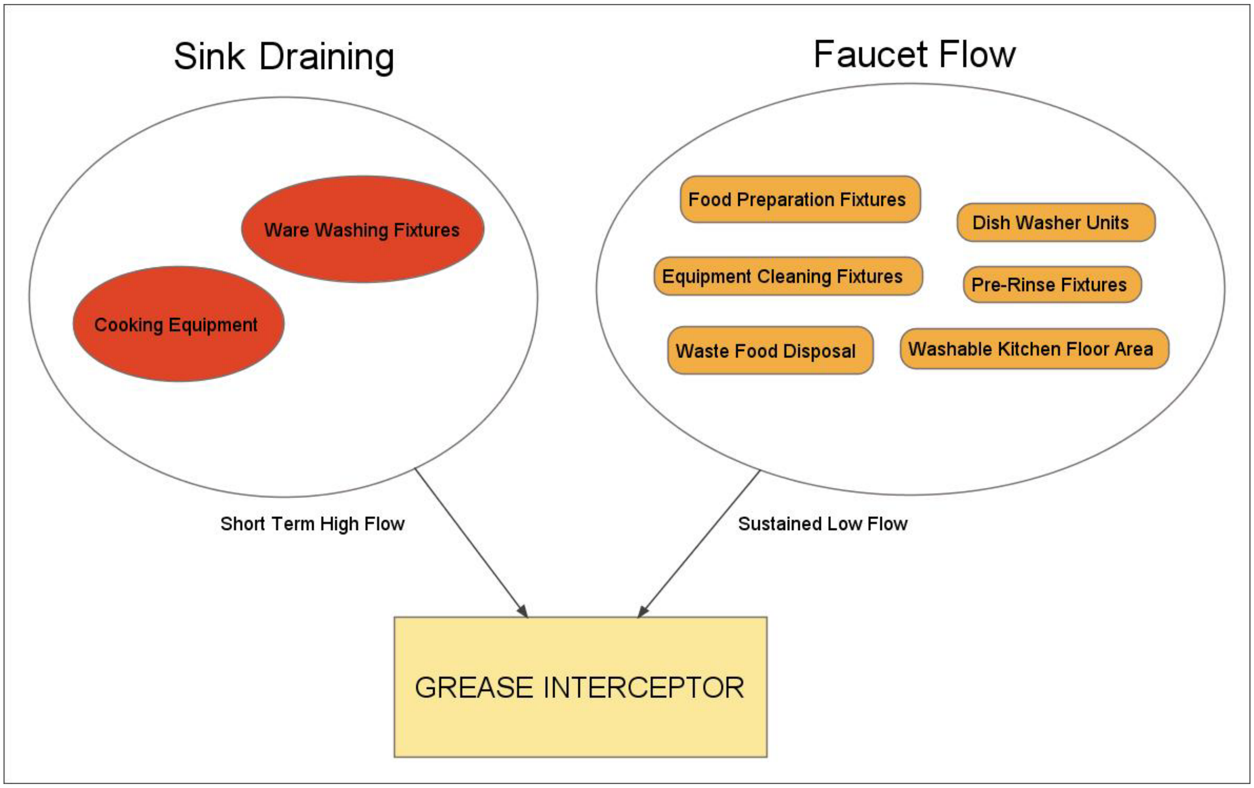


Figure 3-4. Graphic of Flow Contribution from Various Sink Fixtures.

3.1.2 Calculation of Maximum Flow Rate

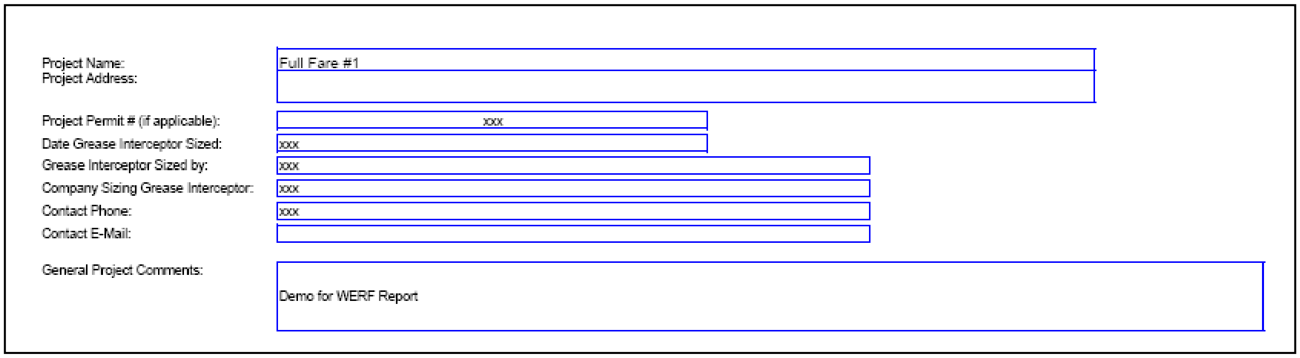
The calculation of the maximum flow rate from a FSE kitchen is one of the key parameters for sizing an interceptor. The use of drainage fixture units (DFUs), as proposed by the 2006 UPC, is a common term for plumbers, but is often uncommon to pretreatment coordinators and officials dealing with the regulation of GIs. In addition, the DFU, though reported to take into account the magnitude and frequency of flow, does not differentiate between a fixture flow and a drained sink flow. Of utmost importance, perhaps, for the regulation of GIs, is the development of a transparent, readily adaptable approach to quantify flow into a GI. Transparency is important so that FSE owners and regulators are aware of the assumptions behind the flow calculations. Adaptability is also important so that future knowledge can be incorporated into the flow calculations as needed.

As stated above, the flow calculations for an FSE GI depend on the number and type of fixtures present in a kitchen. An attached spreadsheet, developed with the Town of Cary, North Carolina, allows for input of the various fixture types, sizes, and characteristics for the calculation of the maximum flow rate into a GI. As a demonstration of the spreadsheets capabilities, a description of an FSE is given in Table 3-3 with the associated inputs to the spreadsheet (Figures 3-5 to 3-7) to compute the flow.

Table 3-3. Summary of Sample FSE for Calculation of Maximum Flow.

Fixture Type	Dimensions	Pipe Diameter (or Fixture Flow)
3 Compartment Wash Sink	3 x 24x24x10	2.0”
2 Compartment Vegetable Prep Sink	2 x 24x24x10	2.5gpm
Pre Rinse Sink	20x20x5	2.5gpm
Dish Machine	-	5gpm
Tilt Kettle	30x24x14	1.5”
Mop Sink	36x36x6	5gpm

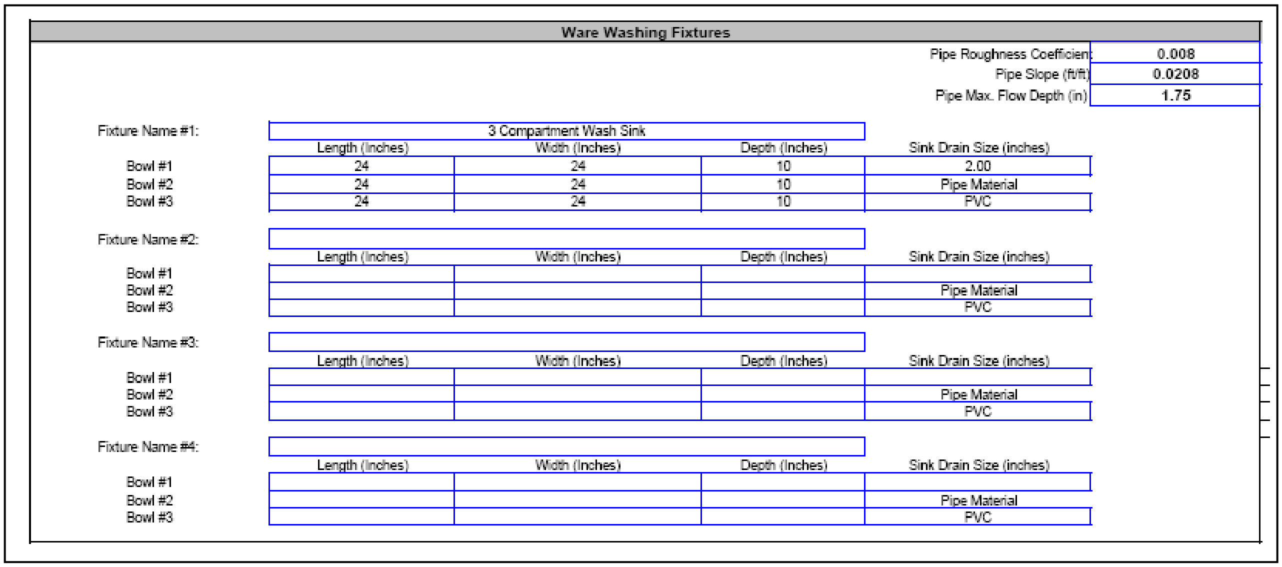
The data from Table 3-3 can easily be input into a spreadsheet embedded with the appropriate characterizations and equations for each fixture type. Such a spreadsheet is available with this report as well as at the Town of Cary website. The beginning of the spreadsheet features a section for data input regarding the FSE name and contact information, in conjunction with any added user notes (Figure 3-5).



Project Name: Full Fare #1
Project Address:
Project Permit # (if applicable): xxx
Date Grease Interceptor Sized: xxx
Grease Interceptor Sized by: xxx
Company Sizing Grease Interceptor: xxx
Contact Phone: xxx
Contact E-Mail:
General Project Comments: Demo for WERF Report

Figure 3-5. Contact Information and FSE Input at the Top of the Spreadsheet.

Following this basic description input, the user is presented with the “Ware Washing Fixtures” section of the spreadsheet (Figure 3-6). In this section, the user inputs all the ware washing sinks and their dimensions. The sink drain size is also required in this section. At the top right side of this section, the user can see a small table describing pipe roughness, pipe slope, and maximum flow depth. These values are set automatically for common pipe slopes, roughness coefficients, and a conservative estimate of the maximum flow depth in the pipe. The values can all be modified as needed. The embedded equations within the spreadsheet then make the appropriate Manning’s Equation calculations for this fixture.



Ware Washing Fixtures

Pipe Roughness Coefficien	0.008
Pipe Slope (ft/ft)	0.0208
Pipe Max. Flow Depth (in)	1.75

Fixture Name #1: 3 Compartment Wash Sink

	Length (Inches)	Width (Inches)	Depth (Inches)	Sink Drain Size (inches)
Bowl #1	24	24	10	2.00
Bowl #2	24	24	10	Pipe Material
Bowl #3	24	24	10	PVC

Fixture Name #2:

	Length (Inches)	Width (Inches)	Depth (Inches)	Sink Drain Size (inches)
Bowl #1				
Bowl #2				Pipe Material
Bowl #3				PVC

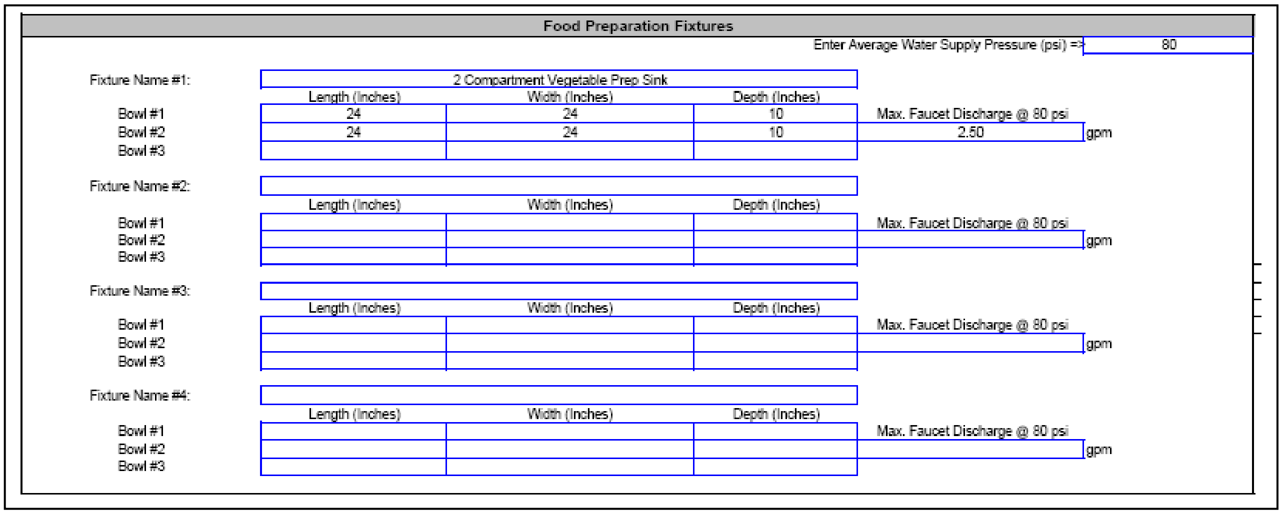
Fixture Name #3:

	Length (Inches)	Width (Inches)	Depth (Inches)	Sink Drain Size (inches)
Bowl #1				
Bowl #2				Pipe Material
Bowl #3				PVC

Fixture Name #4:

	Length (Inches)	Width (Inches)	Depth (Inches)	Sink Drain Size (inches)
Bowl #1				
Bowl #2				Pipe Material
Bowl #3				PVC

Figure 3-6. Data Input for Ware Washing Fixtures.



Food Preparation Fixtures

Enter Average Water Supply Pressure (psi) => 80

Fixture Name #1: 2 Compartment Vegetable Prep Sink

	Length (Inches)	Width (Inches)	Depth (Inches)
Bowl #1	24	24	10
Bowl #2	24	24	10
Bowl #3			

Max. Faucet Discharge @ 80 psi 2.50 gpm

Fixture Name #2:

	Length (Inches)	Width (Inches)	Depth (Inches)
Bowl #1			
Bowl #2			
Bowl #3			

Max. Faucet Discharge @ 80 psi gpm

Fixture Name #3:

	Length (Inches)	Width (Inches)	Depth (Inches)
Bowl #1			
Bowl #2			
Bowl #3			

Max. Faucet Discharge @ 80 psi gpm

Fixture Name #4:

	Length (Inches)	Width (Inches)	Depth (Inches)
Bowl #1			
Bowl #2			
Bowl #3			

Max. Faucet Discharge @ 80 psi gpm

Figure 3-7. Food Preparation Fixture Input Section.

As an example of a faucet-flow fixture, the food preparation sink input section (Figure 3-7) displays the required inputs for this section. The user inputs the sink dimensions and the faucet discharge. This discharge and the pressure at the faucet (top right corner) is a readily available number from the plumbing association.

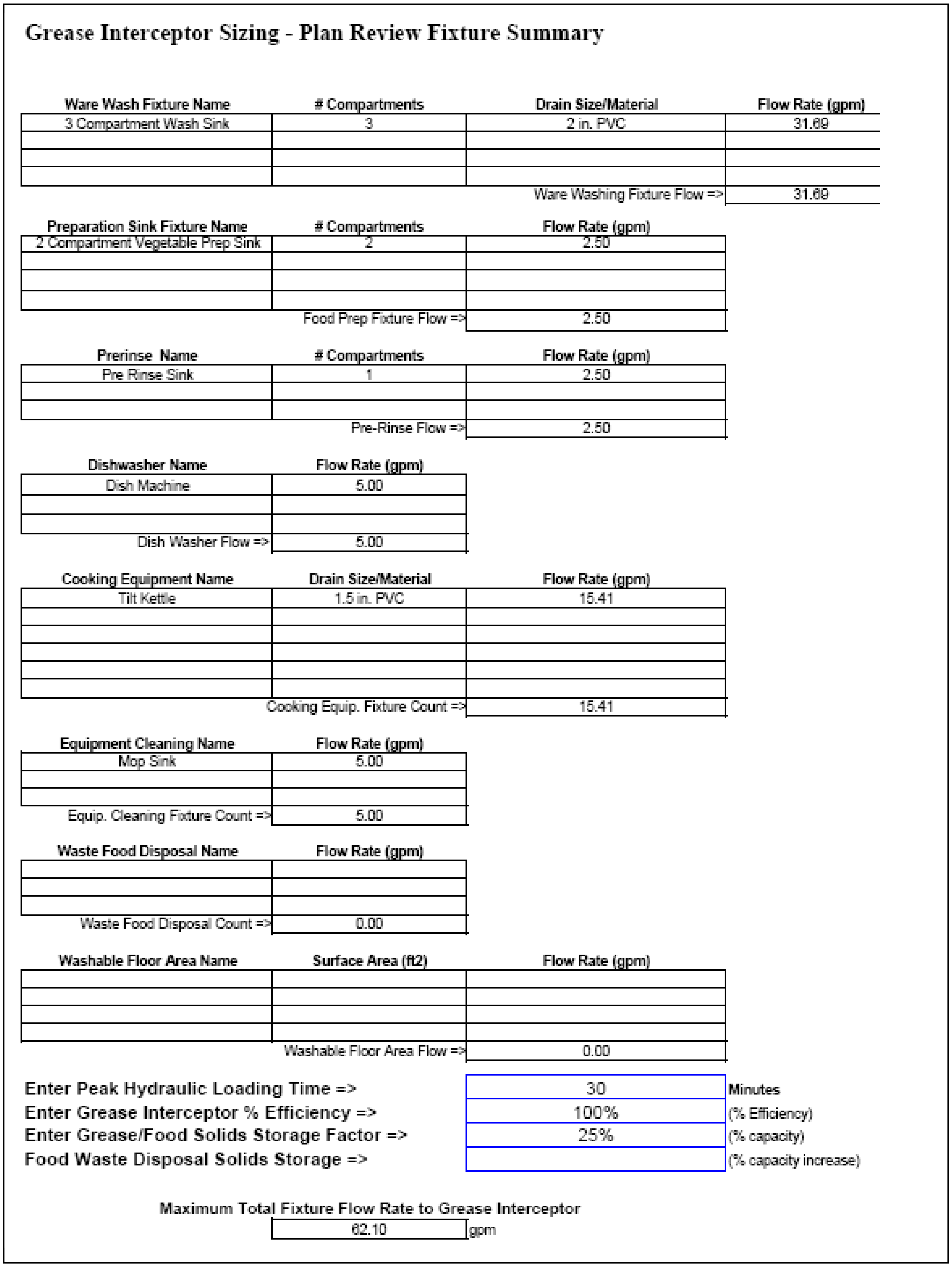
Figures 3-6 and 3-7 display examples of the two types of fixtures present at an FSE. The magnitude of the flow rate may, of course, change depending on the site specific conditions. However, the process described above is the same. The current version of the spreadsheet includes input regions for all the fixtures described in Table 3-1. After this data is input, the bottom of the spreadsheet features a summary table describing the flow contribution from each of the fixtures and the total maximum flow expected from the FSE (Figure 3-8).

As can be seen from the bottom of Figure 3-8, the maximum potential flow from this FSE is 62.10 gallons per minute. This value is an estimate of the worst case scenario flow from an FSE, when all fixtures are running and all sinks are draining simultaneously. Clearly, this is an unlikely scenario. The project team's investigation into the flow observed from FSEs seems to confirm this unlikely scenario. In fact, the FSE described above was monitored during the hours of operation and is displayed in Figure 3-9.

In Figure 3-9, the peak flow shown for the day observed is approximately 21 gpm, far less than the maximum flow rate calculated with the spreadsheet. If a 62 gpm flow rate was utilized for the design flow, it would result in a GI of approximately 2000 gallons at a 30 minute retention time. As a result, a modification is necessary to develop a feasible design flow coming into an interceptor.

Observation of the behavior of several field GIs indicated that approximately one-third of the maximum flow rate would be an appropriate fraction for a design flow rate (companion report 03CTS16TA, *Assessment of Grease Interceptor Performance*). This value appears to be appropriate for the bulk of the fluid passing through the interceptor while handling the likely peak flow rates. For the example full-fare restaurant described above, a design flow rate of approximately 21 gpm would be determined using Equation 3.3.

$$\text{Design Flow (gpm)} = \frac{1}{3} Q_{\text{max}} \tag{3.3}$$



Grease Interceptor Sizing - Plan Review Fixture Summary

Ware Wash Fixture Name	# Compartments	Drain Size/Material	Flow Rate (gpm)
3 Compartment Wash Sink	3	2 in. PVC	31.69
		Ware Washing Fixture Flow =>	31.69

Preparation Sink Fixture Name	# Compartments	Flow Rate (gpm)
2 Compartment Vegetable Prep Sink	2	2.50
	Food Prep Fixture Flow =>	2.50

Prerinse Name	# Compartments	Flow Rate (gpm)
Pre Rinse Sink	1	2.50
	Pre-Rinse Flow =>	2.50

Dishwasher Name	Flow Rate (gpm)
Dish Machine	5.00
Dish Washer Flow =>	5.00

Cooking Equipment Name	Drain Size/Material	Flow Rate (gpm)
Tilt Kettle	1.5 in. PVC	15.41
	Cooking Equip. Fixture Count =>	15.41

Equipment Cleaning Name	Flow Rate (gpm)
Mop Sink	5.00
Equip. Cleaning Fixture Count =>	5.00

Waste Food Disposal Name	Flow Rate (gpm)
Waste Food Disposal Count =>	0.00

Washable Floor Area Name	Surface Area (ft2)	Flow Rate (gpm)
	Washable Floor Area Flow =>	0.00

Enter Peak Hydraulic Loading Time =>	30	Minutes
Enter Grease Interceptor % Efficiency =>	100%	(% Efficiency)
Enter Grease/Food Solids Storage Factor =>	25%	(% capacity)
Food Waste Disposal Solids Storage =>		(% capacity increase)

Maximum Total Fixture Flow Rate to Grease Interceptor

62.10 gpm

Figure 3-8. Summary of All Fixtures and Flow Contribution.

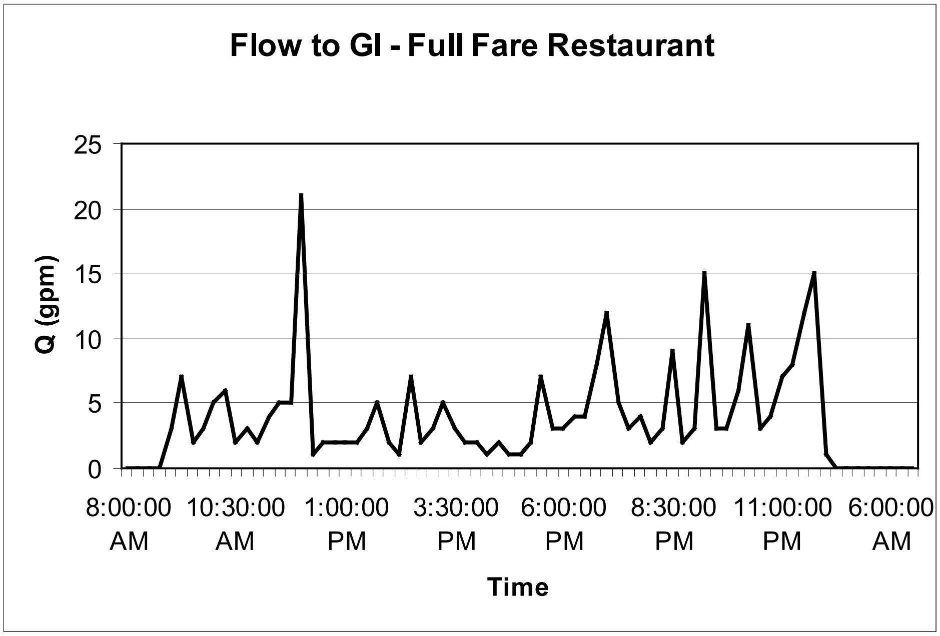


Figure 3-9. Flow Data Collected Over Operational Hours at Full-Fare FSE.

3.1.2 Maximum Flow Rate Table

Table 3-4 was developed to provide a simplified alternative approach to quantify the maximum flow-rate into a GI without the need to use the GI design spreadsheet.

Table 3-4. Maximum Flow Rate Table.

		Fixture Flows		
i	**Fixture Type**	**1.5"**	**2.0"**	**2.5"**
A	Ware Washing Fixtures	15	30	60
B	Food Preparation Fixtures	2.5		
C	Pre-Rinse Fixtures	2.5		
D	Dish Washer Units	5		
E	Cooking Equipment	15	30	60
F	Equipment Cleaning Fixtures	5		
G	Waste Food Disposal	2.5		
H	Washable Kitchen Floor Area	5		

In conjunction with Table 3-4, Equation 3.4 could then be applied for the calculation of the maximum flow rate from an FSE.

$$Q_{\max} = \sum_{i=A}^{H} Q_i n_i \tag{3.4}$$

In Equation 3.4, Q_i represents the flow contribution of a given fixture type and n_i represents the number of fixtures within each fixture type. The maximum flow rate is then determined by the summation of all the flow fixtures multiplied by the quantity of each fixture. This flow rate value will likely be conservative (i.e., produce a larger maximum flow rate) as it does not take into account site specific sink sizes for Manning's Equation calculations or site specific pipe roughness or slope. The assumptions used to make Table 3-4 include: the peak fixture flow rates described for the faucet-flow fixtures, the use of 0.0208 for the value of the slope (S) in Manning's Equation, and the use of the new PVC value for Manning's 'n' (0.008).

In the example shown in Table 3-3, the use of the summary Table 3-4 would indicate the following:

$$Q_{\max} = 30(1) + 2.5(1) + 2.5(1) + 5(1) + 15(1) + 5 = 60\text{gpm}$$

For the example given, the summary table happens to be approximately the same size as the spreadsheet utilized. This similar result is, of course, due to the table flow values coming from the same slope and pipe roughness values currently used in the spreadsheet. However, if the slope for the site specific food service establishment was 0.04 instead of 0.0208 as used in Table 3-4, then the computed max flow would be 81 gpm based on inputting the data into the spreadsheet and be under predicted using Table 3-4 since it would still predict a max flow of 60 gpm. The user should be aware of the assumptions of Table 3-4 before readily using it to compute the FSE flowrate for their specific location. The spreadsheet should be used if the site specific FSE are not consistent with the assumptions listed for Table 3-4.

3.2 Grease Interceptor Sizing

As mentioned earlier, grease interceptors are simple gravity separators that are impacted by the quantity and type of material that is being separated, the hydraulic behavior of the interceptor, cleanout cycle of the grease interceptor, and the operational conditions of the food service establishment. While the hydraulic behavior and quantity and type of FOG were previously discussed, no information was provided on how to compute the necessary size of the grease interceptor based on the operational needs of the food service establishment. Current methods used to assess grease interceptor size based on the food service establishments operating conditions include the following:

Environmental Protection Agency

$$\text{Size (Gallons)} = (\#\,seats)\left(\frac{gallons}{meal}\right)(loading\ factor)(storage\ factor)\left(\frac{hours\,open}{2}\right)$$

where gallons per meal is a constant set equal to 5, storage factor equals 1.7, hours open equals 8, and loading factor equals 1.0.

*Uniform Plumbing Code (2004)***:**

$$\text{Size (Gallons)} = (\#\,seats)(flowrate)(hydraulic\ retention\ time)(storage\ factor)$$

where flow rate is equal to 6 gallons per hr and includes the dishwasher flow, the hydraulic retention time is 2.5 hrs, and storage factor equal to 2.0 if the FSE is operated for 16 hours. The revised UPC (2006) computation utilizes an elaborate calculation involving DFUs as described in a previous section and cannot be calculated with a simple relationship as shown above.

Other relationships exist in the literature that are specific to individual municipalities and include more or less similar terms as those used by the UPC (2004) or U.S. EPA equations above. These approaches have been previously criticized in this report since they do not account for the uniqueness in the grease interceptor design. Moreover, they will likely oversize the grease interceptor, which could lead to undesirable conditions such as odors from biological activity in regions that have remain anaerobic too long between cleanout cycles.

As shown in the companion report 03CTS16A, *Assessment of Grease Interceptor Performance*, a large percentage (over 65%) of the field grease interceptors operate with a minimum one hour hydraulic retention time (based on peak flow) with 100% operating at a minimum 30 minutes hydraulic retention time. The flow data in this companion report reveals that only 1% of the total time the food service establishment discharge FOG and solids into the grease interceptor occurs at the maximum flow. When the hydraulic retention time was recalculated using the 90% mark from the cumulative distribution (see Figure 1-2 in *Assessment of Grease Interceptor Performance*), 100% of the grease interceptors operated at a minimum hydraulic retention time of one hour with a majority of those food service establishments (80%) having retention times of two hours. The results in Figure 1-2 of *Assessment of Grease Interceptor Performance* show that the flow representing the 90% mark on the cumulative distribution function is typically 1/3 of the maximum flow rate.

The laboratory results of this study show that tripling the retention time from 20 minutes to one hour only resulted in a 10% increase in the removal of FOG. Further, geometric modifications to the inlet and outlet resulted in similar improvements to removal efficiency at the 20 minutes residence time operation compared with the 60 minutes residence time results. Consequently, it is the project team's recommendation that a 30 minutes residence time, with the geometric configurations discussed in the previous section, represents a reasonable balance between grease interceptors that can operate at 90% removal efficiency while minimizing the chance for development of odors due to anaerobic microbial activity between cleanout periods.

The relationships developed by UPC and the U.S. EPA were not only to account for the hydraulic loading into the grease interceptor but also account for the FOG and solids loading. Work from a previous study (unpublished) has shown that individual plates, utensils, and serving items (i.e., trays, pans, etc.) can generate 3-5 grams of FOG per person served that would be washed down into the grease interceptor. If the maximum FOG amount (5 g/person) is used for a full-fare restaurant serving 500 persons per hour during peak time, then approximately 2.5 kg per hour would be received by the grease interceptor. During this same period, a large full fare restaurant will likely produce a maximum flow of 45 gpm of water from cleanup and dishwashing.

Based on a 30 minute proposed residence time and a 45 gpm peak flow rate, the minimum volume required is 450 gallons. (Note that the peak flow rate was multiplied by 1/3 to represent the 90% flow rate value on the cumulative distribution function (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance.*) The required storage space for FOG based on the 2.5 kg/hr loading rate is 120 gallons. This value assumes 12 hours of peak operation per day, 15 days between clean out cycles, and 90% FOG removal. It should be noted that the required volume for FOG separation in this example assumes that the FOG characteristics are in the free globule size range (i.e., globule sizes that are larger than 150 microns) for effective gravity separation. The amount of solids that accumulates at the bottom of the grease interceptor will also require space. Food solids analyzed in *Assessment of Grease Interceptor Performance*, displayed very high settling rates, suggesting that the typical empirical relationships for sludge volume index (SVI) may not be used. The computation of the SVI was performed based on first principles as follows:

Stokes particle settling:

$$\mathrm{v_s} = \frac{(\rho_p - \rho_f) g d_p^2}{18\mu} \tag{3.5}$$

$$\mathrm{SVI} = \frac{\text{dry weight of suspended solids}}{\text{wet solids volume}} = \frac{1}{(\rho_p - \rho_f)} \tag{3.6}$$

Substituting 3.5 into 3.6

$$\mathrm{SVI} = \frac{g d_p^2}{18\mu \mathrm{v_s}} \tag{3.7}$$

The viscosity of the fluid containing the solids was estimated assuming non-spherical particles as (Rao, 1999):

$$\frac{\mu}{\mu_f} = \left(1 - \frac{\phi}{A}\right)^{-2} \tag{3.8}$$

where μ_f is the fluid viscosity, ϕ is the mass fraction, and A is a constant equal to 0.44 for food particles that have aspect ratios (L/D) between 6-8, which Rao (1999) suggests is a good approximation for most food particles. For the food particles identified in the field studies (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*), the average

SVI value is approximately 0.06 gallons per lb of solids (This value assumes a solids fraction of 0.003 with the particle sizes identified in this companion report. The maximum storage volume needed for a 2 week pumping frequency is 366 gallons. So for the large restaurant example, the total volume required is 1210 gallons (a standard GI size is 1250**).**

If calculated using either the U.S. EPA or UPC (2004) approach, the GI size would have been 17,000 and 15,000 (UPC 2004) gallons respectively. Using the alternative UPC (2006) requires more information about the items responsible for generating the 45 gpm flow in the food service establishment. In general, utilizing the revised UPC will result in much smaller grease interceptors than its original 2004 approach. Large GIs as recommended by the U.S. EPA guidelines would result in extremely long solids retention time and lead to significant odors due to low dissolved oxygen content from significant microbial activity. Moreover, it is unclear how the revised UPC (2006) determines the contribution of FOG or solids loading into the grease interceptor using DFUs.

In summary, the recommended approach for computing the size of the grease interceptor should be performed using Equation 3.9

$$\text{Size(Gallons)} = \frac{1}{3}Q_{\max} \times (\text{HRT}) + (\text{FOG Storage Volume}) + (\text{Solids Storage Volume}) \tag{3.9}$$

The FOG Storage Volume can be calculated with Equation 3.10, where Y is the duration between cleanouts.

$$\text{FOG Storage Volume} = \left(5\frac{g}{seat-hr}\right)\left(X\frac{\text{operation hrs.}}{\text{day}}\right)(Y\text{ days})(0.9)(\#\text{seats})\left(\frac{264\,\text{gal/m}^3}{\text{FOG Density}}\right) \tag{3.10}$$

The Solids Storage Volume is then calculated by Equation 3.10, where A represents an approximate solids concentration.

$$\text{Solids Storage Volume} = (A[\text{ppm}])\left(\frac{Q_{\max}}{3}\right)\left(X\left[\frac{\text{operation hrs.}}{\text{day}}\right]\right)(Y[\text{days}])(SVI) \tag{3.11}$$

CHAPTER 4.0

FACTORS EFFECTING GI PERFORMANCE

4.1 Impact of Emulsifiers on Grease Interceptor Performance

Detergents may contain emulsifiers to aid in the removal of FOG from dishware and kitchen utensils. The role of emulsifiers is to stabilize the interfacial surface by reducing the interfacial tension and preventing FOG from coalescing. Although the effectiveness of detergents containing emulsifiers is to enhance the removal of FOG from utensils and dishware, its addition may also reduce the effectiveness of grease interceptors to separate FOG from the liquid stream. The FOG globules generally achieve a smaller maximum diameter when emulsifiers are included since the surface tension of the FOG globules has been reduced. Hinze (1955) has described how a drop will break in isotropic turbulent flow in the inertial subrange as:

$$d_{\max} = C\varepsilon^{2/5}\left(\frac{\sigma}{\rho_c}\right)^{3/5} \tag{4.1}$$

In Equation 4.1, C is an empirical constant, ε is the local energy dissipation rate, σ is the disperse continuous phase surface tension, ρ_c is the continuous phase density. While this relationship does not characterize all types of turbulent breakup of drops, it does demonstrate that any action leading to the reduction of the surface tension may also lead to the reduction of the maximum drop size. The end result would be the reduction of the FOG globule migration velocity and consequently the removal efficiency (companion report, 03CTS16TA, *Assessment of Grease Interceptor Performance*).

Detergents with emulsifiers' detrimental impact on gravity separation type processes suggest that some counteracting procedure should be employed to increase the size of the FOG globules within the grease interceptor. While this study did not investigate the use of demulsifying agents, the results of this study suggest that any compound that leads to the reduction of the influent FOG globule size will significantly reduce the separation performance as shown in *Assessment of Grease Interceptor Performance* and should be avoided. Best management practices recommend that kitchen cleaners should not use detergents with emulsifying agents to reduce their impact on the grease interceptor separation performance (Stoll and Gupta, 1997).

4.2 Impact of High Temperature Washwater on Grease Interceptor Performance

Experimental tests performed with high temperature water flow into the grease interceptor containing cooler bulk temperatures has demonstrated a density up-flow effect due to the lower relative density of the influent stream compared to the grease interceptor bulk temperature. However, the experimental results showed that short term impact of this density up flow was minor on the effluent FOG concentration and over time, the effluent FOG concentration would be similar to previous uniform influent/bulk temperature results. The experimental results showed that mid-baffle wall provided no significant advantage during the occurrence of a density up-flow event.

While the separated FOG layer may be disturbed by this density up-flow event, the location of the effluent pipe towards the bottom of the grease interceptor suggest that this design requirement may be sufficient to reduce its impact of increasing the FOG effluent concentration due to the disturbed separated FOG layer. Consequently, one design requirement that may be essential to grease interceptors to reduce the impact of density up-flow events on the FOG effluent concentration is the overall depth of the grease interceptor and the close proximity of the effluent pipe towards the bottom of the grease interceptor. Currently, the design calls for depth of the effluent pipe is approximately 1/5 of the depth off bottom.

4.3 The Role of Grease Interceptor Maintenance on Performance

As discussed above, the incorporation of food solids and FOG storage capacity into a GI is an important design consideration when sizing a GI. Equations 3.9, 3.10, and 3.11 already account for this consideration. However, without proper maintenance, the effective size of the GI may be reduced substantially. Though explicit evidence of the result of poor maintenance is currently unknown, observation of field GIs, as shown in the companion report, indicates that scouring of food solids and the already separated FOG layer may be a consequence of substantial buildup in a GI.

The research team recommends that care be taken when establishing a GI clean-out frequency. The best practice may be a simplified maturation study of GIs suspected to have substantial FOG or solids loadings. Such a maturation study would involve taking sludge judge samples of the interceptor at various locations between cleanout frequencies. If a marginal change in FOG or solids layer (or a decrease in those layers) is observed, then it should be noted that the interceptor may have reached its capacity for storage and may need a change in pump-out frequency.

CHAPTER 5.0

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

Establishing a fair and protective GI size and design guide are challenging goals. The aim of this report has been to establish a set of transparent, fact-based guidelines for the design, sizing, and maintenance of grease interceptors. When combined with the report, *Assessment of Grease Interceptor Performance* (03CTS16TA), detailing the field, experimental, and numerical results for GI performance, the reader should be able to clearly see the basis for the guidelines established in this document.

The current research indicates that a non-compartmentalized, open configuration may provide similar and sometimes enhanced FOG separation over certain compartmentalized designs, contrary to previous literature information regarding GI design. Inlet and outlet piping configurations play a major role in influencing design considerations (i.e. whether mid-baffle walls should be included or omitted). In this study, a few GI design configurations have been proposed to provide at least 90% FOG removal in the free globule size range with a residence time of 30 minutes. These design configurations should be used in conjunction with proposed method to determine the GI size for a specific food service establishment.

This report presents an alternative method to compute the GI size. The approach utilizes a spreadsheet that calculates the flow from a FSE kitchen to a GI based on the available plumbing fixtures utilized within the kitchen. The proposed flow calculations employ the use of common practices and kitchen plumbing in order to quantify a total flow into the grease interceptor. FOG and solids loading are also included in the proposed GI sizing approach to account for the additional storage volume required for separated material accumulated between cleanout cycles.

5.2 Future Work

Research into the area of GI design, operation and maintenance is still in its infancy. Future work in this field will have to consider several factors not included in the present study.

1) Alternatives to the large, below ground gravity interceptor are being used by restaurants, such as below sink mechanical and passive traps. As this report does not make any claims into the effectiveness of these devices; it is necessary that similar studies be performed in order to determine the effectiveness of these traps for FOG removal.
2) Though the present research has provided insight into the nature of FOG deposits, no information is currently available regarding the physical mechanism by which they accumulate and form the hardened pipe blockages. With this knowledge, further research may lead to the specific form of FOG that will need to be removed by grease interceptors.
3) Future research needs to include a methodology to characterize the food service establishment waste stream. This detailed characterization would provide better guidance

into the extent of FOG and solids that can be removed within the GI and possibly offer alternative recommendations into improving the GI removal.

4) Additional GI field observations need to be performed across different types of food service establishments that have retrofitted the GI based on the recommendations in this report. This additional field data would validate the proposed design configurations and increase the much needed transparency in the entire GI design process.

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WERF Stock No. 03CTS16TBRP

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Email: publications@iwap.co.uk
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IWAP ISBN: 978-1-84339-527-0/1-84339527-4

Oct 08