EPA-600/2-75-065c.2
December 1975

Environmental Protection Technology Series

AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS – 1975

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/2-75-065 c.2
December 1975

AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS - 1975

by

Philip E. Shelley
George A. Kirkpatrick

EG&G WASHINGTON ANALYTICAL SERVICES CENTER, INC.
Rockville, Maryland 20850

Contract No. 68-03-0409

Project Officer

Hugh E. Masters
Storm and Combined Sewer Section
Municipal Environmental Research Laboratory (Cincinnati)
Edison, New Jersey 08817

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The deleterious effects of storm and combined sewer overflows upon the nation's waterways have become of increasing concern in recent times. Efforts to alleviate the problem depend upon accurate characterization of these flows in both a quantity and quality sense. This report presents a state-of-the-art survey of automatic wastewater sampling devices that might be appropriate for the quality measurement of stormwater and combined sewer flows as well as other wastewater discharges, and will be of interest to those who have a requirement for the characterization of such flows.

Louis W. Lefke
Acting Director
Municipal Environmental
Research Laboratory

PREFACE

This report represents a revision and update of an earlier report, "An Assessment of Automatic Sewer Flow Samplers," published as Environmental Protection Technology Series Report No. EPA-R2-73-261, June 1973, which is hereby superseded. The major areas of change are in the descriptions of commercially available equipment, which have been revised to reflect equipment changes and new offerings that have appeared since the preparation of the original report in the fall of 1972. Additional project experience and reviews of custom designed samplers have also been given, and some modifications have been made to other portions of the text to reflect new material. As a result, over 80 percent of the present report represents new or revised content as compared to its predecessor.

Mention should be made of a collateral effort reported in "Design and Testing of a Prototype Automatic Sewer Sampling System," which is to be published soon as an Environmental Protection Technology Series Report. It describes the design implementation of a new, improved prototype automatic sampling system specifically intended for storm and combined sewers. Covered also are the results of preliminary field testing of the prototype device as well as extensive controlled laboratory testing using synthetic sewage flows. The results of side-by-side comparative testing of the prototype device and four popular commercial designs is also given, and should be of interest to the reader of the present report.

ABSTRACT

A brief review of the characteristics of storm and combined sewer flows is given followed by a general discussion of the purposes for and requirements of a sampling program. The desirable characteristics of automatic sampling equipment are set forth and problem areas are outlined.

A compendium of 82 model classes covering over 200 models of commercially available and custom designed automatic samplers is given with descriptions and characterizations of each unit presented along with an evaluation of its suitability for a storm and/or combined sewer application.

A review of field experience with automatic sampling equipment is given covering problems encountered and lessons learned. A technical assessment of the state-of-the-art in automatic sampler technology is presented, and design guides for development of a new, improved automatic sampler for use in storm and combined sewers are given.

This report was submitted in partial fulfillment of Contract Number 68-03-0409 under the sponsorship of the Municipal Environmental Research Laboratory (formerly the National Environmental Research Center), Office of Research and Development, United States Environmental Protection Agency. Work was completed in February, 1975.

CONTENTS

CONTENTS (Cont'd)

FIGURES

FIGURES (Cont'd)

TABLES

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS (Cont'd)

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS (Cont'd)

INDEX OF CUSTOM DESIGNED SAMPLERS

ACKNOWLEDGEMENTS

The cooperation and support of the commercial manufacturers and suppliers of automatic liquid sampling equipment and their representatives is acknowledged with sincere thanks. They supplied information about their current products and proposed new developments, took time to answer questions and provide operational insights, and made the preparation of much of this report possible. All equipment illustrations were provided by the respective manufacturers, and appreciation for their use in this report is hereby acknowledged.

The encouragement, cooperation, and support of users of automatic samplers, including EPA Surveillance and Analysis Division personnel (and especially Messrs. W. J. Keffer - Region VII, M. D. Lair - Region IV, and F. P. Nixon - Region II), is deeply appreciated. They freely gave of their time to discuss problems with individual pieces of equipment, to provide insights into many difficulties of field use, and to share their views on where equipment improvements were desired.

The support of this effort by the Storm and Combined Sewer Section (Edison, New Jersey) of the EPA Municipal Environmental Research Laboratory, Cincinnati, Ohio, and especially Mr. Richard Field and Mr. Hugh E. Masters, Project Officers, for their guidance, suggestions and inputs, and thorough manuscript review is acknowledged with gratitude.

SECTION I

CONCLUSIONS

1. An automatic liquid sampler is one tool of several commonly employed for the characterization of a flow stream. Its selection must be based upon consideration of the overall sampling program to be undertaken, the characteristics of the flows to be sampled, the physical characteristics of the sampling sites, and the sample analyses that are available and desired.

2. In view of the large number of highly variable parameters associated with the storm and combined sewer application, no single automatic sampler can exist that is universally applicable with equal efficacy. Some requirements are conflicting, and a careful series of trade-off studies is required in order to arrive at a "best" selection for a particular program. Such a selection may not be well suited for a different program, and a systems approach is required for either the selection or design of automatic sampling equipment for storm and combined sewer application.

3. The proper selection of sampling sites can be as important as the selection of sampling methods and equipment. A clear understanding of the data requirements and ultimate use is necessary as is a familiarity with the sewer system to be examined.

4. Over 40 prospective manufacturers of automatic liquid sampling equipment were contacted. Although some omissions undoubtedly have been made, it is felt that all major principles and techniques commercially available today have been included. These automatic samplers have been individually described and evaluated for application in a storm and/or combined sewer sampling program. Most of the units surveyed were not designed for such use, and many manufacturers do not recommend them for such applications.

5. Although certain commercially available automatic samplers may be suitable for certain storm and/or combined sewer sampling programs, no single unit appears eminently suitable for such an application. Improvements in intake design, sample intake and transport velocity, line sizes, and sample capacity appear warranted.

6. A number of custom designed, one-of-a-kind automatic samplers were reviewed and evaluated for application in a storm and/or combined sewer sampling program. Although some of these embodied fairly clever innovations, they were generally tailored around local peculiarities of the application site or program. None was deemed ideally suited for broad scale use as a storm or combined sewer sampling unit.

7. Field experience with automatic sampling equipment was reviewed with emphasis on recent EPA projects. Leaks in vacuum operated units; faulty automatic starters; inlet blockage and line plugging; limited suction lift; low transport velocities; complicated electrical systems; and failures of timers, micro-switches, relays and contacts, and reed switches were among the difficulties frequently encountered.

8. There is a plethora of sampling devices available in the marketplace today. These automatic samplers are of various designs and capabilities and incorporate both good and poor features. There are numerous claims (and counter-claims) made by the various manufacturers and their representatives, including limited data in certain instances, as to the efficacy of one particular piece of equipment (i.e., design approach) or another. The present state of affairs can be summarized as follows:

   (a) Comparisons of water quality data gathered using different commercially available samplers demonstrate without question that there can be marked differences in results obtained with different types of equipment;

   (b) Different wastewater flow characteristics call for different equipment requirements in order to assure representative sampling;

   (c) The results of manual sampling are extremely methodologically dependent, and data strongly indicate that they may or may not be representative of the wastewater flow in question; and

   (d) No satisfactory way has yet been developed to meaningfully and uniformly evaluate the performance capabilities of automatic sample collection systems.

9. One of the greatest problem areas is in the design of a sampler intake that can gather a representative sample, even in a stratified flow condition, and at the same time be relatively invulnerable to clogging or damage due to solids or debris in the flow stream. Separate considerations are required for intakes to be used for sampling floatables (especially oil and grease) or coarser bottom solids including bed load. Some generally desirable sampler intake characteristics include:

   (a) Sample intake velocity should equal or exceed the velocity of the stream being sampled;

   (b) Intake geometry such as diameter, beveled inside or outside, radiused, etc., is not critical insofar as sampling representativeness is concerned;

   (c) Gravity filled intakes usually have a varying sample intake velocity which is undesirable in most instances; and

   (d) The sampler intake should prevent ingestion of unwanted material that could clog or damage other portions of the sampler.

10. Selection of the sample gathering method to be used is more site dependent than any other design attribute. The requirement to minimize obstructions to the flow eliminates most mechanical and forced flow designs from consideration. The suction lift gathering method appears to offer the most advantages and flexibility overall. The pumping portion of the unit should be separable from the remainder of the device for use at sites that exceed the recommended lift of the pump. The first flow of suction lift devices should be returned to waste unless it is part of a large sample.

11. All sample transport lines should be large enough to minimize clogging, yet small enough to assure adequate transport velocity for the largest suspended solids to be sampled. For the storm and combined sewer application, minimum line sizes of 0.95-1.27 cm (3/8-1/2 in.) inside diameter appear desirable. Minimum transport velocities of 0.6-0.9 m/s (2-3 fps) would appear warranted. The sampling train should be free of internal constrictions due to valves, fittings, etc., and have a minimum of twists and bends. It is desirable for the sample to be carried under pressure all the way to its container.

12. Composite samplers cannot represent the time history of a storm event, and consequently, discrete samplers are more often desired. The quantity of sample required is dependent upon the subsequent analyses to be performed, but at least a liter is generally desired. The sample containers should either be easy to clean or disposable. Provision for cooling the samples until they can be taken to the laboratory should be included. Immersion-proof construction is advantageous.

13. The sampler should be capable of accepting automatic start signals from some external sensor. It should have an internal timer and also be capable of being paced by an external flowmeter. For composite samplers particularly, the sample volume should be constant and not vary with lift, water level, etc. Solid-state electronics appear desirable.

SECTION II

RECOMMENDATIONS

1. There is an urgent need for determining the capabilities of various types of sample collection systems to gather representative samples of wastewater flows over a wide range of characteristics. This must be done under controlled conditions if results are to be quantified in any way other than as relativistic comparisons. It is recommended that a number of sample collection systems of the types that represent the majority of present day equipment be assembled and tested under controlled laboratory conditions representing a wide range of wastewater flow characteristics.

2. There is at present no well-defined manual sampling protocol. It is recommended that equipment and procedures be developed that will allow representative samples to be gathered from a variety of sites under a wide range of wastewater flow characteristics.

3. There are no specific guides to aid a would-be purchaser of automatic wastewater sampling equipment generally available at the present time. It is recommended that performance specifications and standard testing and acceptance procedures be developed for a number of classes of wastewater, including stormwater and combined sewage.

4. Representative sampling of bed load and floatables (including oil and grease) continues to be an extremely difficult problem. It is recommended that a program to develop equipment that is suitable for these purposes be initiated in the near future.

5. In view of the potential for increase in commercially available equipment and changes and improvements introduced by manufacturers subsequent to the publication of this report, it is recommended that it be updated in two years.

SECTION III

INTRODUCTION

"By a small sample we may judge of the whole."

Cervantes (1605)

Since the very beginnings of primitive man's existence he has been faced with the necessity to sample, his first experiences probably being in the area of food and water selection. The need to sample arises from a data requirement that is necessary in order to make some judgmental decision and presumes the unavailability of the whole. If the data which are to be derived from the sample are to be efficacious in terms of the judgmental decision to be made however, it is necessary that the sample be truly representative of the whole, at least insofar as those parameters which are of interest are concerned. It is this requirement, which arises from the nature of the data sought, that must be the overriding consideration in any sampling effort.

As the civilization of man continued, the exigencies of social awareness and community led to cooperative sampling and judgmental decisions affecting others as well as the sampler himself. In particular, man's requirement for water to maintain his existence and his concern for the quality of this water have partially shaped the course of history and given rise to more formal sampling programs for the common good. The records of ancient civilizations attest to the difficulties man has experienced in obtaining an adequate supply of water, protecting its quality, dealing with sediment transport in natural water courses, and the like. An excellent historical review of water sampling, especially as related to suspended sediment, is given in (1). Suffice it to note here that despite the fact that the first sampling for water quality is lost in the antiquity of man's development, it was not until the early part of the nineteenth century that documentation can be found of the formal sampling efforts of Gorsse and Subuors in the Rhone River in 1808 and 1809.

From such humble beginnings, reinforced by technology and man's increased awareness of his environment and his need to protect it, have arisen even more demanding requirements for water sampling programs and for equipment to carry them out. Today a large number of companies have been formed to produce sampling equipment, and it is to their products that much of the present report will be directed.

PURPOSE AND SCOPE

This report is intended to present a current review of the state-of-the-art and assessment of sampling equipment and techniques. Particular emphasis has been placed on automatic liquid samplers which are commercially available today in the American marketplace. These are described and evaluated in terms of their suitability for use in storm or combined sewer applications. However, a sampling device which is suitable for such applications will most likely suffice for any other municipal wastewater application as well. By collecting and presenting such a review it is hoped that shortcomings and limitations of these devices for such applications can be overcome and that this report can serve as a springboard for the development of new and/or improved devices. In order to assess the probable effectiveness of an existing device for sampling sewage in storm sewers and/or combined sewers, or to select criteria for the design of a new or improved device, consideration of the character of such sewers and sewage is essential. Questions to be considered are: What are their general characteristics? What are the usual flow modes found in such sewers? How do the pollutant materials carried in the sewers vary with time and location?

GENERAL CHARACTER OF SEWAGE

Knowledge of the character of the urban environment leads one to the expectation that stormwater draining from it will be of poor quality. Washings from the sidewalks, streets, alleys, and catch basins are a part of the runoff and include significant amounts of human and animal refuse. In industrial areas, chemicals, fertilizers, coal, ores, and other products are stockpiled exposed to rainfall, so that a significant quantity of these materials appears in the runoff. Extreme quantities of organic materials such as leaves and grass cuttings often appear in storm sewers. In the fall, such sewers at times become almost completely filled with leaves. Often during storms large boards, limbs, rock, and every imaginable kind of debris appear in the sewers, probably as a result of breaks in the sewers and/or accessory equipment designed to screen out the larger items. One of the heaviest pollution loads is that of eroded silts and sediments washed from the land surface. Much of this is from construction areas where the land has been disturbed prior to completion of streets and buildings and reestablishment of plant life. Finally, a significant amount of solids found in storm runoff originates as dustfall from air pollution. According to studies made in Chicago (2), about 3 percent of the total solids load has its source in dustfall.

General observation of the polluted nature of storm runoff from urban areas is supported by a number of studies made in several large cities in the United States, and in Oxney, England; Moscow and Leningrad, U.S.S.R.; Stockholm, Sweden; and Pretoria, South Africa. In (2) the American Public Works Association states, "Stormwater runoff has been found in many instances to be akin to sanitary sewage in its pollutional characteristics and in a few instances some parameters of pollution are even greater". Table 1, which is taken from (5), contains selected data on the characteristics of urban stormwater.

In some areas, sewers classed as storm sewers are, in fact, sanitary or industrial waste sewers due to unauthorized and various other connections made to them. This condition may become so aggravated that a continuous flow of sanitary sewage flows into the receiving stream. Wastes from various commercial and industrial enterprises are often diverted to these so-called storm sewers. A rather common pollutant is the flushings from oil tanks.

Combined sewers are designed and constructed to carry both stormwater and sanitary sewage and/or industrial wastes. Therefore, sewage in them has all the pollutional aspects of storm runoff as described above, but also includes the pollution load of domestic wastes.

Where industrial wastes are contributed also, a very complex sewage, with respect to both varied flow rate and pollution load, is created. The task of sampling and analyzing this creation with reasonable accuracy becomes an extremely difficult one.

Because of normal leaks at joints, pipe breaks, loss of manhole covers, and other unplanned openings to them, separate sanitary sewers often carry large flows of storm runoff and/or infiltrate. This usually occurs in sections of high ground water level, or where the sewer line is constructed in, or adjacent to, a stream bed. Under such conditions, these sewers have much the same character as combined sewers, and require the same types of sampling equipment and methods.

FLOW MODES

Storm sewers, during periods of no rainfall, often carry a small but significant flow. This may be flow from ground water, or "base flow", which gains access to the sewer from unpaved stream courses. Such base flow may appear as runoff from parks or from suburban areas where there are open drains leading to the storm sewer.

TABLE 1. Characteristics of Urban Stormwater*

Characteristic	Range of Values
BOD_5 (mg/l)	1->700
COD (mg/l)	5-3,100
TSS (mg/l)	2-11,300
TS (mg/l)	450-14,600
Volatile TS (mg/l)	12-1,600
Settleable solids (ml/l)	0.5-5,400
Organic N (mg/l)	0.1-16
NH_3N (mg/l)	0.1-2.5
Soluble PO_4 (mg/l)	0.1-10
Total PO_4 (mg/l)	0.1-125
Chlorides (mg/l)	2-25,000†
Oils (mg/l)	0-110
Phenols (mg/l)	0-0.2
Lead (mg/l)	0-1.9
Total coliforms (no./100 ml)	$200-146 \times 10^6$
Fecal coliforms (no./100 ml)	$55-112 \times 10^6$
Fecal streptocci (no./100 ml)	$200-1.2 \times 10^6$

* Taken from Reference 5.

† With highway deicing.

Unfortunately, much of the flow in storm sewers during periods of no rainfall is composed of domestic sewage and/or industrial wastes. Where municipal ordinances concerning connections to sewers are not rigidly enforced, it appears to be reasonably certain that unauthorized connections to storm sewers will appear. In some cases, the runoff from septic tanks is carried to them. Connections for the discharge of swimming pools, foundation drains, sump pumps, cooling water, and pretreated industrial process water to storm sewers are permitted in many municipalities, and contribute to flow during periods of no rainfall.

Storm runoff is the excess rainfall which runs off the ground surface after losses resulting from infiltration to ground water, evaporation, transpiration by vegetation, and ponding occur. A small portion of the rainfall is held in depression storage, resulting from small irregularities in the land surface. The quantity, or rate of flow, of such runoff varies with intensity, duration, and areal distribution of rainfall; character of the soil and plant life; season of the year; size, shape, and slope of drainage basin, and other factors. Ground seepage loss varies during the storm, becoming less as the ground absorbs the water. The period of time since the previous, or antecedent, rainfall significantly affects the storm runoff.

In general, storm runoff is intermittent in accordance with the rainfall pattern for the area. It is also highly variable from storm to storm and during a particular storm.

The design capacity of storm sewers is based on the flow due to a storm occurring, on the average, once in a selected number of years (recurrence interval). Usually a recurrence interval not greater than 10 years is selected for the design of underground storm sewers. As a result, the design capacity of the sewer is exceeded at comparatively frequent intervals, resulting in surcharging and flooding of the overlying surface.

Flow in combined sewers during periods of no rainfall is called dry-weather flow. This is the flow of sanitary sewage and/or industrial wastes, and often includes infiltrated ground water. As the sewer is designed, dry-weather flow generally includes only a small portion of the total sewer capacity, on the order of 10% in the larger sewer sizes. However, due to overloading in many rapidly developing areas, the dry-weather flow sometimes requires a much larger percentage of total capacity. The storm runoff portion of the flow in combined sewers is as described above for storm sewers. However, the design capacity for carrying storm runoff is probably less than is usually provided for storm sewers.

Sewers for intercepting dry-weather flow from a system of combined sewers for transport to a point for treatment or disposal have been designed for enough capacity to include a portion of the stormwater in the system. In the United States, this interceptor capacity ranges from two to four times the dry-weather flow. A weir or other regulating device controls the flow of sewage to the interceptor by diverting the flow above a pre-selected stage to an overflow line. The excess flows, or overflows, are carried to some external channel, such as a creek or river. Thus, raw sewage is carried to the streams with storm runoff during periods of rainfall.

VARIABILITY OF POLLUTANT CONCENTRATION

The pollutant concentration in storm and combined sewers is highly variable, both with respect to the time and with the position in the sewer cross-section. This is true during periods of no rainfall as well as during storm runoff periods, but usually to a lesser extent.

Variability with Time

Probably the most constant character of pollutants occurs in storm sewers when all flow is base flow derived from ground water. Because of the slow movement of water through the ground, changes in concentration of pollutants occur only during relatively long time periods. Where unauthorized connections of domestic sewage and industrial waste lines to storm sewers are found, rapid fluctuations of concentration with time may occur. The domestic sewage constituent varies with time of day, with season of the year, and probably over long-term periods. Industrial wastes vary with specific processes and industries. Very rapid changes may occur with plant shift changes and with process dynamics. Conditions on weekends and holidays may be very different from those on regular work days.

Observation and experience have demonstrated that the heaviest concentration of suspended solids during periods of storm runoff usually occurs during the early part of the storm. At this time, the stage is rising and accumulated dry-weather solid residue is being flushed from the sewers and washed and eroded from the tributary land areas. As runoff recedes, the sewer and land area surfaces exposed to flow are reduced, the flow velocities which serve to flush and erode are decreased, and the more easily dislodged solids have been acted upon. Thus, suspended material is reduced in concentration. This pattern of variation may not be followed during a period of storm runoff which immediately follows a previous storm runoff period because the land surface and sewer lines are relatively clean.

Pollutants derived from point sources, such as those from stockpile drainage, vary at the sampling location with time of travel from the source to the point of observation. Maximum concentration may occur after the peak of storm runoff. It is conceivable that there would be no contribution from some point sources during a specific storm because of areal variation of rainfall in the basin.

The variability of concentration of pollutants in combined sewer dry-weather flow is similar to that of storm sewers having unauthorized connections of domestic sewage and/or industrial waste lines. The fluctuations in domestic sewage and industrial waste concentration are discussed above.

<u>Variability with Position in the Sewer Cross-Section</u>

Many factors influence the variability of composition with position in the sewer cross-section. Among them are:

(a) Turbulent flow (as opposed to laminar) which occurs at the velocities and with the boundary conditions found in sewers, is particularly high during periods of storm runoff. A description of these two states of flow is given by Chow (3), as follows:

> "Depending on the effect of viscosity relative to inertia, the flow may be laminar, turbulent, or transitional. In laminar flow, the water particles appear to move in definite smooth paths, or streamlines, and infinitesimally thin layers of fluid seem to slide over adjacent layers. In turbulent flow, the water particles move in irregular paths which are neither smooth nor fixed but which in the aggregate still represent the forward motion of the entire stream."

(b) Varying velocities within the section, with higher velocities near the surface and lower velocities near the bottom. Average velocity in the vertical is at about

0.6 depth. Velocities are higher near the center of the pipe or conduit than near the outer boundaries. Such velocity distributions are generally characteristic of open-channel flow conditions, but are not all necessarily valid when the sewer becomes surcharged.

(c) The tendency for flows transporting materials of different density, and having different temperatures, to remain separate from each other for quite some distance following their convergence.

(d) The fact that substances in solution may well behave independently of suspended particles. Little is known of the lateral dispersion of solutions in sewage. Conversions from solution to suspension, and the reverse, would occur under some conditions.

(e) Vertical drops, chutes, or hydraulic jumps a short distance upstream from the section which will produce violent turbulence, resulting in improved distribution of suspended solids in the cross-section.

Suspended solids heavier than water have their lowest concentrations near the surface, and the concentration increases with depth. Near the bottom of the sewer may occur a "bed load" composed almost entirely of heavier solids. This may "slide" along the bottom or, with insufficient flow velocity, may rest on the bottom. As the velocity and turbulence increase, the "bed load" may be picked up and suspended in the sewage.

At the beginning of storm runoff, as water picks up solids which have accumulated in the sewer upstream during periods of no rainfall, the flow may be composed largely of sewage solids, or "bed load", which appears to be pushed ahead by the water.

Suspended materials lighter than water, such as oils and greases, float on the surface, as do leaves, limbs, boards, bottles, and cloth and paper materials. Other small, light particles are moved randomly within the flow by turbulence. These may be well distributed in the cross-section without significant effect of variable velocity within the section.

Larger, heavier suspended and floating solids tend to move to the outside of a horizontal curve as a result of centrifugal inertia force. Particles with a specific gravity much less than 1.00 may tend to move toward the inside of the curve. Because the effect of curvature on flow often continues downstream a considerable distance, it is probable that a normal distribution of suspended matter is not found on a curve, or downstream for a distance of several sewer widths.

Incoming sewage from an upstream lateral with different density and temperature may not mix well, and often flows for long distances without combining with the main body of the sewer. The appearance may be of two streams flowing side-by-side, each with different quality characteristics. A sample taken from either stream is not representative of the entire stream character.

SECTION IV

REQUIREMENTS AND PURPOSES OF SAMPLING

Sampling of sewage is performed to satisfy various purposes and requirements. These include the planning, design and operation of facilities for the control and treatment of sewage; the enforcement of water quality standards and objectives; and general research to increase our knowledge of the characterization of sewage.

Development of a program of sampling is presently based on a limited number of properties and constituents for which analyses are made. The type of sample collected depends on the purpose of the program, and on both technical and economic considerations.

COMMON PROPERTIES AND CONSTITUENTS

Although the constituents of sewage include most substances known to man, there are a limited number of measurements made to determine the more common properties and constituents. Most of these are shown in Table 2, which is taken from (4).

It is a practical impossibility either to perform instant analyses of a sample on the spot or to completely and unequivocally preserve it for subsequent examination. Preservative techniques can only retard the chemical and biological changes that inevitably continue following extraction of the sample from its parent source. In the former case, changes occur that are a function of the physical conditions - metal cations may precipitate as hydroxides or form complexes with other constituents; cations or anions may change valence states under certain reducing or oxidizing conditions; constituents may dissolve or volatize with time, and so on. In the latter case, biological changes taking place may change the valence state of an element or radical; soluble constituents may be converted to organically bound materials in cell structures; cell lysis may result in release of cellular material into solution, etc. Preservation methods are generally limited to pH control, chemical addition, and refrigeration. Recommendations for preservation of samples according to the measurement analysis to be performed are given in Table 2.

Figures given for sample size are generally large. For example, much smaller samples are needed with use of various systems of automatic analysis. The Technicon Auto-Analyzer

TABLE 2. Properties and Constituents of Sewage

Measurement	Vol Req (ml)	Container	Preservative	Holding Time[6]
Acidity	100	P,G[2]	Cool, 4°C	24 Hrs
Alkalinity	100	P,G	Cool, 4°C	24 Hrs
Arsenic	100	P,G	HNO_3 to pH <2	6 Mos
BOD	1000	P,G	Cool, 4°C	6 Hrs[3]
Bromide	100	P,G	Cool, 4°C	24 Hrs
COD	50	P,G	H_2SO_4 to pH <2	7 Days
Chloride	50	P,G	None Req	7 Days
Chlorine Req	50	P,G	Cool, 4°C	24 Hrs
Color	50	P,G	Cool, 4°C	24 Hrs
Cyanides	500	P,G	Cool, 4°C NaOH to pH 12	24 Hrs
Dissolved Oxygen				
Probe	300	G only	Det on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Fluoride	300	P,G	Cool, 4°C	7 Days
Hardness	100	P,G	Cool, 4°C	7 Days
Iodide	100	P,G	Cool, 4°C	24 Hrs
MBAS	250	P,G	Cool, 4°C	24 Hrs
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH <2	6 Mos
Suspended			Filter on site	6 Mos
Total	100		HNO_3 to pH <2	6 Mos
Mercury				
Dissolved	100	P,G	Filter HNO_3 to pH <2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Kjeldahl	500	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	100	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	50	P,G	Cool, 4°C	24 Hrs[4]
NTA	50	P,G	Cool, 4°C	24 Hrs
Oil and Grease	1000	G only	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
Organic Carbon	25	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
pH	25	P,G	Cool, 4°C Det on site	6 Hrs[3]
Phenolics	500	G only	Cool, 4°C H_3PO_4 to ph <4 1.0g $CuSO_4$/l	24 Hrs
Phosphorus				
Orthophosphate, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Hydrolyzable	50	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Total	50	P,G	Cool, 4°C	24 Hrs[4]
Total, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Residue				
Filterable	100	P,G	Cool, 4°C	7 Days
Nonfilterable	100	P,G	Cool, 4°C	7 Days
Total	100	P,G	Cool, 4°C	7 Days
Volatile	100	P,G	Cool, 4°C	7 Days
Settleable Matter	1000	P,G	None Req	24 Hrs
Selenium	50	P,G	HNO_3 to pH 2	6 Mos
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P,G	Cool, 4°C	24 Hrs[5]
Sulfate	50	P,G	Cool, 4°C	7 Days
Sulfide	50	P,G	2 ml zinc acetate	24 Hrs
Sulfite	50	P,G	Cool, 4°C	24 Hrs
Temperature	1000	P,G	Det on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs
Turbidity	100	P,G	Cool, 4°C	7 Days

NOTES:

1. Taken from Reference 4.
2. Plastic or Glass.
3. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data hould indicate the actual holding time.
4. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/ℓ, especially if a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
5. If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.
6. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.

requires samples of less than 30 ml, and is recommended for total alkalinity, chloride, cyanide, fluoride, total hardness, nitrogen (ammonia), nitrogen (Kjeldahl), nitrogen (nitrate - nitrite), phosphorus, sulfate, COD, and others.

TYPE OF SAMPLE

The type of sample collected depends on a number of factors such as the rate of change of flow and of the character of the sewage, the accuracy required, and the availability of funds for conducting the sampling program. All samples collected, either manually or with automatic equipment, are included in the following types:

1. Manual "grab" samples which are obtained by dipping a container into the sewer and bringing up a sample of wastewater. Containers are sometimes devised to grab a sample at a stationary depth or so that a sample integrated from bottom to top of the stream is collected. Water flows gradually into the container as it passes through the flow.

2. Automatic "grab", or discrete, samples which are collected at selected intervals, and each sample is retained separately for analysis. Usually each sample is collected at a single point in the sewer cross-section. However, in a few instances samplers with multiple ports have been used to allow simultaneous collection from several points in the cross-section.

3. Simple composite samples, which are made up of a series of smaller samples (aliquots) of constant volume (Vc) collected at regular time intervals (Tc) and combined in a single container. The series of samples is collected over a selected time period, such as 24 hours, or during a period of storm runoff, for example. The simple composite represents the average condition of the waste during the period only if the flow is constant.

4. Flow-proportional composite samples, which are collected in relation to the flow volume during the period of compositing, thus indicating the "average" waste condition during the period. One of two ways of accomplishing this is to collect samples of equal volume (Vc), but at time intervals (Tv) that are inversely proportional to the volume of flow. That is, the

time interval between samples is reduced as the volume of flow increases, and a greater total sample volume is collected. Flow proportioning can also be achieved by increasing the volume of each sample collected in proportion to the flow (Vv), but keeping the time interval between samples constant (Tc).

5. Manually composited samples which are obtained, where recording flow records are available, from fixed volume "grab", or discrete, samples collected at known times and proportioned manually to produce a flow proportioned composite sample.

6. Sequential composite samples, which are composed of a series of short-period composites, each of which is held in an individual container. For example, each of several samples collected during a 1-hour period may be composited for the hour. The 24-hour sequential composite is made up from the individual 1-hour composites.

ADEQUACY OF A SAMPLING PROGRAM

The adequacy of a sampling program depends largely on the optimum selection of sampling sites. Both the program cost and its effectiveness in collecting samples representative of the character of sewer flows are seriously affected by the care exercised in site selection. Similarly, the kinds of samplers selected determine the adequacy of the program with respect to obtaining suitable data for the needs of the particular sampling program.

In most cases, use of mathematical statistical analysis for determining the probable errors in the data obtained by sewer sampling is not practical. A single "grab" sample of 1 liter, even in dry-weather flows, is not necessarily indicative of the average character of the flow. With respect to an instant of time, the indicated character of the sewage may vary with the point in the cross-section from which it was "grabbed". One must consider the universe of sewage volumes represented by the sample. At the instant of sampling, it may be all the liters of sewage in the cross-section at that instant. But, if the sewage is not thoroughly mixed, we know that the sample is biased, that is, it may represent only a portion of the 1-liter samples in the cross-section, possibly only those near the surface of the flow.

In periods of storm runoff, it is known, if only by observation, that the character of the sewage is continually changing, possibly with great rapidity. There, then, becomes no single universe represented by the "grab" sample. Instead, there is an infinite number of universes, and the single "grab" sample is without meaning in determining the character of the sewage. A similar situation exists in the case of sewers carrying industrial wastes. The variability of flow and of quality parameters during periods of storm runoff are illustrated in figure 1, wherein quantity and quality data for a storm on the Bloody Run sewer watershed at Cincinnati, Ohio, are graphically presented.

It becomes apparent, then, that a large number of samples is required to adequately characterize the character of sewage in a combined sewer during and immediately after a storm event, particularly if the character is to be related to flow rate. Compositing the samples in proportion to flow rate may determine the average character of the sewage during the period of compositing. However, it does nothing to describe the pattern of changes which may occur during that period.

Awareness of the general character of sewer flows and of flow modes in storm sewers and combined sewers, and knowledge of the variability of pollutant concentration, leads to an understanding of how best to select sites for sampling. Some of the considerations in making such selections are:

1. Maximum accessibility and safety -- Manholes on busy streets should be avoided if possible; shallow depths with manhole steps in good condition are desirable. Sites with a history of surcharging and/or submergence by surface water should be avoided if possible. Avoid locations which may tend to invite vandalism.

2. Be sure that the site provides the information desired -- Familiarity with the sewer system is necessary. Knowledge of the existence of inflow or outflow between the sampling point and point of data use is essential.

3. Make certain the site is far enough downstream from tributary inflow to ensure mixing of the tributary with the main sewer.

4. Locate in a straight length of sewer, at least six sewer widths below bends.

5. Locate at a point of maximum turbulence, as found in sewer sections of greater roughness and of probable higher velocities. Locate just downstream from a drop or hydraulic jump, if possible.

6. In all cases, consider the cost of installation, balancing cost against effectiveness in providing the data needed.

Presently available sewage samplers have a great variety of characteristics with respect to size of sample collected, lift capability, type of sample collected (discrete or composite), material of construction, and numerous other both good and poor features. A number of considerations in selection of a sampler are:

1. Rate of change of sewage conditions
2. Frequency of change of sewage conditions
3. Range of sewage conditions
4. Periodicity or randomness of change
5. Availability of recorded flow data
6. Need for determining instantaneous conditions, average conditions, or both
7. Volume of sample required
8. Need for preservation of sample
9. Estimated size of suspended matter
10. Need for automatic controls for starting and stopping
11. Need for mobility or for a permanent installation
12. Operating head requirements.

Because of the variability in the character of storm and/or combined sewage, and because of the many physical difficulties in collecting samples to characterize the sewage, precise characterization is not practicable, nor is it possible. In recognition of this fact, one must guard against embarking on an excessively detailed sampling program, thus

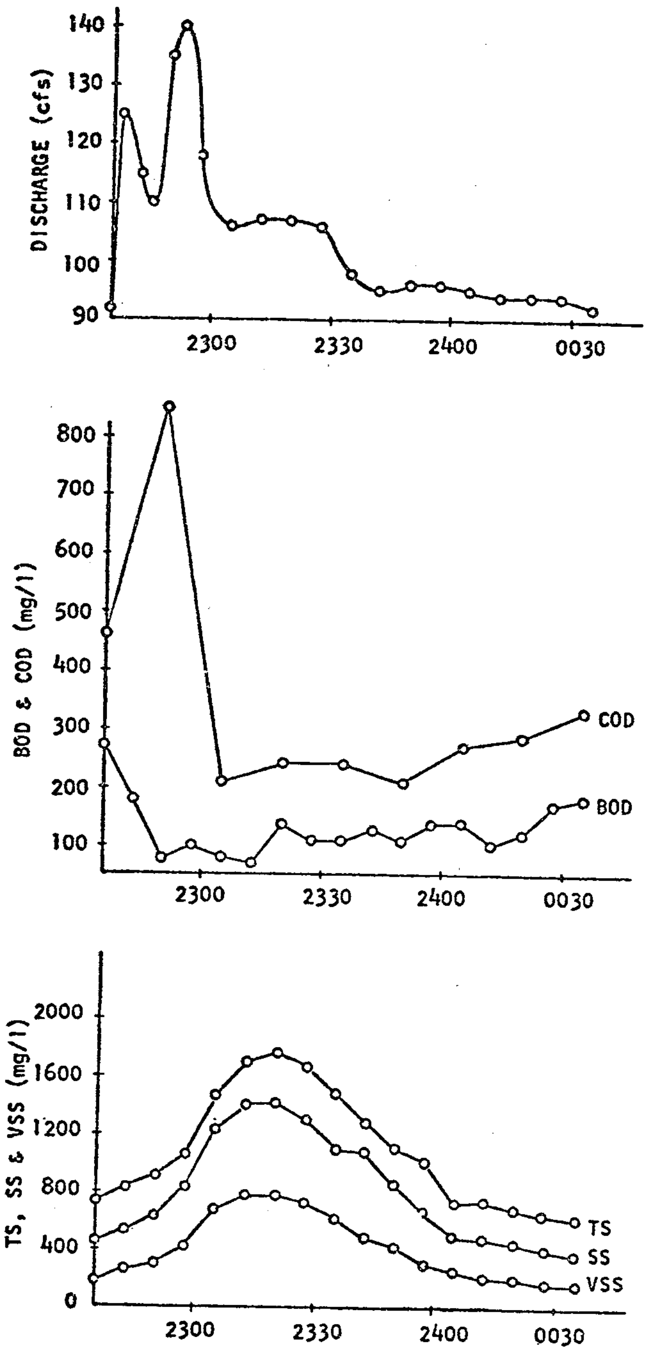


Figure 1. Runoff Quantity and Quality Data, Bloody Run Sewer Watershed*

* Taken from Reference 19

increasing costs, both for sampling and for analyzing the samples, beyond costs that can be considered sufficient for conducting a program which is adequate for the intended purpose.

A careful study of costs should be made prior to commencing a program of sampling, balancing cost against the number of samples and analyses required for adequate characterization of the wastewater. As the program progresses, current study of the results being obtained may make it reasonable to reduce or increase the number of samples collected.

The unit cost of handling and analyzing samples can often be reduced by careful planning and scheduling of field work, and by coordination with laboratory requirements. If the volume of samples is large, and the program is to continue over a long time period, consideration should be given to use of equipment for automatic analyses and in-situ monitoring. A number of equipment types and methods, such as specific ion electrodes and probes, are available for these purposes. As an example, approximately 15 samples per hour can be analyzed for chloride, using the Technicon Auto-Analyzer. Samples of only 4 ml volume are required. Caution is needed in selecting equipment suitable for a series of parameters for which analyses are to be made. With some equipment, the time required for making necessary adjustments between each of a series of tests may counteract the rapidity of making analyses for a single parameter.

SPECIFIC SAMPLING PURPOSES AND REQUIREMENTS

Sampling programs are set up for various purposes for which the requirements are not necessarily the same. That is, parameters important to one kind of project may not be needed for another project having a different objective. As an example, parameters of interest for operation of facilities for control and treatment of stormwater and/or combined sewage may be more limited in number than those needed for planning and design of the facilities. In the operation stage, experience at the particular location and with the unique facilities, may have demonstrated a more limited sampling need. On the other hand, where stormwater is combined with industrial wastes, analyses for additional parameters may be required.

A number of physical, chemical, combinations of physical-chemical, and biological methods have been considered in the Storm and Combined Sewer Pollution Control Program of the EPA for treatment of stormwater and combined sewage. In most cases, some type of control such as reduction of instantaneous peak flows is essential for practical application of treatment methods. These include storage facilities of many types, flow regulation and routing, and remote flow and overflow sensing and telemetering.

Specific processes which have been investigated are (5):

Physical - (1) Fine mesh screening; (2) Microstrainer; (3) Screening/Dissolved-air flotation; (4) High-rate single-, dual-, or tri-media filtration; (5) Swirl and helical separation; (6) Tube settlers; etc.

Chemical - (1) Coagulant and polyelectrolyte aids for sedimentation, filtration, flotation and microstraining; (2) Chemical oxidation and use of ozone for oxidation; and (3) Disinfection -- chlorination, ozonation, high rate application, on-site generation, and use of combined halogens (chlorine and iodine) and chlorine dioxide.

Physical-Chemical - (1) Screening plus dissolved-air flotation with flotation aids; (2) Screening - chemical flocculation - sedimentation - high-rate filtration; (3) Powdered and granular activated carbon adsorption; (4) Chemical flocculation - tube sedimentation - tri-media filtration; and (5) Screening - coagulation - high rate dual-media filtration.

Biological - (1) High-rate plastic and rock media trickling filters; (2) Bio-adsorption (contact stabilization); (3) Stabilization ponds; (4) Rotating biological contactor; and (5) Deep-tank aerobic and anaerobic treatment.

For planning and designing such facilities and processes, and for testing their impact on receiving streams, sampling for certain basic wastewater parameters is essential. In general these include:

1. Biochemical oxygen demand (BOD) - Used to determine the relative oxygen requirement of the wastewater. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants.

2. Chemical oxygen demand (COD) - Provides additional information concerning the oxygen requirement of wastewater. It provides an independent measurement of organic matter in

the sample, rather than being a substitute for the BOD test. For combined sewer overflows and stormwater, COD may be more representative of oxygen demand in a receiving stream because of the presence of metals and other toxicants which are relatively non-biodegradable.

3. Total oxygen demand (TOD) - A recently developed test to measure the organic content of wastewater in which the organics are converted to stable end products in a platinum-catalyzed combustion chamber. The test can be performed quickly, and results have been correlated with the COD in certain locations.

4. Total organic carbon (TOC) - Still another means of measuring the organic matter present in water which has found increasing use in recent times. The test is especially applicable to small concentrations of organic matter.

5. Chloride - One of the major anions in water and sewage. The concentration in sewage may be increased by some industrial wastes, by runoff from streets and highways where salt is used to control ice formation, salt water intrusion in tidal areas, etc. A high chloride content is injurious to vehicles and highway structures, and may contaminate water supplies near the highway.

6. Nitrogen Series - A product of microbiologic activity, is an indicator of sewage pollution, or pollution resulting from fertilizers, automobile exhausts, or other sources. Its presence may require additional amounts of chlorine, or introduction of a nitrogen fixation process, in order to produce a free chlorine residual in control of bacteria.

7. pH - The logarithm of the reciprocal of hydrogen ion activity. State regulations often prescribe pH limits for effluents from industrial waste treatment plants. Provides a control in chemical and biological treatment processes for wastewater.

8. <u>Solids (Total, Suspended, Volatile, and Settleable)</u> - Usually represent a large fraction of the pollutional load in combined sewage. Inorganic sediments, in a physical sense, are major pollutants, but also serve as the transporting or catalytic agents that may either expand or reduce the severity of other forms of pollution (6).

9. <u>Oil and Grease</u> - Commonly found in sanitary sewage, but also appear in industrial wastes as a result of various industrial processes. Present a serious problem of removal in wastewater treatment facilities.

10. <u>Bacterial Indicators (Total Coliform, Fecal Coliform, Fecal Streptococcus)</u> - Indicate the level of bacterial contamination.

Where more exotic wastes are combined with stormwater and sanitary sewage, additional treatment facilities may be required for the removal of industrial byproducts and nutrients such as cyanide, fluoride, metals, pesticides, nitrogen, phosphorus, sulfate and sulfide. For planning and design of such treatment facilities, additional analyses are required in accordance with the pollutant material expected in the wastewater. This may, in turn, require significant expansion of the sampling program.

Sampling and analyses of wastewater are necessary to the satisfactory operation of treatment plants. Pollutants in the incoming storm sewer or combined sewer are compared with those in the effluent from the treatment plant to determine the effectiveness of the treatment process. Additionally, sampling of the receiving stream before and after treatment/control system installation indicates the benefits gained from the installation. Knowledge of the concentration of pollutants entering the plant can be used also to make adjustments to the treatment process as required. Continuous monitoring of the stream below the treatment/control facility is important to facility operation. Depending on the type or types of treatment process used, the number of parameters required for sampling and analyses is usually less than those required for planning and design. For example, where treatment consists only of sedimentation and chlorination, analyses for oxygen demand, suspended solids, bacterial indicators, and for chlorine residual may be sufficient. If chemicals are used to assist the sedimentation process, determination of pH may be needed. The sampling program can be determined largely in accordance with previous experience and knowledge of the pollutants found.

Sampling programs should start long before installation of combined sewer overflow and stormwater treatment/control facilities to establish the objectives of the facilities and to provide necessary design and operation criteria. A much longer time period for sampling may be required than anticipated because of the need to sample during periods of storm runoff, which may be few in drought years.

In some cases, the availability of historical quality data may provide a basis for prediction of future character for planning and design purposes. Dependence on such predicted data is not sufficient, and collection of current data is required to verify predictions and, later, to measure facility effectiveness.

Programs of sampling and analyses of wastewater in storm and/or combined sewers are frequently used for the enforcement of water quality standards or objectives. Such programs provide information leading to the source of various types of pollution. Often, the wastewater is continually monitored to check on compliance with pollution control laws and regulations. The range of different parameters to be measured for these purposes is continually expanding with the development of new processes. There appears to be no limit to future analytical requirements.

SECTION V

DESIRABLE EQUIPMENT CHARACTERISTICS

Having reviewed some of the vagaries of the storm and combined sewer sampling problem in the preceding sections, it is intuitively obvious that a single piece of equipment cannot exist that is ideal for all sampling programs in all storm and combined sewer flows of interest. One can, however, set down some general requirements for sampling equipment that is to be used in the storm or combined sewer application.

EQUIPMENT REQUIREMENTS

The success of an automatic sampler in gathering a representative sample starts with the design of the sampler intake. This obviously will be dependent upon conditions at the particular site where the sample is to be extracted. If one is fortunate enough to have a situation where the sewer flow is homogeneous with respect to the parameters being sampled, then a simple single point of extraction for the sample will be adequate. In the more typical case, however, there is a spatial variation in the concentration of the particular constituent that is to be examined as part of a sampling program, and then the sampling intake must be designed so that the sample which is gathered will be nearly representative of the actual flow. Several different designs have been utilized in an attempt to meet this objective. However, none can be considered as ideal or universally applicable. In a rather comprehensive study reported in (7), the characteristics of the sampler orifice geometry were examined with particular regard to the ability of the sampler to gather a representative sample of suspended solids. Among parameters varied were size of orifice, shape of orifice and intake velocity. All orifices were located in a vertical plate forming part of the wall of the test section of the flume which was used for this study. The sample flow was therefore extracted at right angles to the stream flow. The major conclusion that was reached by the investigators was that, as far as suspended solids were concerned, the geometry of the orifice at most played a secondary role and that the most representative samples were obtained when the sampler intake tube velocity was equal to the free stream velocity. In situations where flow velocity gradients are strongly present, this observation must be taken into account in the design of a proper sampler intake.

The automatic sampler must be capable of lifting the sample to a sufficient height to allow its utilization over a rather wide range of operating heads. It would appear that a minimum sample lift of 3 meters or so is almost mandatory in order to give a fairly wide range of applicability. It is also important that the sample size not be a function of the sample lift; that is, the sample size should not become significantly less as the sample lift increases.

The sample line size must be large enough to give assurances that there will be no plugging or clogging anywhere within the sampling train. However, the line size must also be small enough so that complete transport of suspended solids is assured. Obviously, the velocities in any vertical section of the sampling train must well exceed the settling velocity of the maximum size particle that is to be sampled. Thus, the sample flow rate and line size are connected and must be approached together from design considerations.

The sample capacity that is designed into the piece of equipment will depend upon the subsequent analyses that the sample is to be subjected to and the volumetric requirements for conducting these analyses. However, in general, it is desirable to have a fairly large quantity of material on hand, it being safer to err on the side of collecting too much rather than too little. For discrete samples, 500 mℓ is frequently the bare minimum, and a liter or more is often desirable. For composite samples, at least 4 liters and preferably more should be collected.

The controls on the automatic sampler should allow some degree of freedom in the operation and utilization of the particular piece of equipment. A built-in timer is desirable to allow preprogrammed operation of the equipment. Such operation would be particularly useful, for example, in characterizing the buildup of pollutants in the early stages of storm runoff. However, the equipment should also be capable of taking signals from some flow measuring device so that flow proportional operation can be realized. It is also desirable that the equipment be able to start up automatically upon signal from some external device that might indicate the onset of storm flow phenomena such as an external rain gauge, flow height gauge, etc. Flexibility in operation is very desirable.

A power source will be required for any automatic sampler. It may take the form of a battery pack or clock type spring motor that is integral to the sampler itself. It may be pressurized gas, air pressurized from an external source, or electrical power, depending upon the availability at the site.

In addition to being able to gather a representative sample from the flow, the sampling equipment must also be capable of transporting the sample without pre-contamination or cross-contamination from earlier samples or aliquots and of storing the gathered sample in some suitable way. As was noted in section IV, chemical preservation is required for certain parameters that may be subject to later analyses, but refrigeration of the sample is also required and is stated as the best single means of preservation.

DESIRABLE FEATURES

In addition to the foregoing requirements of automatic sampling equipment, there are also certain desirable features which will enhance the utility and value of the equipment. For example, the design should be such that maintenance and troubleshooting are relatively simple tasks. Spare parts should be readily available and reasonably priced. The equipment design should be such that the unit has maximum inherent reliability. As a general rule, complexity in design should be avoided even at the sacrifice of a certain degree of flexibility of operation. A reliable unit that gathers a reasonably representative sample most of the time is much more desirable than an extremely sophisticated complex unit that gathers a very representative sample 10 percent of the time, the other 90 percent of the time being spent undergoing some form of repair due to a malfunction associated with its complexity.

It is also desirable that the cost of the equipment be as low as practical both in terms of acquisition as well as operational and maintenance costs. For example, a piece of equipment that requires 100 man-hours to clean after each 24 hours of operation is very undesirable. It is also desirable that the unit be capable of unattended operation and remaining in a standby condition for extended periods of time.

The sampler should be of sturdy construction with a minimum of parts exposed to the sewage or to the highly humid, corrosive atmosphere associated directly with the sewer. It should not be subject to corrosion or the possiblity of sample contamination due to its materials of construction. The sample containers should be capable of being easily removed and cleaned; preferably they should be disposable.

For portable automatic wastewater samplers, the list of desirable features is even longer. In a recent EPA publication (8), a number of features of an "ideal" portable sampler are given based upon sampler comparison studies and over 90,000 hours of field experience. Included were:

- Capability for AC/DC operation with adequate battery energy storage for 120-hour operation at 1-hour sampling intervals.
- Suitable for suspension in a standard manhole and still provide access for inspection and sample removal.
- Total weight including batteries under 18 kilograms (40 pounds).
- Sample collection interval adjustable from 10 minutes to 4 hours.
- Capability for collecting both simple and flow-proportional composite samples.
- Capable of collecting a single 9.5ℓ (2.5 gal) sample and/or collecting 500 mℓ (0.13 gal) discrete samples in a minimum of 24 containers.
- Capability for multiplexing repeated aliquots into discrete bottles (i.e., sequential composite).
- Intake hose liquid velocity adjustable from 0.61 to 3 m/sec (2.0 to 10 fps) with dial setting.
- Minimum lift of 6.1 meters (20 feet).
- Explosion proof.
- Watertight exterior case to protect components in the event of rain or submersion.
- Exterior case capable of being locked and with lugs for attaching steel cable to prevent tampering and provide some security.
- No metal parts in contact with waste source or samples.

- An integral sample container compartment capable of maintaining samples at 4°C (39°F) for a period of 24 hours at ambient temperatures up to 38°C (100°F).

- With the exception of the intake hose, capable of operating in a temperature range between -10 to 40°C (14 to 104°F).

- Purge cycle before and after each collection interval and sensing mechanism to purge in event of plugging during sample collection and then collect complete sample.

- Capable of being repaired in the field.

PROBLEM AREAS

The sampler by its design must have a maximum probability of successful operation in the very hostile storm and combined sewer environment. It should offer every reasonable protection against obstruction or clogging of the sampling ports and, within the sampler itself, of the sampling train. It is in a very vulnerable position if it offers any significant obstruction to the flow because of the large debris which are sometimes found in such waters. The unit must be capable of operation under the full range of flow conditions which are peculiar to storm and combined sewers and this operation should be unimpeded by the movement of solids within the fluid flow. If the unit is to be designed for operation in a manhole, it almost certainly should be capable of total immersion or flooding during adverse storm conditions which very frequently cause surcharging in many manhole areas. It is also necessary that the unit be able to withstand and operate under freezing ambient conditions, and that it be able to withstand the high flow velocities and the associated high momentums found in storm and combined sewer flows.

Probably one of the most significant problem areas lies in the attempt to gather a sample that is representative of low as well as high specific gravity suspended solids. The different momentum characteristics call for differing approaches in sampler intake design and in intake velocities. Another problem area arises in a sampling program where it is desirable to sample floatable solids and materials such as oils and greases as well as very coarse bottom solids and bed load proper.

For samples which are to be analyzed for constituents which require chemical fixing soon after the sample is collected, there are other problems. Although it is true that the required amount of fixing agent could be placed in the sample container prior to placing it in the field, for composite samples in particular, where the eventual total sample is built up of smaller aliquots gathered over an extended period of time, the initial high concentrations of the fixing agent as it becomes mixed with the early aliquots may well be such as to render the entire sample unsuitable for its intended purpose.

The precision of the analyses that the sample is to be subjected to should also be kept in mind by the designer of the equipment. For example, in (4) it is noted that 86 analysts in 58 laboratories analyzed natural water samples plus an exact increment of biodegradable organic compounds. At a mean value of 2.1 and 175 milligrams per liter BOD, the standard deviation was plus or minus 0.7 and 26 milligrams per liter, respectively. This points out again the need for the designer to look at the left as well as the right of the decimal point.

Finally, the materials of construction used in the sampling train may well create problems. Absorption of certain pollutants by these materials (especially those of the sample container with its longer contact time) may well result in a non-representative sample. The problem is compounded by the fact that no single material is ideally suited for use with all possible pollutants.

SECTION VI

REVIEW OF COMMERCIALLY AVAILABLE AUTOMATIC SAMPLERS

INTRODUCTION

Although some types of automatic liquid sampling equipment have been available commercially for some time, project engineers continue to design custom sampling units for their particular projects due to a lack of commercial availability of suitable equipment. In the last few years, however, there has been a proliferation of commercial sampling equipment designed for various applications. In the present survey, after a preliminary screening, over 40 prospective sampler manufacturers were contacted. Although a few of these companies were no longer in business, it was much more typical that new companies were being formed and existing companies were adding automatic sampling equipment to their product lines. In addition to their standard product lines, most manufacturers of automatic sampling equipment provide special adaptations of their equipment or custom designs to meet unique requirements of certain projects. Some designs which began in this way have become standard products, and this can be expected to continue.

The products themselves are rapidly changing also. Not only are improvements being made as field experience is gathered with new designs, but attention is also being paid to certain areas that have heretofore been largely ignored. For example, one company is introducing sampling probes that allow gathering oil or various other liquids from the flow surface; solid-state electronics are being used more and more in sampler control subsystems; new-type batteries are offering extended life between charges and less weight; and so on. Table 3 lists the names and addresses of 32 manufacturers who are known to offer standard lines of automatic wastewater sampling equipment. In view of the burgeoning nature of this product area, it is inevitable that some omissions have been made. Obviously, it would be presumptive to state that this survey is complete in every detail. Any manufacturers that have possibly been overlooked or that have (or plan to) introduce new models or changes to existing ones are urged to communicate details about their equipment to the USEPA Project Officer and/or the authors, at the addresses indicated on the title page of this report, so that they can be included in future updates of this work.

In order to facilitate the reader's comparison of the 71 descriptions that are presented covering over 200 models of

TABLE 3. AUTOMATIC WASTEWATER SAMPLER MANUFACTURERS

Bestel-Dean Limited
92 Worsley Road North,
Worsley
Manchester, England M28 5QW

BIF Sanitrol
P.O. Box 41
Largo, Florida 33546

Brailsford and Company, Inc.
Milton Road
Rye, New York 10580

Brandywine Valley Sales Co.
20 East Main Street
Honey Brook, PA 19344

Chicago Pump Division
FMC Corporation
622 Diversey Parkway
Chicago, Illinois 60614

Collins Products Co.
P.O. Box 382
Livingston, Texas 77351

Environmental Marketing
Associates
3331 Northwest Elmwood Dr.
Corvallis, Oregon 97330

ETS Products
12161 Lackland Road
St. Louis, Missouri 63141

Fluid Kinetics, Inc.
3120 Production Drive
Fairfield, Ohio 45014

Horizon Ecology Company
7435 North Oak Park Drive
Chicago, Illinois 60648

Hydra-Numatic Sales Co.
65 Hudson Street
Hackensack, NJ 07602

Hydraguard Automatic
Samplers
850 Kees Street
Lebanon, Oregon 97355

Instrumentation Specialties
Company
Environmental Division
P.O. Box 5347
Lincoln, Nebraska 68505

Kent Cambridge Instrument
Company
73 Spring Street
Ossining, New York 10562

Lakeside Equipment Corp.
1022 East Devon Avenue
Bartlett, Illinois 60103

Manning Environmental Corp.
120 DuBois Street
P.O. Box 1356
Santa Cruz, California 98061

Markland Specialty Eng. Ltd.
Box 145
Etobicoke, Ontario (Canada)

Nalco Chemical Company
180 N. Michigan Avenue
Chicago, Illinois 60601

Nappe Corporation
Croton Falls Industrial Complex
Route 22
Croton Falls, New York 10519

N-Con Systems Company
308 Main Street
New Rochelle, New York 10801

Paul Noascono Company
805 Illinois Avenue
Collinsville, Illinois 62234

TABLE 3. AUTOMATIC WASTEWATER SAMPLER MANUFACTURERS (Cont'd)

Peri Pump Company, Ltd.
180 Clark Drive
Kenmore, New York 14223

Phipps and Bird, Inc.
303 South 6th Street
Richmond, Virginia 23205

Protech, Inc.
Roberts Lane
Malvern, PA 19355

Quality Control Equipment
Company
P.O. Box 2706
Des Moines, Iowa 50315

Rice Barton Corporation
P.O. Box 1086
Worcester, MA 01601

Sigmamotor, Inc.
14 Elizabeth Street
Middleport, New York 14105

Sirco Controls Company
8815 Selkirk Street
Vancouver, B. C. (Canada)

Sonford Products Corporation
100 East Broadway, Box B
St. Paul Park, MN 55071

Testing Machines, Inc.
400 Bayview Avenue
Amityville, New York 11701

Tri-Aid Sciences, Inc.
161 Norris Drive
Rochester, New York 14610

Williams Instrument Co., Inc.
P.O. Box 4365, North Annex
San Fernando, California 91342

automatic samplers, a common format has been designed. A few words about the headings of this format are in order.

Designation: Identifies the particular sampler model that is being considered. In some instances several models are described under the same general heading. This occurs when there does not appear to be a fundamental difference in the basic principles of operation, but rather, the manufacturer has chosen to give separate designations based upon the addition of certain features such as refrigeration, a weatherproof case, etc.

Manufacturer: Lists the company that supplies the particular model in question, its address, and its telephone number.

Sampler Intake: Describes the part of the sampler that actually extracts fluid from the stream being sampled. It may be, for example, a supplied custom designed intake probe, a dipping bucket or scoop, etc. However, many of the samplers do not provide any form of intake other than the end of a tube through which a sample is to be transported to the equipment.

Gathering Method: Addresses the method for gathering the sample and transporting it to its container. Three basic categories are identified: Mechanical, where dippers, scoops, etc., are utilized; Suction Lift, employing either evacuated vessels, vacuum pump, or mechanical pump; and Forced Flow, utilizing pneumatic ejection, a submerged pump, etc.

Sample Lift: Addresses the maximum practical vertical lift that the particular piece of equipment is capable of in operation.

Line Size:	Describes the minimum line diameter of the sampling train wherever it may occur in the particular piece of equipment. Due to the presence of tube fittings, screens, valves, etc., in some designs, it does not necessarily represent maximum particle size.
Sample Flow Rate:	Gives the flow rate of the sample as it is being transported within the sampling train of the piece of equipment in question.
Sample Capacity:	Addresses the size of the sample that is being collected. In the case of composite samplers, the aliquot size is also given.
Controls:	Addresses those controls within the sampler that can be utilized to vary its method of operation. For example, built-in timers, inputs from external flowmeters, etc.
Power Source:	Gives power source or sources that may be utilized to operate the equipment.
Sample Refrigerator:	Addresses the type of cooling that may be available to provide protection to collected samples.
Construction Materials:	Primary attention here has been devoted to the sampling train proper, although certain other materials such as case construction are also noted.
Basic Dimensions:	The overall package is described here in order to give the reader a general feel for the size of the unit. For those units which might be considered portable, a weight is also given. For units that are designed for fixed installations only, this fact is also noted.

<u>Base Price</u>:	The base price of the unit is given here. Certain options or accessories that may be of general interest are also included with their prices. Prices given are generally those quoted for January 1975 delivery. Because of the economic conditions prevalent at that time, however, many manufacturers recommend checking with them, even for estimating or planning purposes.
<u>General Comments</u>:	Here any additional comments that are felt to be pertinent to the particular piece of equipment in question are given. This includes any additional descriptions that are felt necessary in order to understand better the operating principles that are involved. Also included are certain performance claims that may be made by the manufacturer.

An overall matrix, which summarizes the detailed descriptions to facilitate comparisons, is presented in Table 4. There are several column headings for each sampler model (or class of models). "Gathering Method" identifies the actual method used (mechanical, forced flow, suction lift) and type (peristaltic-, vacuum-, centrifugal-pump, etc.). Depending upon the gathering method employed, the sample flow rate may vary while a sample is being taken, vary with parameters such as lift, etc. Therefore, the "Flow Rate" column typically lists the upper end of the range for a particular piece of equipment and values significantly less may be encountered in a field application. "Lift" indicates the maximum vertical distance that is allowed between the sampler intake and the remainder of the unit (or at least its pump in the case of suction lift devices).

"Line Size" indicates the minimum line diameter of the sampling train. "Sample Type" indicates which type or types of sample, as identified in section IV, the unit (or series) is capable of gathering. Not all types can necessarily be taken by all units in a given model class; e.g., an optional controller may be required to enable taking a TvVc type sample, etc. The "Installation" column is used to indicate if the manufacturer considers the unit to be portable or if it is primarily intended for a fixed installation. "Cost Range" indicates either the approximate cost for a typical unit or the lowest price for a basic model and a higher price reflecting the addition of options (solid state controller, battery,

TABLE 4. SAMPLER CHARACTERISTIC SUMMARY MATRIX

Sampler	Gathering Method	Flow Rate (ml/min)	Lift (m)	Line Size (mm)	Sample Type	Instal-lation	Cost Range ($)	Power
Bestel-Dean Mk II	S-Watson-Marlow	690	6.1	6.4	D, TcVc, TvVc	Portable	Unk.	AC/DC
Bestel-Dean Crude	S-screw type	Unk.	6.1	19.1	D, TcVc, TvVc	Portable	Unk.	AC
BIF 41	M-cup on chain	NA	4.9	25.4	TcVc, TvVc	Fixed	∿1,000	AC
Brailsford DC-F & EP	S-piston type	10	∿2	4.8	Continuous	Portable	296-373	DC
Brailsford EVS	S-vacuum pump	5	3.7	4.8	TcVc, TvVc	Portable	520-672	AC/DC
Brailsford DU-2	S-piston type	10	<2	4.8	TcVc, TvVc	Portable	373	DC
BVS PP-100	F-pneumatic	*	85	3.2	TcVc, TvVc	Portable	853-1,525	AC/DC
BVS PE-400	F-submersible pump	7,600	9.8	12.7	TcVc, TvVc	Portable	1,500-2,510	AC/DC
BVS SE-800	F-submersible pump	7,600	9.8	12.7	D, TcVc, TvVc	Fixed	5,650	AC
BVS PPE-400	F-pneumatic	*	85	3.2	TcVc, TvVc	P or F	1,450-3,350	AC/DC
Chicago Pump	user supplied	∿133,000	NA	25.4	TcVc, TvVc	Fixed	2,600-3,200	AC
Collins 42	user supplied	>3,785	NA	2.4	TcVc, TvVc	P or F	985-2,478	AC
Collins 40	user supplied	∿5,000	NA	2.4	TcVc, TvVc	P or F	835-2,328	AC
EMA 200	F-piston type	Unk.	<1	9.5	TcVc, TvVc	Portable	199-456	AC/DC
ETS FS-4	S-peristaltic	∿20	8.8	6.4	Continuous	Portable	1,095-up	AC
Horizon S7570	S-peristaltic	100	9.1	0.8	Grab	Portable	∿410	AC/DC
Horizon S7576	S-peristaltic	100	9.1	0.8	TcVc	Portable	∿220	AC
Horizon S7578	S-peristaltic	100	9.1	0.8	Continuous, TcVc	Portable	595	DC
Hydraguard HP	F-pneumatic	*	>9	6.4	TcVv	Portable	246-541	Air
Hydraguard A	F-pneumatic	*	>9	6.4	TvVc	Portable	286-668	Air & AC
Hydra-Numatic	S-centrifugal	5,700	4.6	6.4	TcVc, TvVc	Portable	1,800	AC
ISCO 1392	S-peristaltic	1,500	7.9	6.4	D, TcVc, TvVc, S	Portable	1,095-1,498	AC/DC
ISCO 1480	S-peristaltic	NA	7.9	6.4	TcVc, TvVc	Portable	645-1,020	AC/DC
ISCO 1580	S-peristaltic	1,400	7.9	6.4	TcVc, TvVc	Portable	750-1,130	AC/DC
Kent SSA	S-peristaltic	150	4.9	6.4	Discrete	Portable	1,240	AC/DC
Kent SSB	S-peristaltic	200	4.0	6.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Kent SSC	S-screw type	33,000	5.0	25.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Lakeside T-2	M-scoop	NA	0	12.7	TcVv	Fixed	∿700-up	AC
Manning S-4000	S-vacuum pump	3,800	6.7	9.5	D, S	Portable	1,290	DC
Markland 1301	F-pneumatic	*	18.3	6.4	TcVc, TvVc	Portable	1,095-1,350	Air & DC
Markland 101 & 102	F-pneumatic	*	18.3	6.4	D, TcVc	Fixed	594-2,189	Air & DC
Markland 104T	F-pneumatic	*	18.3	6.4	D, TcVc, TvVc	Fixed	1,094-2,644	Air & AC
Nalco S-100	F-submersible pump	28,400	7.6	12.7	TcVc, TvVc	Portable	Unk.	AC
Nappe Porta-Positer	S-flexible impeller	11,400	1.8	6.4	TcVc	Portable	225-285	AC/DC
Nappe Series 46	S-flexible impeller	13,200	4.6	9.5	TcVc, TvVc	Fixed	1,100-1,800	AC
Noascono Shift	S-peristaltic	8	9.1	4.8	Continuous	Portable	Unk.	AC
N-Con Surveyor II	S-flexible impeller	20,000	1.8	6.4	TcVc, TvVc	Portable	290-590	AC
N-Con Scout II	S-peristaltic	150	5.5	6.4	TcVc, TvVc	Portable	575-935	AC/DC
N-Con Sentry 500	S-peristaltic	150	5.5	6.4	Sequential	Portable	1,125-1,205	AC/DC
N-Con Trebler	M-scoop	NA	0	12.7	TcVv	Fixed	1,050-1,350	AC
N-Con Sentinel	user supplied	63,000	NA	25.4	TcVc, TvVc	Fixed	∿2,600	AC

TABLE 4. SAMPLER CHARACTERISTIC SUMMARY MATRIX (Cont'd)

Sampler	Gathering Method	Flow Rate (ml/min)	Lift (m)	Line Size (mm)	Sample Type	Instal-lation	Cost Range ($)	Power
Peri 704	S-peristaltic	160	7.6	6.4	TcVc	Portable	Unk.	DC
Phipps and Bird	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	~1,000-up	AC
ProTech CG-110	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	485	-
ProTech CG-125	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	695-1,205	-/AC
ProTech CG-125FP	F-pneumatic	1,000	9.1	3.2	TcVc, TvVc	Portable	925-1,610	AC/DC
ProTech CEG-200	F-pneumatic	1,000	16.8	3.2	TcVc, TvVc	P or F	1,345-2,445	Air/AC
ProTech CEL-300	F-submersible pump	~6,000	9.1	12.7	TcVc, TvVc	P or F	1,495-2,750	AC
ProTech DEL-4005	F-submersible pump	~6,000	9.1	12.7	Discrete	Fixed	3,995-4,765	AC
QCEC CVE	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	570-1,030	AC/DC
QCEC CVE II	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	~1,000-up	AC/DC
QCEC E	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	~1,000-up	AC
Rice Barton	S-vacuum pump	Unk.	3.7	25.4	TcVc	Fixed	Unk.	AC
SERCO NW-3	S-evacuated jars	Varies	~3	6.4	Discrete	Portable	~1,000	-
SERCO TC-2	user supplied	42,000	NA	~19	TcVc, TvVc	Fixed	~2,500	Air & AC
Sigmamotor WA-1	S-peristaltic	60	6.7	3.2	TcVc	Portable	430-730	AC/DC
Sigmamotor WAP-2	S-peristaltic	60	6.7	3.2	TcVc, TvVc	Portable	650-870	AC/DC
Sigmamotor WM-3-24	S-peristaltic	60	6.7	3.2	Discrete	Portable	975-1,525	AC/DC
Sigmamotor WA-5	S-peristaltic	80	5.5	6.4	TcVc	Portable	750-990	AC/DC
Sigmamotor WAP-5	S-peristaltic	80	5.5	6.4	TcVc, TvVc	Portable	850-1,215	AC/DC
Sigmamotor WM-5-24	S-peristaltic	80	5.5	6.4	Discrete	Portable	1,225-1,775	AC/DC
Sirco B/ST-VS	S-vacuum pump	12,000	6.7	9.5	TcVc, TvVc	P or F	1,900-3,000	AC/DC
Sirco B/IE-VS	M-cup on cable	NA	61	9.5	TcVc, TvVc	Fixed	1,500-3,000	AC
Sirco B/DP-VS	user supplied	-	NA	9.5	TcVc, TvVc	P or F	1,600-3,000	AC/DC
Sirco MK-VS	S-vacuum pump	6,000	6.7	9.5	D, TcVc, TvVc, S	Portable	~1,300-up	AC/DC
Sonford HG-4	M-dipper	NA	0.5	19.0	TcVc, TvVc	Portable	325-495	AC/DC
Streamgard DA-24S1	user supplied	NA	NA	6.4	Discrete	Portable	775	-
TMI Fluid Stream	F-pneumatic	*	7.6	12.7	TcVc	Fixed	~800	Air & AC
TMI Mk 3B (Hants)	S-evacuated jars	Varies	~3	3.2	Discrete	Portable	~700-up	-
Tri-Aid	S-peristaltic	500	7.5	9.5	TcVc, TvVc	P or F	650-985	AC
Williams Oscillamatic	S-diaphragm type	60	3.6	6.4	TcVc	P or F	438	-

Legend:
M - Mechanical
F - Forced Flow
S - Suction Lift
* - Depends on pressure and lift
NA - Not Applicable
Unk - Unknown at time of writing

refrigerator, etc.) that might enhance the utility of the device. Finally, the "Power" column is used to indicate whether line current (AC), battery (DC), or other forms of power (e.g., air pressure) are required for the unit to operate.

In general, the commercially available automatic samplers have been designed for a particular type of application. In the present work, however, they are being considered for application in a storm or combined sewer setting. Because of the vagaries of such an application as outlined in Sections III and IV of this report, it is altogether possible that a particular unit may be quite well suited for one particular application and totally unsuitable for use in another. It is not the intention of this report to endorse any particular piece of equipment. Rather, they are being compared and evaluated for their suitability in general in a storm or combined sewer application. This evaluation takes the form of 12 points which are addressed for each model sampler that has been considered. They are as follows:

1. Obstruction or clogging of sampling ports, tubes, and pumps.

2. Obstruction of flow.

3. Operation under the full range of flow conditions peculiar to storm and combined sewers.

4. Operation unimpeded by the movement of solids such as sand, gravel and debris within the fluid flow; including durability.

5. Operation automatic (during storm conditions), unattended, self-cleaning.

6. Flexibility of operation allowed by control system.

7. Collection of samples of floatable materials, oils and grease, as well as coarser bottom solids.

8. Storage, maintenance and protection of collected samples from damage and deterioration as well as the sample train and containers from precontamination.

9. Amenability to installation and operation in confined and moisture laden places such as sewer manholes.

10. Ability to withstand total immersion or flooding during adverse flow conditions.

11. Ability to withstand and operate under freezing ambient conditions.

12. Ability to sample over a wide range of operating head conditions.

DESCRIPTIVE FORMS AND EVALUATIONS

The descriptive forms and evaluations, as discussed above, are presented in the following pages for various commercially available automatic samplers. The arrangement is alphabetical, and an index is provided on pages x through xii.

Designation:	BESTEL-DEAN MARK II
Manufacturer:	Bestel-Dean Limited 92 Worsley Road North, Worsley Manchester, England M28 5QW Phone FARNWORTH 75727
Sampler Intake:	End of 6.10m (20 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift (from a Watson-Marlow type MHRK fixed speed flow inducer).
Sample Lift:	6.10m (20 ft) maximum lift.
Line Size:	0.64 cm (1/4") I.D.
Sample Flow Rate:	Approximately 690 mℓ per minute.
Sample Capacity:	Composites adjustable size aliquots from 5 mℓ to 2 liters in an external user-supplied sample container. With optional portable bottler, the unit takes 24-250 mℓ discrete samples.
Controls:	Sample timer which controls sample volume is adjustable from 1 to 4 minutes, interval timer from 5 to 60 minutes, and purge timer from 1 to 4 minutes, all being controlled by a solid state unit having three adjustable timers. The sampling cycle can be initiated by a test button, by the internal pre-set timer, or by remote pulse from an external flowmeter.
Power Source:	115/230 VAC or 12 VDC.
Sample Refrigerator:	None.
Construction Materials:	Casing and base are reinforced fiberglass, tubing is neoprene.

Basic Dimensions: 61 x 37 x 28 cm (24x14.5x11 in.) in operational state; weight is 10.65 kgs (23.5 lbs) less battery; portable unit. Bottler is 30.5 cm (12 in.) H x 38 cm (15 in.) dia.

Base Price: Unknown.

General Comments: Unit is also designed to work as a discrete sampler when used in conjunction with the Bestel-Dean portable bottler unit. All controls are front panel, solid state. Unit is fully portable. Battery unit and sample container must be supplied by user.

Bestel-Dean Mark II Evaluation

1. Sampler should be relatively free from clogging.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Unit should operate reasonably well over entire range of flow conditions.

4. Movement of solids should not affect operation adversely.

5. No automatic starter. At start of each cycle, pump operates in reverse to clear line of previous sample to help minimize cross contamination and offer a sort of self cleaning.

6. Unit can take fixed-time interval samples or flow proportional composite samples or discrete samples with optional bottler.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. No sample collector provided. Unit can be connected to the optional Bestel-Dean bottler unit. Cross-contamination should be small.

9. Unit should be able to operate in a manhole environment.

10. Unit cannot withstand total immersion.

11. Unit does not appear suited for operation in freezing ambients.

12. Maximum lift of 6.1m (20 ft) does not place great operating restriction on unit.

Designation:	BESTEL-DEAN CRUDE SEWAGE SAMPLER
Manufacturer:	Bestel-Dean Limited 92 Worsley Road North, Worsley Manchester, England, M28 5QW Phone FARNWORTH 75727
Sampler Intake:	End of 6.10m (20 ft) long suction tube fitted with a special deflector and strainer and installed to suit by user.
Gathering Method:	Suction lift from progressive cavity screw-type pump.
Sample Lift:	6.10m (20 ft) maximum lift.
Line Size:	1.9 cm (3/4 in.) I.D.
Sample Flow Rate:	Unknown.
Sample Capacity:	Collects either 24 discrete 250 mℓ samples or a 25 liter composite made up of 250 mℓ aliquots.
Controls:	Cycle timer is adjustable for settings from 0-4-1/2 hours with minimum time setting of 12 minutes. Purge timer can be set for up to 13-1/2 minutes with a minimum of 30 seconds. May also be paced by an external flowmeter.
Power Source:	240 VAC
Sample Refrigerator:	None.
Construction Materials:	The pipework system with valves and sample container are plastic. Casing is weatherproof sheet steel with an epoxy resin coating. Pump rotor is stainless steel and stator is nitrile rubber.
Basic Dimensions:	76 x 76 x 107 cm (30x30x42 in.). Designed for fixed installation.

Base Price: Unknown.

General Comments: Discharge line should be located downstream from suction line to prevent possible contamination of new sample. On installations where flow integrating equipment does not have available a suitable pulsing contact, a load-free impulse device which can be adapted to any flowmeter is optionally available. A solid state electronic power unit is available as an option for use with the impulse unit. Standard equipment is set to take a 250 mℓ volume aliquot. Other volumes, between 250 mℓ and 100 mℓ, can be supplied by special order. Thermostat for heater is optionally available.

Bestel-Dean Crude Sewage Sampler Evaluation

1. The deflector and strainer will help prevent blockage, and unit does not appear at all vulnerable to clogging due to large I.D. piping and choke-free valve design.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Unit should operate reasonably well under all flow conditions.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; purging action before each sample should clear the sampler of any fluid left from the previous sample.

6. Unit can take either fixed time interval samples paced by a built-in timer or flow proportional samples paced by an external flowmeter.

7. Unit does not appear suitable for collecting either floatable or coarser bottom solids.

8. Unit offers reasonable sample protection, but offers no refrigeration.

9. Unit is intended for permanent outdoor installation, but is not designed for confined space or manhole operation.

10. Unit cannot withstand total immersion.

11. An electrical heater is mounted inside the case and can be manually switched on or thermostatically controlled for operation during freezing conditions.

12. Maximum lift of 6.10m (20 ft) does not place a severe operating restraint on unit.

Designation:	BIF SANITROL FLOW-RATIO MODEL 41
Manufacturer:	BIF Sanitrol P.O. Box 41 Largo, Florida 33540 Phone (813) 584-2157
Sampler Intake:	Dipping bucket
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	41 cm (16 in.) to 4.9m (16 ft)
Line Size	2.5 cm (1 in.) O.D. tube connects collection funnel to sample container
Sample Flow Rate:	Not applicable
Sample Capacity:	Dipping bucket holds 30 mℓ (1 oz); user supplies sample composite container to suit.
Controls:	Sampling cycle can either be started at fixed, selected intervals from a built-in timer (15, 7.5, 3.75, or 1.88 minutes) or in response to signals from an external flowmeter.
Power Source:	115 VAC
Sample Refrigerator:	Separate automatic refrigerated sample compartment with two 3.8ℓ (1 gal) jugs available.
Construction Materials:	Dipper and funnel are stainless steel; sprockets and chain are stainless steel; enclosure is fiberglass.
Basic Dimensions:	Upper portion is approximately 24 x 24 x 20 cm (9x9x8 in.); lower portion is 24 x 10 cm (9x4 in.); fixed installation.
Base Price:	$545 with 41 cm (16 in.) mild steel chain plus $40 per foot (0.3m) for additional length. $595 with 16" stainless steel chain plus $50 per foot (0.3m) for additional length.

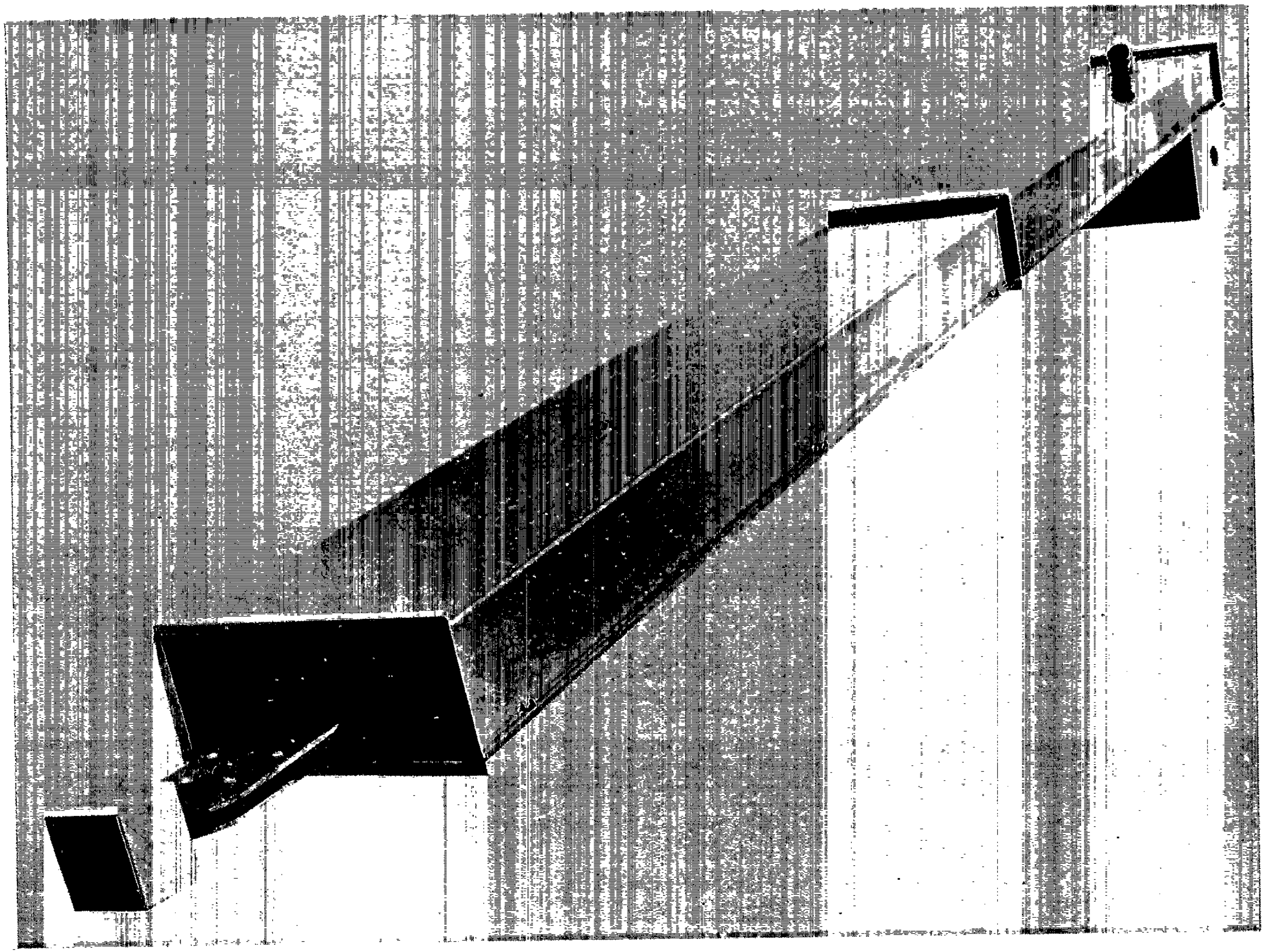


Figure 2. BIF Sanitrol Flow - Ratio Model 41 Sampler

Photograph courtesy of BIF Sanitrol.

General Comments: Manufacturer states unit was designed to sample raw or effluent wastes. A heavy duty model is available for applications where mixed wastes are present such as a paper mill where wood chips and fiber are present in waste liquid.

BIF Sanitrol Flow-Ratio Model 41 Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket line is vulnerable to jamming by rags, debris, etc.

2. Unit provides a rigid obstruction to flow.

3. Unit should operate over full range of flows.

4. Movement of solids could jam unit.

5. No automatic starter; no self cleaning features.

6. Collects fixed size aliquots paced by built-in timer and composites them in a suitable container.

7. Does not appear well suited for collecting either floatables or coarser bottom solids.

8. No sample collector provided. Optional refrigerated sample container is available.

9. Unit is capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit is not suitable for prolonged operation in freezing ambients.

12. 4.9m (16 ft) maximum lift puts some restriction on operating head conditions.

Designation:	BRAILSFORD MODEL DC-F
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 1.8m (6 ft) long sampling tube; weighted and fitted with 50 mesh strainer.
Gathering Method:	Suction lift by positive displacement pump.
Sample Lift:	Pump is capable of 3m (10 ft) lift but manufacturer recommends that lift be restricted to 0.9 to 2.1m (3 to 7 ft).
Line Size:	0.48 cm (3/16 in.) I.D.
Sample Flow Rate:	Adjustable from about 1.6 to 9.8 mℓ (0.1 to 0.6 cu in.) per minute.
Sample Capacity:	Pump output is collected in a 7.6ℓ (2 gal) jug.
Controls:	Pump stroke is adjustable by means of a slotted yoke on the piston rod. On/Off Switch.
Power Source:	6 VDC dry cell battery
Sample Refrigerator:	None
Construction Materials:	Stainless steel, teflon, vinyl, polyethylene; case is laminated Formica-wood construction, plastic rain boot.
Basic Dimensions:	48 x 30.5 x 24 cm (19x12x9.5 in.) weighs 8.5 kg (19 lbs) empty; portable.
Base Price:	$296.
General Comments:	Pump is valveless oscillating cylinder type. No lubrication is required for the life of the unit. Driven by a brushless D.C. motor of

patented design with a service life in excess of 3,000 hours. Continuous running pump is automatically shut off when sample jug is full.

Model EP is an explosion proof unit that is basically similar to the DC-F except for the housing. It also provides the pressure of a 10 cm (4 in.) water column on the sample to prevent the loss of volatile fractions or dissolved gases. A choice of 3.8ℓ (1 gal) sample containers (rectangular can or polyethylene bottle) is available. Price is $373.

A Model DU-2 is also available at $373. It is essentially a Model DC-F with the addition of an electronic timing circuit which can set the pumping rate for a sample frequency of between 1.75 and 13 minutes. An optional head detector is available for use with a weir to achieve a form of flow proportional sampling. Plugging in the head detector disconnects the timing circuit. The head detector is basically an array of magnetic switches connected to a series string of resistors and sealed within an insulating strip. A float containing a magnet slides up and down the strip as the water level changes, thereby altering the resistance in the circuit and, hence, the pumping rate. Price of the head detector is $98. The DU-2 can also be paced by an external flowmeter which provides momentary contact closures at a rate proportional to flow.

Brailsford Model DC-F Evaluation

1. 50 mesh strainer on end of sampling tube might be prone to clogging.

2. Minimal obstruction of flow.

3. Should operate reasonably well under all flow conditions, but low intake velocity will affect representatives of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. Continuous flow unit, no automatic starter, no other self cleaning features.

6. Unit collects a continuous, low flow rate stream of sample and composites it in a 7.6ℓ (2 gal) jug. Model DU-2 offers several composite type options.

7. Unsuitable for collection of floatables or coarser bottom solids.

8. No refrigerator. Continuous flow eliminates cross contamination.

9. Appears fairly well suited for manhole operation.

10. Cannot withstand immersion.

11. Not suited for operation in freezing environments.

12. Recommended lift of 1.2m (4 ft) puts restriction on use of unit.

Designation:	BRAILSFORD MODEL EVS
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 3.7m (12 ft) long sampling tube fitted with a molded plastic inlet scoop-strainer to help prevent blockage by rags, paper, etc.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	3.7m (12 ft) maximum.
Line Size:	0.48 (3/16 in.) I.D.
Sample Flow Rate:	Depends upon lift, but under 5 mℓ per minute.
Sample Capacity:	A 3.8ℓ (1 gal) composite sample is accumulated from small adjustable size aliquots.
Controls:	A control switch permits the choice of four timing intervals which will cause a 3.8ℓ (1 gal) sample to be collected in either 8, 16, 24 or 48 hours. The unit may also be paced by the head detector described under Model DC-F or an external flowmeter.
Power Source:	115 VAC or 12 VDC electricity.
Sample Refrigerator:	None
Construction Materials:	Sampling train is all plastic; case is laminated Formica-wood construction.
Basic Dimensions:	30.5 x 23 x 48 cm (12 x 9 x 19 in.); weighs 8.5 kg (19 lbs) empty; portable.
Basic Price:	\$520 115 VAC \$627 with N. Cad battery \$672 with N. Cad battery and AC power unit.

General Comments: Unit was designed for flows with a high percentage of suspended solids or where volatiles are present. Sample never passes through pump or valves or orifices which could become clogged. In operation, a small vacuum pump evacuates air from a small metering chamber to which the sample bottle and inlet tube are connected. When chamber is filled to a predetermined level, a magnetic sensing switch stops the pump and opens a vacuum relief valve so a portion of the sample flows into the jug and the remainder backflushes the inlet tube.

Brailsford Model EVS Evaluation

1. Specially designed inlet scoop-strainer may help prevent blockage. Rest of sample train should be free from clogging.
2. Minimal obstruction of flow.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocities could affect representativeness of sample at high flow rates.
4. Movement of solids should not hamper operation.
5. No automatic starter - backflushing of inlet tube at end of each cycle provides a self cleaning function of sorts.
6. Unit collects a fixed time interval or flow proportional composite in a one gallon jug.
7. Unsuitable for collection of floatables or coarser bottom solids.
8. No refrigerator. Backflushing will help reduce cross contamination.
9. Appears well suited for manhole operation.
10. Unit cannot withstand immersion.
11. Not suitable for operation in freezing ambients.
12. Maximum lift of 3.7m (12 ft) puts some restrictions on use of unit.

Designation:	BVS MODEL PP-100
Manufacturer:	Brandywine Valley Sales Company 20 East Main Street Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake:	Plastic cylindrical sampling probe which is gravity filled. A row of small holes around the circumference near the bottom forms an inlet screen; weighted base.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Up to 85m (280 ft); requires one pound of pressure for every 0.6m (2 ft) of vertical lift.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	Depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volume is 50 mℓ; sample composited in 9.5ℓ (2.5 gal) jug in standard model or 5.7ℓ (1.5 gal) jug in refrigerated model.
Controls:	Pressure regulator connecting gas supply is set between 0.35 and 9.8 kg/sq cm (5 and 140 psi) depending upon lift required; sampling interval timer is adjustable to allow from 2 seconds to 60 minutes to elapse between aliquots; manual on/off switch standard. Optional control package accepts signals from external flow meter or totalizer.
Power Source:	One 6.8 kg (15 lb) can of refrigerant is standard gas source; 12 VDC or 117 VAC required for refrigerated models or flow proportional control option.
Sample Refrigerator:	Model PPR-100 offers an absorption refrigerator cooled sample case.

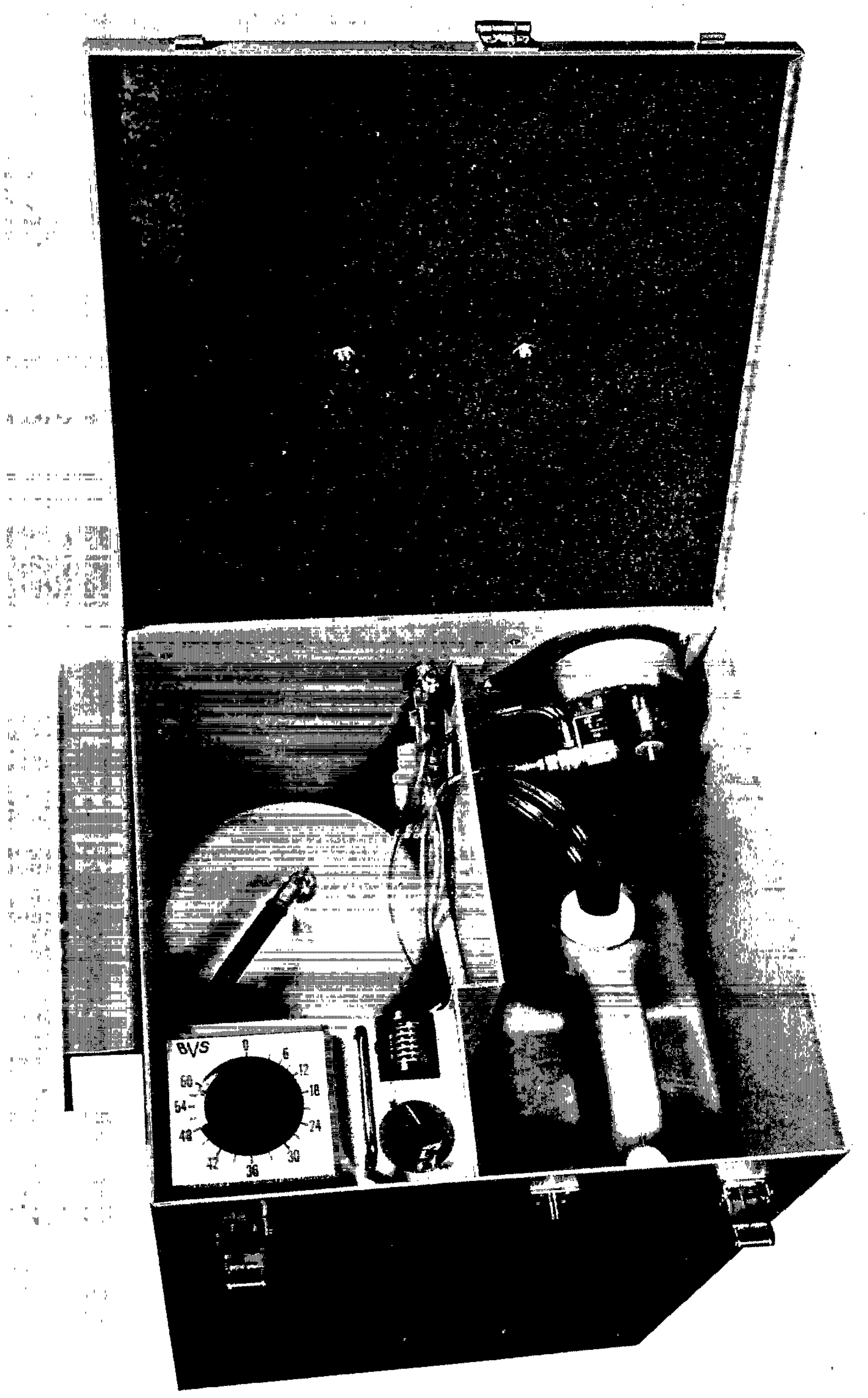


Figure 3. BVS Model PP-100 Sampler

Photograph Courtesy of Brandywine Valley Sales Company

Construction Materials:	Sampling probe is PVC standard, teflon or stainless steel available; plastic sampling line standard, teflon available; polyethylene sample container; Armorhide finished aluminum case.
Basic Dimensions:	Non-refrigerated - 35.6 x 35.6 x 53.3 cm (14x14x21 in.); refrigerated - 43.2 x 55.9 x 43.2 cm (17 x 22 x 17 in.); both models portable.
Base Price:	\$853 for basic unit including 50 mℓ sampling probe, one 6.8 kg (15 lb) cylinder of R-12, and 3-6.1m (20 ft) lengths of tubing. Refrigerated model PPR-100 is \$1150. Add \$100 for winterizing system; \$275 for solid state control package for flow proportional operation.
General Comments:	Timing circuits are controlled by fluidic and pneumatic components. Absorption refrigerator has no moving parts. After each aliquot is gathered, the inlet strainer of the sampling probe is purged by vent pressure from timing valve. Two year parts and labor warranty. Alternate sampling probes available include a surface sampling probe for surface oil, vertical stratum sampling probe for sampling at 15 cm (6 in.) depth intervals, and float mounted probes for sample quantity accuracy that is independent of head.

BVS Model PP-100 Evaluation

1. Sampling probe is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is unobstructed 0.3 cm (1/8 in.) I.D. tube which should pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following intake screen purge at end of previous cycle. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature for the intake screen is accomplished by using vent pressure from the timing valve to purge it.

6. Collects fixed size aliquots at either preset time intervals or paced by external flowmeter if equipped with control option, and composites them in a suitable container.

7. Special sampling probe available for surface oil sampling, etc.; appears unsuitable for sampling coarser bottom solids.

8. Automatic refrigerated sample compartment available, but sample size is reduced. Some cross-contamination appears likely.

9. Unit appears capable of manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Optional winterizing kit is available for use in very cold ambients.

12. Unit has a very wide range of operating head conditions. High lifts will result in faster depletion of gas supply.

Designation:	BVS MODEL PE-400
Manufacturer:	Brandywine Valley Sales Company 20 East Main Street Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake	PVC screen over pump inlet.
Gathering Method:	Forced flow from submersible pump.
Sample Lift:	9.8m (32 ft) maximum.
Line Size:	1.3 cm (1/2 in.) I.D. inlet hose.
Sample Flow Rate:	3.8-7.6 ℓpm (1-2 gpm) typical.
Sample Capacity:	Aliquot volume is a function of the preset diversion time; sample composited in 9.5ℓ (2.5 gal) container.
Controls:	Unit operates on a continuous flow principle, returning uncollected flow to waste. Sample is pumped through a stainless steel, non-clogging diverter valve. Upon receiving a signal from either the built-in timer or an external flow-meter, the unit diverts the flow for a preset period of time (adjustable from 0.02 to 1.0 seconds) to the sample container. When operating in the timed sampling mode, the sampling frequency rate is continuously adjustable from 0.2 seconds to 60 hours. When operating in the flow-proportional mode the sampler is triggered directly by the external flow meter.
Power Source:	115 VAC electricity.
Sample Refrigerator:	Model PER-400 is refrigerated, but case is not weather-proof.

Construction Materials: Sampling train, PVC, stainless steel, plastic, polyethylene, cabinet is aluminum with Armorhide finish.

Basic Dimensions: Non-refrigerated - 35.6 x 35.6 x 53.3 cm (14 x 14 x 21 in.); refrigerated - 53.3 x 58.4 x 96.5 cm (21 x 23 x 38 in.); both models portable.

Base Price: $1,500 including 6.1m (20ft) of 2.1 cm (13/16 in.) OD x 1.3 cm (1/2 in.) ID nylon reinforced plastic inlet tubing, 6.1m (20 ft) of 3.5 cm (1-3/8 in.) OD x 2.5 cm (1 in.) ID nylon reinforced plastic tubing for waste return, clamps, pump support bracket, pump strainer, pump with 11m (36 ft) cord, and flow proportional connection cable. For refrigerator add $300; for 30 day strip chart recorder add $260. Model PE-500 at $1,700 is similar but designed for high flow rates and solids sizes to 1.9 cm (3/4 in.) and does not include pump, tubing, clamps or sample container. Model PE-600 at $1,950 is similar to Model PE-500 but has dual-solenoid diversion valve and passes solids to 4.4 cm (1.75 in.).

General Comments: Submersible pump has magnetic drive, is self-priming. Manufacturer claims design will handle solids to 0.95 cm (3/8 in.) diameter. Model SE-400 is a refrigerated version designed for fixed installations and priced at $3,000. It is housed in a 66 x 76 x 122 cm (26x30x48 in.) weather-proof case on 20 cm (8 in.) legs with a thermostatically controlled heater, vent system to control moisture, and manual sample take-off line. Model SE-800 is similar to SE-400 but can take 24-500 mℓ discrete samples or a 19ℓ (5 gal) composite sample. It has an inkless strip-chart event recorder and is priced at $5,650. Model SE-500 is similar to PE-500 with additional features of SE-400 and is priced at $3,200; Model SE-600 is similar to PE-600 with additional features of SE-400 except 19ℓ (5 gal) sample container and is priced at $3,600. SE prices include installation, start-up, and operator training by BVS. Two-year warranty on parts and labor for all models. Life-time warranty on sample diversion valve.

BVS Model PE-400 Evaluation

1. Large sampling screen over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.

2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flows.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter since designed for continuous flow. Continuous flow serves a self-cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flowmeter and composites them in a suitable container. SE-800 collects 24 discrete samples.

7. Appears unsuitable for collection of either floatables or coarser bottom solids.

8. Automatic refrigerated sample compartment available. Cross-contamination should not be too great.

9. Portable unit appears capable of manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients if fitted with winterizing kit.

12. Upper lift limit of 9.8m (32 ft) does not pose a great restriction on operating head conditions.

Designation:	BVS MODEL PPE-400
Manufacturer:	Brandywine Valley Sales Company 20 East Main Street Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake:	Plastic cylindrical sampling probe which is gravity filled. A row of small holes around the circumference near the bottom forms an inlet screen; weighted base.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Up to 85m (280 ft); requires one pound of pressure for every 0.6m (2 ft) of vertical lift.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	Depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volume is 50 mℓ; sample composited in 9.5ℓ (2.5 gal) container.
Controls:	Pressure regulator connecting gas supply is set between 0.35 and 9.8 kg/sq cm (5 and 140 psi) depending upon lift required; 0.5 to 100 second sample duration; otherwise similar to Model PE-400.
Power Source:	115 VAC plus pressurized gas supply.
Sample Refrigerator:	Model PPER-400 is refrigerated, but case is not weatherproof.
Construction Materials:	Sampling probe is PVC standard; teflon and stainless steel are available. Plastic sampling line standard; teflon is available;

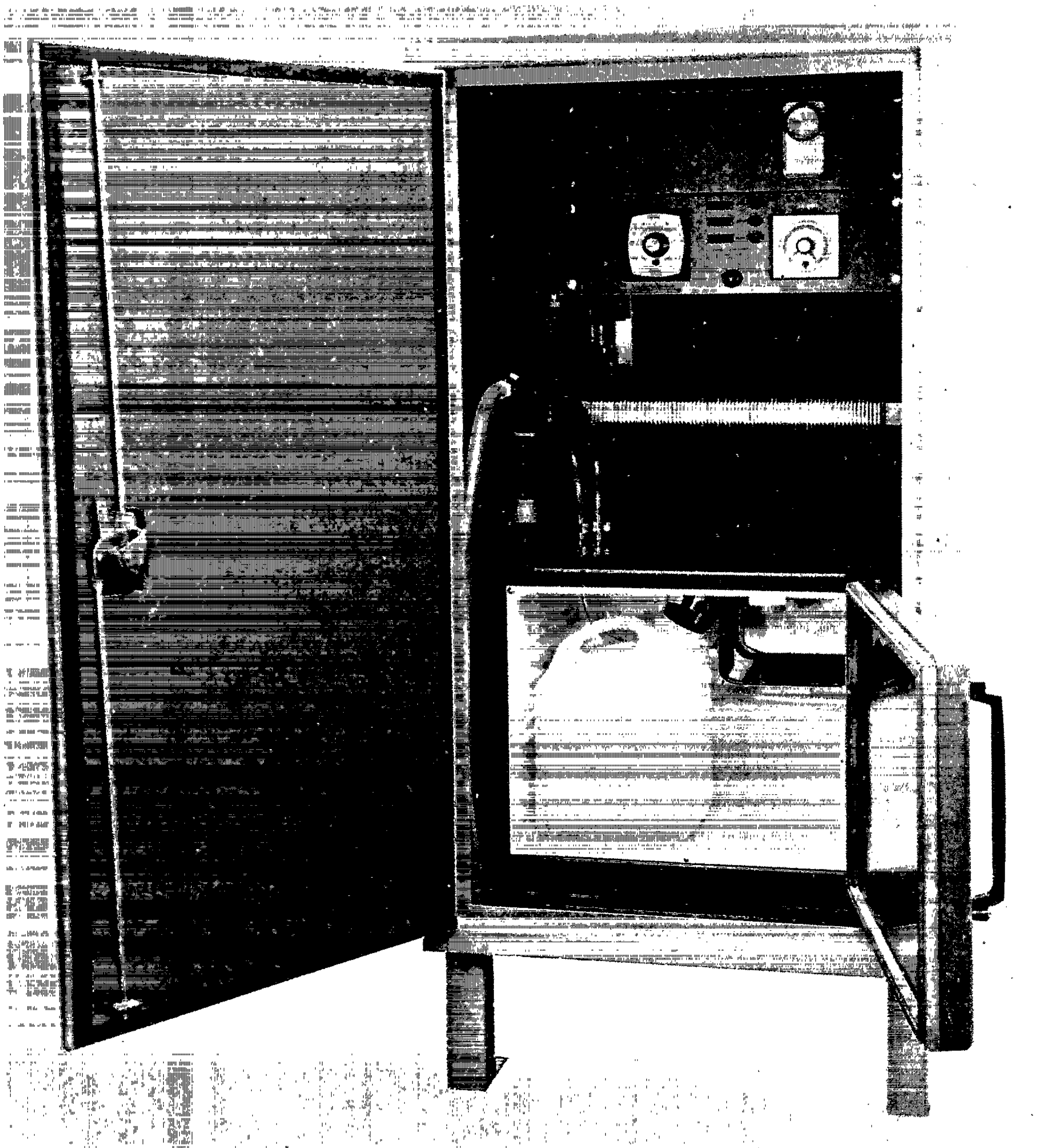


Figure 4. BVS Model SE and SPE Series Sampler

Photograph Courtesy of Brandywine Valley Sales Company

Polyethylene sample container; Armorhide finished aluminum case.

Basic Dimensions: Non-refrigerated - 35.6 x 35.6 x 53.3 cm (14x14x21 in.); refrigerated - 53.3 x 58.4 x 96.5 cm (21x23x28 in.); both models portable.

Base Price: Basic unit handling up to 0.3 cm (1/8 in.) solids is $1,450; Model PPE-500 for solids up to 0.6 cm (1/4 in.) is $1,600; Model PPE-600 for solids up to 0.95 cm (3/8 in.) is $1,750; Model PPE-700 for solids up to 1.3 cm (1/2 in.) is $2,000; add $300 for refrigerated version. Stationary (SPE) models with features of the SE-400 (except for flow-regulating valves and manual sample take-off line) are about $1,600 more than comparable PPE models.

General Comments: Basic unit is similar to PE-400 but utilizes pressure to lift the sample as does model PP-100.

BVS Model PPE-400 Evaluation

1. Sampling probe is vulnerable to blockage of a number of sampling parts at one time by paper, rags, plastic, etc. Sampling train is unobstructed 0.3 cm (1/8 in.) I.D. tube which should pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following intake screen purge at end of previous cycle. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature for the intake screen is accomplished by using vent pressure from the timing valve to purge it.

6. Collects fixed size aliquots at either preset time intervals or paced by external flowmeter option and composites them in a suitable container.

7. Special sampling probe available for surface oil sampling, etc.; appears unsuitable for sampling coarser bottom solids.

8. Automatic refrigerated sample compartment available. Some cross-contamination appears likely.

9. Unit appears capable of manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Optional winterizing kit is available for use in very cold climates.

12. Unit has a very wide range of operating head conditions. High lifts will result in faster depletion of gas supply.

Designation:	CHICAGO "TRU TEST"
Manufacturer:	Chicago Pump Division FMC Corporation 622 Diversey Parkway Chicago, Illinois 60614 Phone (312) 327-1020
Sampler Intake:	Provided by user, a screen with maximum openings of 1.3 cm (0.5 in.) recommended; sampler has standard 5 cm (2 in.) pipe inlet.
Gathering Method:	External head to provide flow through a sampling chamber from which a rotating dipper extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the sample bottle; it appears to be about 2.5 cm (1 in.).
Sample Flow Rate:	Recommended flow rate through sampler is 95 to 190 ℓpm (25 to 50 gpm) with 133 ℓpm (35 gpm) as optimum. Minimum velocity in inlet line, 5 cm (2 in.) diameter recommended, should be 0.6m (2 ft) per second. Below 95 ℓpm (25 gpm) fungus growth and settling in sampling chamber will affect the sample quality.
Sample Capacity:	Sampling dipper collects a 25 mℓ sample; a 7.6ℓ (2 gal) composite container is provided.
Controls:	Constant rate sampling (between 3 and 20 samples per hour) is controlled by built-in timer; flow proportional sampling provided by either transmitter control or totalizer control from external flow measuring device.
Power Source:	110 VAC electricity.

Sample Refrigerator: Automatic refrigerator to maintain samples at 4° to 10°C is available.

Construction Materials: Bisphenol polyester resin, polypropylene, stainless steel, and polyethylene; case is laminated fiberglass.

Basic Dimensions: 49 x 53 x 132 cm (19 x 21 x 52 in.); designed for fixed installation.

Base Price: $2,600 non-refrigerated. $3,200 refrigerated.

General Comments: Sampling chamber has adjustable weir plates to regulate the sewage level. Manufacturer recommends that intake line be limited to 15.2m (50 ft) or less in length.

Chicago "Tru Test" Evaluation

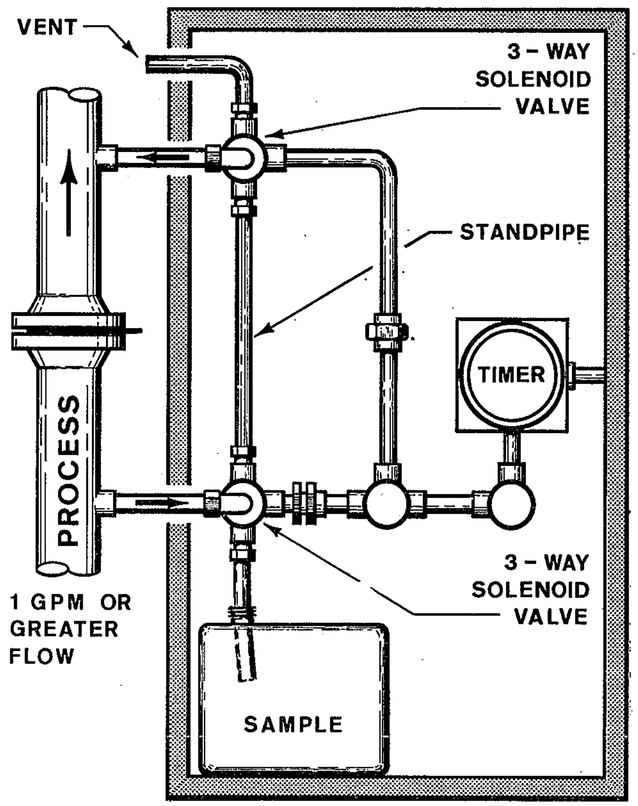
1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross-contamination.
6. Can collect either flow proportional or fixed time interval composites.
7. Ability to collect samples of floatables and coarser bottom solids will depend upon design of sampling intake.
8. Automatic refrigeration maintains samples at 4° to 10°C. Offers good sample protection and freedom from precontamination; sample composite bottle is sealed to funnel with hose clamps.
9. Not designed for confined space or manhole operation.

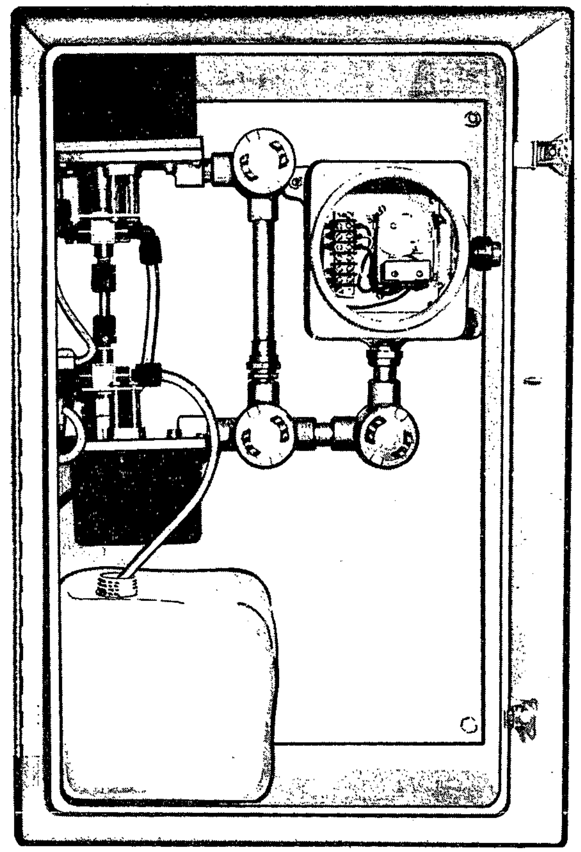
10. Cannot withstand total immersion.

11. Does not appear capable of prolonged exposure to extremely cold ambient conditions.

12. Operating head is provided by user.

Designation:	COLLINS MODEL 42 COMPOSITE SAMPLER
Manufacturer:	Collins Products Company P.O. Box 382 Livingston, Texas 77351 Phone (713) 327-4200
Sampler Intake:	Provided by user.
Gathering Method:	External head to cause sample to flow continuously through a standpipe assembly until two, three-way valves are energized, whereupon incoming and return flows are blocked and the sample trapped in the standpipe drains into the collection container.
Sample Lift:	Not applicable.
Line Size:	The smallest passage is 0.2 cm (3/32 in.) in the solenoid valve; 0.5 cm (3/16 in.) with optional ball valve.
Sample Flow Rate:	As provided by user; minimum of 3.8 ℓpm (1 gpm) at a minimum pressure of 0.14 kg/sq cm (2 psi).
Sample Capacity:	Fixed size (normally 6 mℓ) aliquots are composited in a 9.5ℓ (2.5 gal) collapsible plastic container.
Controls:	Constant rate sampling (normally one aliquot every 70-80 seconds) is controlled by built-in timer; flow proportional operation achieved by connecting to external flow totalizer providing either a contact closure or a pulse (24 VDC, 115 VDC, or 115 VAC), or to a 0.2 to 1.1 kg/sq cm (3 to 15 psi) pressure source proportional to flow depth (linear, 1/2, 3/2, and 5/2 exponent laws available).





EXPLOSION-PROOF MODEL
WITH BALL VALVE

Figure 5. Collins Model 42 Composite Sampler

Photograph Courtesy Collins Products Co.

Power Source;	115 VAC
Sample Refrigerator:	Available as an option.
Construction Materials:	Sampling train would appear to be plastic, stainless steel, and brass. Casing is corrosive-resistant fiberglass. The refrigerated model has a baked enamel-covered steel enclosure with plastic interior.
Basic Dimensions:	Weatherproof enclosures for refrigerator models are 76 x 61 x 183 cm (30x24x72 in.); designed for fixed installation.
Base Price:	\$985; add \$16 for refrigerator; \$610 for refrigerator in weatherproof enclosure; \$210 for ball valve model; and \$27 for delay relay, \$300 for predetermined counter, or \$630 for integrating flow proportional operation.
General Comments:	A standpipe assembly accurately measures the amount of sample taken. Flow is maintained in a turbulent state to keep solids suspended. Sample through sampler continuously purges out system where sample pulse switch is in off position. Sampler was originally designed to take samples from pressurized systems such as pipelines. A wood or angle iron frame is optionally available for mounting the sampler, pump, and motor. In the refrigerated Model 42, the electronics and standpipe assembly is mounted on top of the refrigerator with the collection tube running inside. The refrigerated model is non-explosionproof and housing should be provided for it. A thermostat-controlled heater is optionally available for cold weather operation.

Collins Model 42 Evaluation

1. Should be relatively free from clogging, but even the ball valve model could experience difficulty with some flows unless an intake screen is provided by user. Continuous flow helps to remove particle buildup. Sampling intake must be designed by user.

2. Sampler itself offers no flow obstruction.

3. Should operate reasonably well over entire range of flow conditions.

4. Movement of small solids should not hamper operation.

5. No automatic starter since it is designed for continuous flow. This serves as a self-cleaning function and should minimize cross-contamination.

6. Collects fixed-size aliquots from a continuous flow triggered by a preset timer or external flowmeter and composites them in a suitable container. Representativeness of sample will be a function of intake which is not a part of this unit.

7. Ability to collect samples of floatables and coarser bottom solids will depend upon design of sampling intake.

8. Refrigeration available as an option. Due to continuous flow, cross-contamination should be minimized.

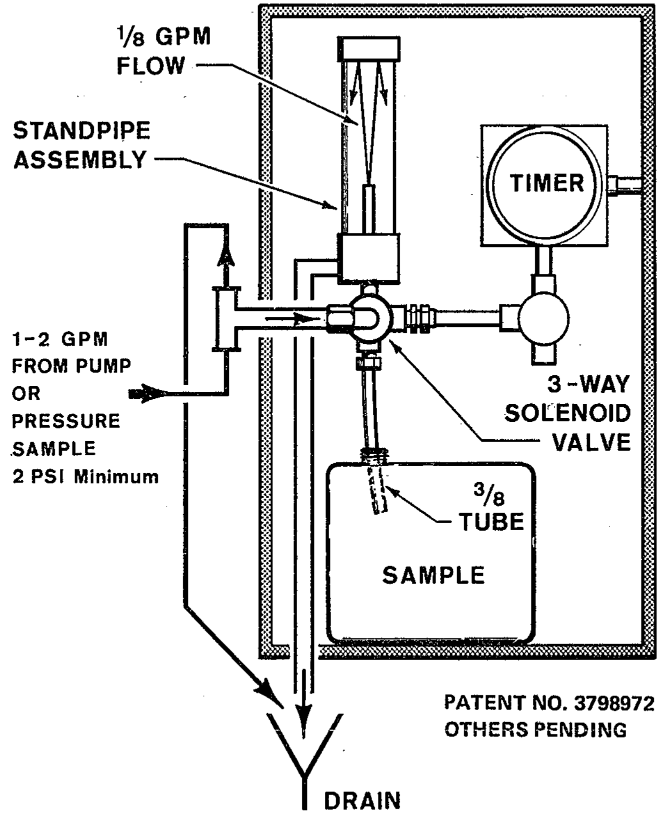
9. Not designed for manhole operation.

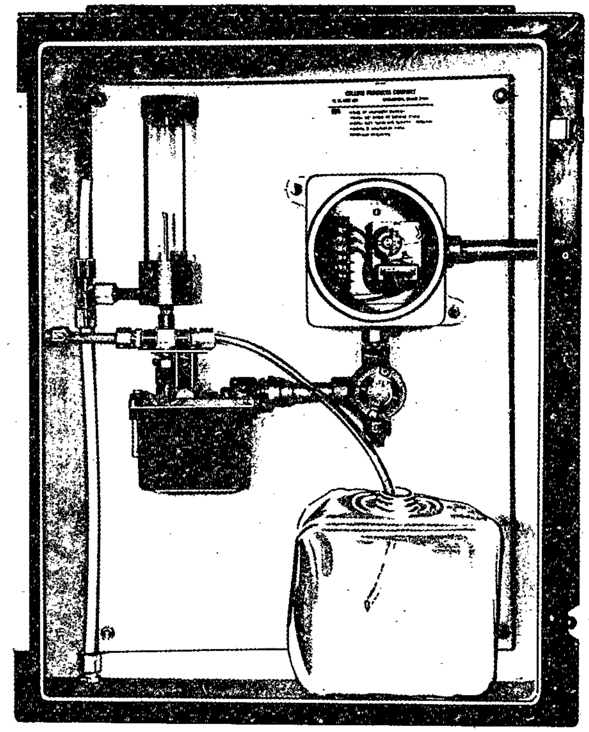
10. Cannot withstand total immersion.

11. Not suited for prolonged operation in extremely cold climates unless provided with optional heating element.

12. Operating head is provided by user.

Designation:	COLLINS MODEL 40 COMPOSITE SAMPLER
Manufacturer:	Collins Products Company P.O. Box 382 Livingston, Texas 77351 Phone (713) 327-4200
Sampler Intake:	Provided by user.
Gathering Method:	External head to provide continuous flow through the sampler. A portion of this flow is diverted to a metering standpipe from which it is periodically dumped into the sample container.
Sample Lift:	Not applicable.
Line Size:	The smallest passage is 0.2 cm (3/32 in.) in the solenoid valve; 0.5 cm (3/16 in.) with optional ball valve.
Sample Flow Rate:	User must provide a minimum pressure of 0.14 kg/sq cm (2 psi) for a flow of 3.8-7.6 ℓpm (1-2 gpm).
Sample Capacity:	Fixed size (normally 3 mℓ) aliquots are composited in a 9.5ℓ (2.5 gal) collapsible plastic container.
Controls:	Same as Model 42 except built-in timer normally triggers every 30 seconds.
Power Source:	115 VAC
Sample Refrigerator:	Available as an option.
Construction Materials:	Same as Model 42.
Basic Dimensions:	Same as Model 42.
Base Price:	$835; all add-ons priced same as Model 42.





EXPLOSION-PROOF MODEL
WITH BALL VALVE

Figure 6. Collins Model 40 Composite Sampler

Photograph Courtesy of Collins Products Co.

General Comments: This unit uses a single three-way valve and a vertical standpipe through which a portion of the continuous flow from an external pump or other pressure source is circulated before going to drain. Otherwise it is similar to Model 42 and will not be separately evaluated.

Designation:	EMA MODEL 200
Manufacturer:	Environmental Marketing Associates 3331 Northwest Elmwood Drive Corvallis, Oregon 97330 Phone (503) 752-1541
Sampler Intake:	Perforated end of suction pipe attached to an adjustable mounting bracket.
Gathering Method:	Forced flow from solenoid activated piston.
Sample Lift:	Less than 0.9m (1 ft).
Line Size:	0.95 cm (3/8 in.) I.D.
Sample Flow Rate:	Unknown
Sample Capacity:	21 mℓ aliquots are composited in a suitable container.
Controls:	Aliquots can be taken at intervals from 2 to 30 minutes paced by an adjustable timer, or as paced by an external flowmeter.
Power Source:	110 VAC or 12 VDC
Sample Refrigerator:	Sample container is housed in an insulated chest that allows for ice cooling.
Construction Materials:	Housing is PVC, piston is lucite, and piston shaft is aluminum.
Basic Dimensions:	Basic model appears to be about 107 cm (3.5 ft) high.
Base Price:	Model 200 ac - $199 Model 200 dc - $249 (without battery) Model 200 dc floating - $456 (without battery)

General Comments: A battery operated floating model is available mounted on a pontoon float. Unit must be mounted at point of sampling since it is not designed to discharge to higher elevations. The sampler is furnished with an adjustable mounting bracket that supports both the sampler and sample container.

EMA Model 200 Evaluation

1. Sampler intake is vulnerable to blockage by rags or debris. A 0.95 cm (3/8 in.) sampling train has a fitting obstruction at point of attachment to main housing.

2. Unit offers a rigid obstruction to flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, a part of this coming from undischarged sample. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness of suspended solids is also questionable.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the unit unless special protection is provided by user.

5. No automatic starter; an intake purge of sorts is provided by the design which allows the piston to force some of the sample back out of the inlet ports at the beginning of each stroke.

6. Collects fixed size aliquots (volume may vary with flow depth) paced by a built-in timer or external flowmeter and composites them in a suitable container.

7. Does not appear suitable for collecting either floatables or coarser bottom solids.

8. No refrigeration, some sample protection provided by insulated chest. Cross-contamination appears very likely. Limited lift may require placing sampler in a vulnerable location.

9. Unit would appear capable of manhole operation. Limitations will depend on user installation of mounting brackets.

10. Unit cannot tolerate submersion.

11. Not suited for operation in freezing ambients.

12. The unit is extremely limited in range of operational head conditions and does not appear suitable for flows with varying depths.

Designation:	ETS FIELDTEC SAMPLER MODEL FS-4
Manufacturer:	ETS Products 12161 Lackland Road St. Louis, Missouri 63141 Phone (314) 878-1703
Sampler Intake:	Plastic inlet strainer installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	8.8m (29 ft) maximum.
Line Size:	0.6 cm (1/4 in.) I.D. typical.
Sample Flow Rate:	Approximately 1.2ℓ (1/3 gal) per hour depending on tube size used.
Sample Capacity:	Continuous flow from pump sequentially fills 12 individual 3.8ℓ (1 gal) sample containers over a 24-hour period.
Controls:	On/off switch. A kit is available for changing the timing sequence (time period represented in one bottle).
Power Source:	115 VAC
Sample Refrigerator:	None.
Construction Materials:	Sampling train is all plastic; frame and case are aluminum with enamel finish.
Basic Dimensions:	46 x 112 x 53 cm (18x44x21 in.); weighs approximately 32 kg (70 lbs); portable.
Base Price:	$1,095; time conversion kit is $16.

General Comments: Refrigeration or heating accessory available. Motor and pump can be easily removed to a remote location. Pump will discharge up to 14m (46 ft) head. A synchronous timing motor pulls a nylon rider holding the discharge tube along a track over a distribution tray to fill bottles.

ETS Fieldtec Model FS-4 Evaluation

1. Unit should be relatively free from plugging or clogging due to inlet strainer and peristaltic pump design.

2. Obstruction of flow will depend upon user mounting of intake.

3. Should operate reasonably well under all flow conditions, but low intake velocity could affect sample representativeness at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; no self-cleaning feature.

6. Unit takes 12 individual gallon samples over a 24-hour period.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers reasonable sample protection.

9. Unit is not designed for manhole operation; however, motor and pump assembly can be detached for use in manholes.

10. Unit cannot withstand total immersion.

11. Optional heater should allow unit to withstand freezing ambients.

12. Unit should be able to sample over a wide range of operating head conditions.

Designation:	HORIZON MODEL S7570
Manufacturer:	Horizon Ecology Company 7435 North Oak Park Avenue Chicago, Illinois 60648 Phone (312) 647-7644
Sampler Intake:	Weighted end of suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	9m (30 ft) maximum.
Line Size:	Varies from 0.08 to 0.8 cm (0.0315 to 0.313 in.) I.D., depending upon pump head chosen.
Sample Flow Rate:	Depends upon lift and pump head chosen, but typically under 100 mℓ per minute.
Sample Capacity:	Collects a grab sample whose size depends upon pump running time.
Controls:	On/off switch plus power selection switch for internal battery operation, AC operation, 12 VDC operation, recharge on 12 VDC, or recharge on AC.
Power Source:	Internal battery, 12 VDC, or 115 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampling train is uninterrupted Tygon tube; silicone or other tube materials available.
Basic Dimensions:	Approximately 30 x 20 x 18 cm (12x8x7 in.); weighs 7.7 kg (17 lbs); portable.

Base Price:	Approximately $411 for a complete unit; S7570 is $335, pump head is $40, tubing is typically $21 for a 15.2m (50 ft) coil, and intake weight is $15.
General Comments:	Actually a field sampling pump rather than a complete system.

Horizon Model S7570 Evaluation

1. Without a screen, intake is vulnerable to plugging; unbroken tube and peristaltic pump should be relatively free from clogging.

2. Obstruction to flow is minimal.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect sample representativeness at high flow rates.

4. Movement of solids should not hamper operation.

5. Designed for attended use only.

6. Unit takes mechanical grab samples.

7. Unit does not appear suitable for collecting floatables or coarser bottom solids.

8. Sample protection provided by user.

9. Unit can operate in manhole environment.

10. Unit cannot withstand total immersion.

11. Since designed for attended use, freezing ambients present no great problem.

12. Unit should operate reasonably well over a wide range of operating head conditions.

Designation:	HORIZON MODEL S7576
Manufacturer:	Horizon Ecology Company 7435 North Oak Park Avenue Chicago, Illinois 60648 Phone (312) 647-7644
Sampler Intake:	Weighted end of suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	9m (30 ft) maximum.
Line Size:	Varies from 0.08 to 0.8 cm (0.0315 to 0.313 in.) I.D. depending upon pump head chosen.
Sample Flow Rate:	Depends upon lift and pump head chosen, but typically under 100 mℓ per minute.
Sample Capacity:	Collects aliquots (whose size depends upon pump running time) every 15 minutes and composites them in a user supplied container.
Controls:	On/off switch plus timer that controls duration of pump run as a percentage of 15 minutes.
Power Source:	115 VAC
Sample Refrigerator:	None.
Construction Materials:	Sampling train is uninterrupted Tygon tube; silicone or other tube materials available.
Basic Dimensions:	Approximately 30 x 20 x 18 cm (12x8x7 in.); weighs 4 kg (9 lbs); portable.
Base Price:	Approximately $216 for a complete unit; S7576 is $140, pump head is $40, tubing is typically $21 for a 15.2m (50 ft) coil, and intake weight is $15.

General Comments: User must supply sample container and protection to complete this unit.

Horizon Model S7576 Evaluation

1. Without a screen, intake is vulnerable to plugging; unbroken tube and peristaltic pump should be relatively free from clogging.

2. Obstruction to flow is minimal.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect sample representativeness at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter; no self-cleaning features.

6. Unit takes adjustable, fixed-size aliquots and composites them in a user supplied container.

7. Unit does not appear suitable for collecting floatables or coarser bottom solids.

8. Sample protection provided by user.

9. Unit can operate in manhole environment.

10. Unit cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Unit should operate reasonably well over a wide range of operating head conditions.

Designation: HORIZON MODEL S7578

Manufacturer: Horizon Ecology Company
7435 North Oak Park Avenue
Chicago, Illinois 60648
Phone (312) 647-7644

Sampler Intake: Weighted end of suction tube installed to suit by user.

Gathering Method: Suction lift from peristaltic pump.

Sample Lift: 9m (30 ft) maximum.

Line Size: 0.49 cm (0.192 in.) I.D.

Sample Flow Rate: Depends upon lift, but typically under 100 mℓ per minute.

Sample Capacity: Collects adjustable size aliquots (30, 89, or 118 mℓ) and composites them in a 9.7ℓ (2.5 gal) container.

Controls: Time intervals at which unit samples are switch selectable for once every 15 minutes, once every 30 minutes, or continuously; aliquot size is switch selectable.

Power Source: Internal battery, 115 VAC charger.

Sample Refrigerator: None.

Construction Materials: Sampling train is uninterrupted Tygon tube (silicone or other tube materials available); sample container is polyethylene; case is ABS plastic.

Basic Dimensions: Approximately 41 x 23 x 56 cm (16x9x22 in.); weighs 12.6 kg (28 lbs); portable.

Base Price: $595. Battery charger is $68.

General Comments: Tube directs any accidental overflow outside the case to prevent damage.

Horizon Model S7578 Evaluation

1. Without a screen, intake is vulnerable to plugging; unbroken tube and peristaltic pump should be relatively free from clogging.
2. Obstruction to flow is minimal.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect sample representativeness at high flow rates.
4. Movement of solids should not hamper operation.
5. No automatic starter; no self-cleaning features.
6. Unit takes adjustable fixed size aliquots and composites them in a suitable container.
7. Unit does not appear suitable for collecting floatables or coarser bottom solids.
8. No refrigeration; cross-contamination appears likely.
9. Unit can operate in manhole environment.
10. Unit cannot withstand total immersion.
11. Not suited for operation in freezing ambients.
12. Unit should operate reasonably well over a wide range of operating head conditions.

<u>Designation</u>:	<u>HYDRAGUARD AUTOMATIC LIQUID SAMPLER</u>
<u>Manufacturer</u>:	Automatic Samplers 850 Kees Street Lebanon, Oregon 97355 Phone (503) 258-2628
<u>Sampler Intake</u>:	End of rigid metal metering chamber.
<u>Gathering Method</u>:	Forced flow due to pneumatic ejection.
<u>Sample Lift</u>:	Depends upon pressure, but in excess of 9m (30 ft).
<u>Line Size</u>:	0.6 cm (0.25 in.) I.D. (standard).
<u>Sample Flow Rate</u>:	Depends upon pressure and lift.
<u>Sample Capacity</u>:	Aliquots of volume proportional to flow depth are composited in a user-supplied container.
<u>Controls</u>:	Sampling interval is adjustable via a needle valve. An optional electronic control unit is available to operate sampler from flowmeter contacts.
<u>Power Source</u>:	Regulated 1.4 kg/sq cm (20 psi) air supply. 115 VAC required with optional electronic control unit.
<u>Sample Refrigerator</u>:	None.
<u>Construction Materials</u>:	Sampling train is all stainless steel, inlet valve is rubber; control unit is cast aluminum.
<u>Basic Dimensions</u>:	Depends upon model, but all are under 91 cm (36 in.) long and will pass through a 15 cm (6 in.) diameter opening.

Base Price: Model HP-1 (aliquot size linear with flow depth) is $246; Model HP-2 (HP-1 with enlarged sample chamber, lines, and inlet hole) is $286; FP Series (aliquot size characterized for depth in Parshall flume or weirs) is $379; FPE Series (FP series with enlarged sample chamber, lines, and inlet hole) is $401; Model A-1 (adjustable aliquot size is independent of flow depth) is $286; air compressor is $140; portable air tank with pressure regulator is $76.

General Comments; At the start of sampling cycle, liquid flows through the inlet port, displacing the inlet valve, and rises in the sample chamber and outlet tube, to the height of liquid flowing through the flume or weir. Air pressure, in the control chamber of the control relay, holds a diaphragm over the air supply port. This pressure bleeds to atmosphere through a needle valve. When the pressure in the control chamber bleeds low enough, the diaphragm moves away from the air inlet port, allowing air to enter the sample chamber. Air pressure exerted on the liquid in the sample chamber will seal the inlet valve, and force the sample out the outlet tube, to the sample container. As air enters the sample chamber, some air flows through the check valve (in the control relay) into the control chamber. When air pressure in the control chamber is equal to the pressure in the operating chamber, a spring forces the diaphragm back over the air inlet. The air is now shut off, and the sample again rises in the sample chamber, ready for the next cycle.

Hydraguard Liquid Sampler Evaluation

1. Single small sample inlet hole would appear vulnerable to blockage unless user provides a screen; remainder of sample train should be clog-free.

2. Sample intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of next triggering. Representativeness is also questionable at high flow rates.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the unit unless special protection is provided by user.

5. No automatic starter; no self-cleaning feature.

6. Collects either variable size aliquots at constant time intervals or constant size aliquots paced by an external flowmeter, and composites them in a user-supplied container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. No refrigeration available. Cross-contamination appears likely.

9. Unit appears suitable for manhole operation.

10. Will not withstand total immersion.

11. Should be operable in freezing ambients.

12. Should be very little restriction on operating head conditions.

Designation:	HYDRA-NUMATIC COMPOSITE SAMPLER
Manufacturer:	Hydra-Numatic Sales Company 65 Hudson Street Hackensack, New Jersey 07602 Phone (201) 489-4191
Sampler Intake:	End of suction tube installed to suit by user.
Gathering Method:	Suction lift from centrifugal pump.
Sample Lift:	Up to 4.6m (15 ft).
Line Size:	1.3 cm (1/2 in.) I.D.
Sample Flow Rate:	5.7 ℓpm (1.5 gpm).
Sample Capacity:	Aliquot size is adjusted (based upon anticipated flow rates where external flowmeter is to be employed) to fill the 19ℓ (5 gal) composite container in 24 hours.
Controls:	Sampler receives signals from external flow meter through a primary relay and clock system, the clock serving as a memory-collecting impulses representing a given flow - at which time a known, pre-set volume of sample is drawn. The volume of sample is controlled by a finely calibrated clock which opens a free-port solenoid valve for a preset time period thereby diverting the flow to the sample container. A built-in timer can be used to pace the sampler when no flow meter is available. It can either be programmed if rough estimates of daily flow variations are known or function as a fixed time interval pacer.
Power Source:	115 VAC electricity.
Sample Refrigerator:	None

Construction Materials: Polyethylene sample container, Tygon sampling lines with bronze fittings and connections, bronze valves and pump, stainless steel available as alternate; cabinet is stainless steel.

Basic Dimensions: 91 x 33 x 91 cm (36x13x36 in.); portable.

Base Price: $1800.

Hydra-Numatic Composite Sampler Evaluation

1. Fairly large line size and "non-clog" pump should give freedom from clogging; manufacturer recommends unit for streams with high solids content.

2. Obstruction of flow will depend upon way user mounts intake tube.

3. Should operate reasonably well over all flow conditions.

4. Solids in the fluid flow should not impede operation.

5. No automatic starter. Continuous flow serves a self-cleaning function.

6. Unit collects aliquots paced by external flowmeter or built-in timer and composites them in a suitable container.

7. Collection of samples of floatables and bottom solids would require specially designed intake by user.

8. No refrigeration available; sample would appear to be reasonably well protected from damage.

9. Unit appears capable of operation in a high humidity environment, but is too large to pass down a standard manhole.

10. Unit cannot withstand total immersion.

11. Unit appears able to tolerate freezing ambients, at least for moderate periods of time.

12. Lift limit of 4.6m (15 ft) poses some restrictions on use of unit.

Designation:	ISCO MODEL 1392
Manufacturer:	Instrumentation Specialties Co. Environmental Division P.O. Box 5347 Lincoln, Nebraska 68505 Phone (402) 799-2441
Sampler Intake:	Weighted plastic cylindrical strainer with four rows of five 0.3 cm (1/8 in.) holes evenly spaced around its periphery.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	7.9m (26 ft) maximum lift; 96% delivery at 2.4m (8 ft), 80% at 5.5m (18 ft).
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Up to 1.5 ℓpm (0.4 gpm) depending upon lift.
Sample Capacity:	Sample size can be switch selected from 40 mℓ to 460 mℓ at 0.9m (3 ft) lift. 28-500 mℓ plastic sample bottles (350 mℓ glass bottles with special base optional) are provided and are used for collecting discrete samples or up to four-sample sequential composites when used with the optional multiplexer. Alternately, if the sample bottles are removed, a single composite sample of up to 26.5ℓ (7 gal) may be collected directly in a single container in the base section.
Controls:	The time interval between collections can be varied in 1/2 hour increments from 1/2 to 6 hours; optional timers can be varied in 15 minute increments to 3 hours or in 10 minute increments to 2 hours. All use a clock mechanism rather than a repeat cycle timer. Connections for an external flowmeter (ISCO Model 1470 only) to collect samples on the basis of stream flow

Figure 7. ISCO Model 1392 Sampler

Photograph courtesy of Instrumentation Specialities Co., Inc.

rate are provided. An optional automatic starter based on flow depth is also available.

<u>Power Source</u>: 115 VAC, 12 VDC auto battery, or internal NiCad or sealed lead-acid battery.

<u>Sample Refrigerator</u>: Has ice cavity for cooling; will maintain samples up to 22°C (40°F) below ambient for at least 24 hours.

<u>Construction Materials</u>: All plastic construction including insulated case, tubing, and sample bottles; stainless steel hardware.

<u>Basic Dimensions</u>: 49.5 cm (19.5 in.) diameter x 53 cm (21 in.)H; weighs 18.1 kg (40 lbs); portable.

<u>Base Price</u>: $1,095; add $130 for NiCad or $50 for lead-acid batteries, $100 for multiplexer, $22 for optional timers. Glass bottle version is $1,121. Model 1640 automatic starter is $125.

<u>General Comments</u>: Sampler will withstand accidental submersion for short periods of time. All electrical and mechanical components are waterproofed; the programming unit is sealed in a water-tight housing that contains a regeneratable dessicant. Manufacturer claims peristaltic pump tubing can fill more than 80,000 sample bottles before requiring replacement. At least 100-460 mℓ samples may be taken on a single 18-hour battery charge. A rotating "clog-proof" funnel delivers samples to the distributer plate which channels them to their individual bottles. After each sample the pump automatically reverses itself to purge intake tube and minimize cross-contamination. Operator may manually trigger unit for individual test sample or purge at any stage of operation.

ISCO Model 1392 Evaluation

1. Strainer could be vulnerable unless oriented properly; the unobstructed 0.64 cm (1/4 in.) inside diameter sampling line, peristaltic pump, and "non-clog" funnel should pass small solids without difficulty.

2. Obstruction of flow will depend upon user mounting of intake.

3. Should operate reasonably well under all flow conditions.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. Optional automatic starter actuates sampling cycle when flow depth reaches a preset value. Backflushing after taking each sample provides a self-cleaning function of sorts.

6. Unit collects up to 28 discrete samples (or sequential composites with optional multiplexer) or a large single composite. Can be paced by either built-in timer or external flowmeter.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. Unit affords good sample protection; insulated case has ice cavity which will keep samples up to 22°C (40°F) below ambient for 24 hours.

9. Unit comes with a harness for suspending it in manholes.

10. Unit can withstand total immersion for short periods of time.

11. Unit would not appear to function well after prolonged exposure to freezing ambients.

12. Unit should be able to sample over a wide range of operating head conditions.

Designation:	ISCO MODEL 1480
Manufacturer:	Instrumentation Specialties Co. Environmental Division P.O. Box 5347 Lincoln, Nebraska 68505 Phone (402) 799-2441
Sampler Intake:	Weighted plastic cylindrical strainer with four rows of five 0.3 cm (1/8 in.) holes evenly spaced around its periphery.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	7.9m (26 ft) maximum lift.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Uniform aliquots of about 7 mℓ are composited in a 11.4ℓ (3 gal) container (standard) or 18.9ℓ (5 gal) container (optional). The base itself can be used to collect 38ℓ (10 gal) samples and can be replaced by a 57ℓ (15 gal) polyolefin barrel for larger sample requirements.
Controls:	Solid state electronics allow sample collection rate to be varied continuously from 0.2 liters per day to 10.4 liters per hour in timed mode; may also be paced by ISCO Model 1470 flowmeter. Optional automatic starter also available.
Power Source:	115 VAC, 12 VDC auto battery, or internal NiCad or sealed lead-acid battery.
Sample Refrigerator:	Base has 2.5 cm (1 in.) foamed-in-place insulation and ice cavity

that will keep a 11.4ℓ (3 gal) sample below 13°C (55°F) for over 24 hours in a 56°C (100°F) environment.

Construction Materials: All plastic construction including insulated case, tubing, and sample container; stainless steel hardware.

Basic Dimensions: 48 cm (19 in.) diameter x 65 cm (25.5 in.) H; weighs 14 kg (31 lbs); portable.

Base Price: $645; $130 for NiCad or $50 for lead-acid battery; Model 1640 automatic starter is $125.

General Comments: Sampler will withstand accidental submersion for short periods of time. All electrical and mechanical components are waterproofed; the programming unit is sealed in a water-tight housing that contains a regenerable dessicant. Model 1480 is not designed to provide true proportions of heavy suspended solids due to its intermittent pumping action. The peristaltic pump turns in one-half revolution increments with two rollers pinching the tubing at the end of each movement so that the sample will not drain back through the intake.

The optional Model 1470 flowmeter enables the sampler to collect a composite based on the volume of passing fluid rather than on time. Flowmeters other than ISCO are not suited for use with the Model 1480 sampler. Up to 151ℓ (40 gal) of sample may be taken on an 18 hour battery charge.

ISCO Model 1480 Evaluation

1. Strainer could be vulnerable unless oriented properly; the unobstructed 0.64 cm (1/4 in.) inside diameter sampling line allows the passage of solids, but the intermittent pumping action is not likely to gather anything large enough to clog unit.

2. Obstruction of flow will depend upon user mounting of intake.

3. Should operate reasonably well under most flow conditions, but unit is not recommended by manufacturer and should not be used in flows with any appreciable amount of heavy suspended solids, even at low flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. Optional automatic starter; no self-cleaning features; cross-contamination appears very likely.

6. Collects fixed size aliquots paced by either a built-in timer or external flowmeter and composites them in a suitable container.

7. Unit does not appear suitable for collection of coarser bottom solids or floatables.

8. Unit affords good sample protection; insulated case has ice cavity which will keep a 11.4ℓ (3 gal) sample below 13°C (55°F) for over 24 hours in a 56°C (100°F) environment.

9. Unit comes with harness for suspending it in manholes.

10. Unit can withstand total immersion for short periods of time.

11. Unit cannot withstand freezing temperatures.

12. Unit should be able to sample over a wide range of operating head conditions.

Designation:	ISCO MODEL 1580
Manufacturer:	Instrumentation Specialties Company Environmental Division P.O. Box 5347 Lincoln, Nebraska 68505 Phone (402) 799-2441
Sampler Intake:	Weighted plastic cylindrical strainer with four rows of five 0.3 cm (1/8 in.) holes evenly spaced around its periphery.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	7.9m (26 ft) maximum lift.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Up to 1.4 ℓpm (0.37 gpm) depending upon lift.
Sample Capacity:	Adjustable size aliquots (between 40 and 600 mℓ) are composited in a 11.4ℓ (3 gal) container (standard) or 18.9ℓ (5 gal) container (optional). The base itself can be used to collect 38ℓ (10 gal) samples and can be replaced by a 57ℓ (15 gal) polyolefin barrel for larger sample requirements.
Controls:	Sample aliquot size is switch selectable in eight increments from 40 to 600 mℓ; sampling frequency can be adjusted from 2.5 to 320 minutes when operating in the timed mode. A switch multiplies the volume that is transmitted by an external flowmeter by a factor of from 1 to 9 when used in the flow mode. Any flowmeter that provides a contact closure at fixed volumetric intervals can be used.

Power Source:	115 VAC, 12 VDC auto battery, or internal NiCad or sealed lead-acid battery.
Sample Refrigerator:	Base has 2.5 cm (1 in.) foamed-in-place insulation and ice cavity that will keep a 11.4ℓ (3 gal) sample below 13°C (55°F) for over 24 hours in a 56°C (100°F) environment.
Construction Materials:	All plastic construction including insulated case, tubing, and sample container; stainless steel hardware.
Basic Dimensions:	48 cm (19 in.) diameter x 65 cm (25.5 in.) H; weighs 14 kg (31 lbs); portable.
Base Price:	$750; $130 for NiCad or $50 for lead-acid battery; Model 1640 automatic starter is $125.
General Comments:	Sampler will withstand accidental submersion for short periods of time. All electrical and mechanical components are waterproofed; the programming unit is sealed in a water-tight housing that contains a regenerable dessicant. The intake line is purged before and after each aliquot is taken to help minimize cross-contamination and ensure that the sample is representative of the time at which it was taken. The optional automatic starter allows the unit to be activated when the flow depth reaches some predetermined level.

ISCO Model 1580 Evaluation

1. Strainer could be vulnerable unless oriented properly; the unobstructed 0.64 cm (1/4 in.) inside diameter sampling line and peristaltic pump should pass small solids without difficulty.

2. Obstruction to flow will depend upon user mounting of intake.

3. Should operate reasonably well under all flow conditions.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. Optional automatic starter; purging before and after each aliquot is taken provides a self-cleaning action of sorts and should help minimize cross-contamination.

6. Collects predetermined size aliquots paced by either a built-in timer or external flowmeter and composites them in a suitable container.

7. Unit does not appear suitable for collection of coarser bottom solids or floatables.

8. Unit affords good sample protection; insulated case has ice cavity which will keep a 11.4ℓ (3 gal) sample below 13°C (55°F) for over 24 hours in a 56°C (100°F) environment.

9. Unit comes with harness for suspending it in manholes.

10. Unit can withstand total immersion for short periods of time.

11. Unit would not appear to function well after prolonged exposure to freezing ambients.

12. Unit should be able to sample over a wide range of operating head conditions.

Designation:	KENT MODEL SSA
Manufacturer:	Kent Cambridge Instrument Company 73 Spring Street Ossining, New York 10562 Phone (914) 941-8100
Sampler Intake:	Plastic strainer at end of 7.6m (25 ft) suction tube.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Up to 4.9m (16 ft).
Line Size:	0.6 cm (1/4 in.) I.D.
Sample Flow Rate:	Up to 150 mℓ per minute depending upon lift.
Sample Capacity:	Collects 24 discrete samples of up to 177 (or 473) mℓ over a period of 6, 12, or 24 hours.
Controls:	Spring-driven clock triggers unit at one hour intervals; other timing mechanisms are available to allow a sample to be taken at 15 or 30 minute intervals. Sample volume is determined by forward pump run time which is adjustable to compensate for lift and flow depth.
Power Source:	12 VDC lead-acid battery, 115 VAC or 220 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampling train is all plastic; totally enclosing glass reinforced plastic case available.
Basic Dimensions:	45.7 cm (18 in.) diameter by 40.6 cm (16 in.) H; weighs 24.4 kg (54 lbs); portable.

Base Price: $1,240.

General Comments: On signal, pump starts and runs in reverse to clear tubing of fluid, then runs forward for a pre-set time to deliver sample to container, after which it again reverses to purge pump and tubing of fluid. A complete cycle takes from 2 to 5 minutes depending upon lift and the quantity of sample desired.

Kent Model SSA Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. At start of each cycle pump operates in reverse to clear line of previous sample to help minimize cross-contamination and offer a sort of self cleaning.

6. Unit collects 24 discrete samples at preset time intervals. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. No refrigeration. Reasonably good sample protection. Cross-contamination should be small.

9. Designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Maximum lift of 4.9m (16 ft) places some restriction on use of unit.

Designation:	KENT MODEL SSB
Manufacturer:	Kent Cambridge Instrument Company 73 Spring Street Ossining, New York 10562 Phone (914) 941-8100
Sampler Intake:	Fine gauze filter at end of suction tube.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Up to 4m (13 ft).
Line Size:	0.6 cm (1/4 in.) I.D.
Sample Flow Rate:	Less than 200 mℓ per minute depending upon lift.
Sample Capacity:	Collects aliquots of pre-set size and either composites them hourly (standard, 30 and 15 minute intervals optional) in one of 24 discrete 500 mℓ containers or in a single 20ℓ bottle.
Controls:	Rheostat on continuously running pump motor controls speed which, together with lift and a 0-60 second diverter timer, determines aliquot size. In the 24 bottle version, the bottles are mounted on a rotating turntable that indexes hourly (standard, 30, or 15 minute intervals optional). Aliquot interval is either controlled by an external flowmeter (rate or totalized signal) or by an adjustable interval timer.
Power Source:	115 VAC; 240 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampling train is plastic except for diverter which may be stainless steel; cabinet is sheet metal.

Basic Dimensions: 38 x 38 x 87 cm (15x15x34 in.); weighs 30 kg (66 lbs); designed for fixed installation.

Base Price: $2,354.

General Comments: Unit is not recommended for flows that are high in suspended solids. In operation, the discharge from the continuously running pump is directed to a tippler mechanism that normally returns the flow to waste downstream from the intake. On signal the tippler mechanism diverts the flow to the sample discharge line for a predetermined time period. Manufacturer recommends changing pump tubing every two weeks and "regular" cleaning of the tippler mechanism.

Kent Model SSB Evaluation

1. Peristaltic action of pump and gauze filter should reduce probability of clogging.
2. Obstruction of flow will depend upon way user mounts intake.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.
4. Movement of solids should not hamper operation.
5. No automatic starter. Continuous flow will offer a sort of self cleaning. The 24 bottle unit would appear very difficult to clean in the field.
6. Unit collects either 24 sequential composite samples made up of a number of individual aliquots or a single composite sample as paced by either an external flowmeter or by an internal timer. Representativeness of sample will depend upon user mounting of intake tube.
7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. No refrigeration. Reasonably good sample protection. Cross-contamination appears likely.

9. Not designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Maximum lift of 4m (13 ft) places some restriction on use of unit.

Designation:	KENT MODEL SSC
Manufacturer:	Kent Cambridge Instrument Company 73 Spring Street Ossining, New York 10562 Phone (914) 941-8100
Sample Intake:	Fine strainer at end of suction tube which must be immersed at least 5 cm (2 in.) below the surface of the liquid to prevent pump from drawing air.
Gathering Method:	Suction lift from progressive cavity screw-type pump.
Sample Lift:	Up to 5m (16.4 ft).
Line Size:	2.5 cm (1 in.) I.D.
Sample Flow Rate:	Up to 33 ℓpm depending upon lift.
Sample Capacity:	Collects either 24 discrete 280 mℓ samples or a 20ℓ composite sample.
Controls:	Sample interval is either controlled by external flowmeter or fixed at 15, 30, or 60 minutes by interval timer. A 0-300 second delay timer is used to control pump running time to assure that a full 280 mℓ aliquot is taken.
Power Source:	115 VAC; 240 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampling train is rubber, plastic, and stainless steel.
Basic Dimensions:	76 x 125 x 81 cm (30x49x32 in.); weighs 80 kg (176 lbs); designed for fixed installation.
Base Price:	$2,354.

General Comments: On signal, the pump starts and its discharge is directed to a tipping bucket, the force of the jet being sufficient to hold the tippler in an upright position so that its overflow discharges back into the flow stream. After a preset time the pump stops and the weight of the sample in the tippler causes it to overbalance and discharge its contents into the sample container. In the 24 bottle version, the turntable carrying the bottles then rotates to present a fresh container for the next sample. The unit must be mounted adjacent to the channel from which the samples are to be taken with the tippler overflow directed back into the channel. The pump must be primed with water upon installation or at any time when it does not contain residual effluence. Manufacturer states that tippler mechanism must be cleaned regularly.

Kent Model SSC Evaluation

1. Should be relatively free from clogging due to large line size; Moyno pump will handle suspended solids.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. No self-cleaning function.

6. Can collect external flowmeter or built-in timer paced samples-either sequential or composite. Representativeness of sample will depend in part upon user mounting of intake tube. Decanting tippler

design could lead to artificial enhancement of suspended solids.

7. Unsuitable for collection of floatables or coarser bottom solids without specially designed intake by user.

8. No refrigeration. Fair sample protection. Cross-contamination appears likely.

9. Not well suited for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Maximum lift of 5m (16.4 ft) and necessity for mounting adjacent to flow stream place restrictions on use of unit.

Designation:	LAKESIDE TREBLER MODEL T-2
Manufacturer:	Lakeside Equipment Corporation 1022 East Devon Avenue Bartlett, Illinois 60103 Phone (312) 837-5640
Sampler Intake:	Specially designed scoop.
Gathering Method:	Mechanical; rotating scoop traverses entire depth of flow; as scoop is rotated out of flow the sample drains by gravity through the hub and into a composite sample jar.
Sample Lift:	Unit must be in flow stream.
Line Size:	1.3 cm (1/2 in.) diameter pipe connects hub to sample container.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Scoop is shaped to gather a volume of sample that is proportional to the channel flow; can vary typically from 300 to 600 mℓ when installed in a Parshall flume.
Controls:	Timer can be used to trigger sampling cycle at any desired interval of a 1 hour period.
Power Source:	115 VAC electricity.
Sample Refrigerator:	Automatic refrigerator available which maintains sample temperature at approximately 4°C.
Construction Materials:	Cast aluminum frame, steel sprockets and chain drive, plexiglass or cast aluminum scoop, plastic pipe, polyethylene sample bottle.
Basic Dimensions:	Approximately 0.6-0.9m (2-3 ft) of head room above flume is required. Other dimensions depend upon size of flume. Refrigerator case is 76 x 61 x 91 cm (30 x 24 x 36 in.). Fixed installation.

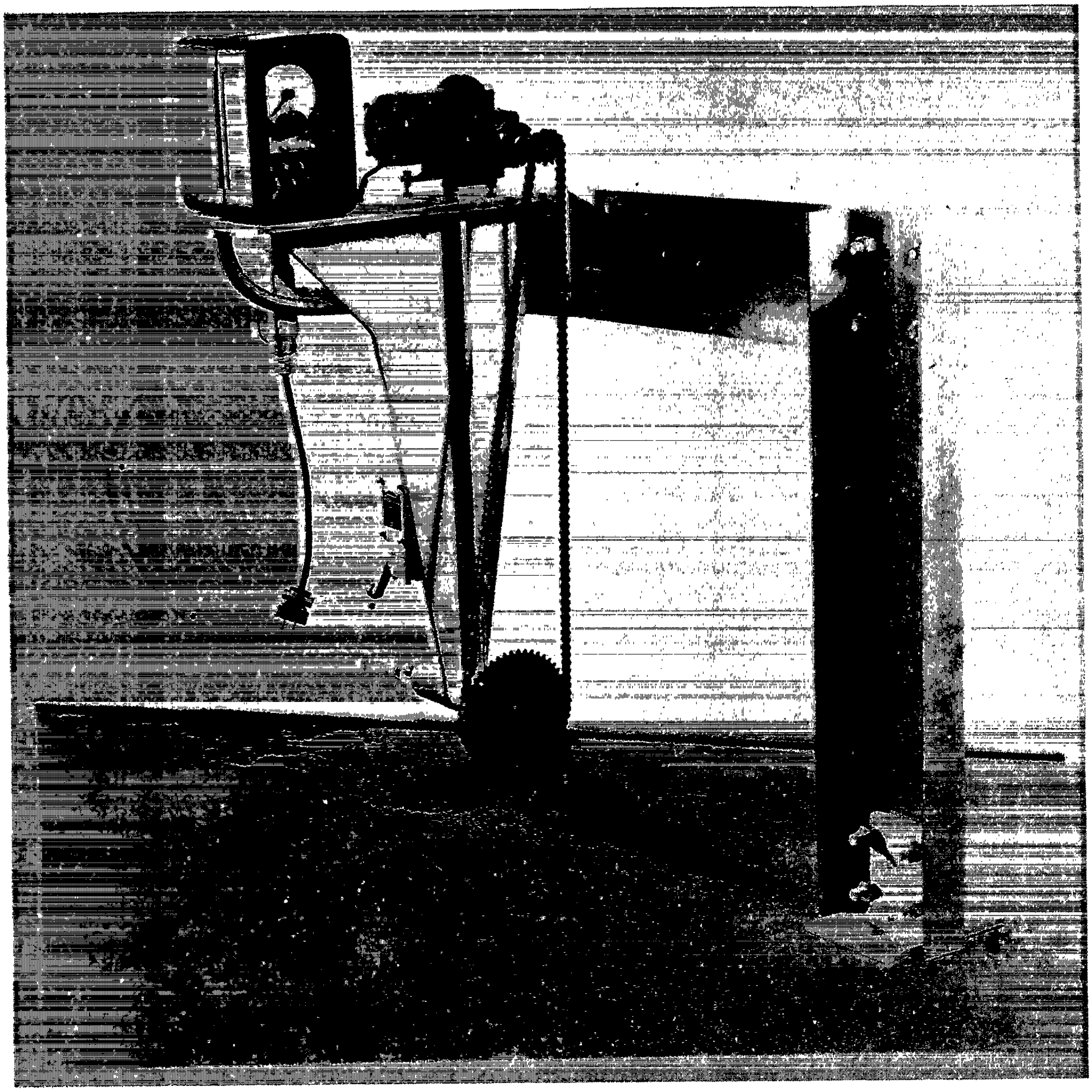


Figure 8. Lakeside Trebler Model T-2 Sampler

Photograph courtesy of Lakeside Equipment Corp.

Base Price:	$688 with plexiglass scoop. $962 with timer. Add $615 for refrigerator.
General Comments:	Without timer the unit takes 30 samples per hour. For accurate sampling the unit must operate in conjunction with a Parshall flume or weir. For raw sewage or industrial wastes with high settleable solids count a Parshall flume is recommended. Daily inspection and weekly cleaning is recommended.

Lakeside Trebler Model T-2 Evaluation

1. Scoop is not likely to pick up any solids large enough to clog sample line.
2. Scoop presents an obstruction over the entire depth of flow during sampling cycle.
3. Scoop must be designed for range of flows anticipated in conjunction with flume. This range has certain limitations.
4. Movement of solids could interfere with scoop rotation; abrasive wear on plexiglass scoop could be high.
5. No automatic starter; no self cleaning features.
6. Collects a sample for compositing from throughout the entire depth of flow that is proportional to depth and hence flow rate through the flume.
7. Will afford some capability of sampling floatables as well as bottom solids.
8. Standard unit has no sample container. Optional refrigerator would appear to offer reasonable protection.
9. Designed for operation in the flow stream but requires a Parshall flume for best operation which would rule out most manholes.
10. Unit cannot withstand total immersion.

11. Unit is not designed to operate in freezing ambients.

12. Unit must be in flow stream to function.

Designation: MANNING MODEL S4000

Manufacturer: Manning Environmental Corporation
120 DuBois Street
P.O. Box 1356
Santa Cruz, California 98061
Phone (408) 427-0230

Sampler Intake: Weighted intake at end of 6.7m (22 ft) sampling tube installed to suit by user.

Gathering Method: Section lift by vacuum pump.

Sample Lift: Up to 6.7m (22 ft).

Line Size: 0.95 cm (3/8 in.) I.D.

Sample Flow Rate: Up to 3.8 ℓpm (1 gpm) depending upon lift.

Sample Capacity: Standard unit takes 24 discrete samples adjustable in size between 50 and 500 mℓ. Options allow for collecting sequential composite samples made up of up to 5 aliquots each or for filling up to 4 bottles in immediate succession.

Controls: Unit may be paced by the contact closure output of an external flowmeter or by an optional internal quartz crystal timer whose interval can be set at 15 or 30 minutes or 1, 2, 3, 4, 6, 8, 12 or 24 hours. Sample size is adjustable (±20 mℓ) by positioning end of syphon in metering chamber. Optional features allow sampler to be switch selectable to take multiple samples in one bottle or the same sample in multiple bottles. There are manual controls for bottle advance and for one complete test cycle.

Power Source: 12 VDC non-spillable wet-cell battery.

Sample Refrigerator:	An ice compartment is provided in the base to facilitate sample cooling.
Construction Materials:	Sampling train is all plastic except for intake; case is molded plastic with stainless steel hardware.
Basic Dimensions:	48 cm (19 in.) diameter x 57 cm (22.5 in.) H; weighs 16 kg (35 lbs); portable.
Base Price:	$1,290.
General Comments:	Sampler may be manually started or actuated by an external device such as a liquid level or rain gage. Cycle begins with compressor purging metering chamber and intake line with air for 15 seconds. A solenoid valve then inverts the compressor lines to create a vacuum in the metering chamber and liquid is drawn up until it is full as detected by an electronic sensor. The solenoid valve then reverses and the metering chamber is again pressurized forcing the excess sample back out the intake hose. A pinch valve opens, permitting the premeasured sample remaining to be forced into the sample bottle, and then closes, permitting purge to continue for 10 seconds. Unit automatically recycles through purge twice, if required.

Manning Model S4000 Evaluation

1. Should be fairly free from clogging due to lack of bends in sample train and high pressure purging feature.

2. Obstruction of flow will depend upon user mounting of intake.

3. Should operate well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. Automatic starter available. Power purge serves a self-cleaning function. Cross-contamination should be minimal.

6. Collects external flowmeter or internal timer paced samples and deposits them in individual containers one at a time or collectively in multiple groups (optional). Sample representativeness will depend upon user mounting of intake.

7. Unsuitable for collection of floatables or coarser bottom solids without specially designed intake by user.

8. Unit affords good sample protection; insulated case has ice cavity which will provide cooling for a limited time. High pressure purge should offer reasonable protection against cross-contamination.

9. Designed to operate in manhole area.

10. Unit appears capable of withstanding accidental, short-time submersion.

11. Unit would not appear to function well after prolonged exposure to freezing ambients.

12. Maximum lift of 6.7m (22 ft) does not place too severe a restriction on use of the unit.

Designation:	MARKLAND MODEL 1301
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Phone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	18.3m (60 ft) standard.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composites 75-mℓ aliquots into a 7.6ℓ (2 gal) bottle.
Controls:	Solid state clock allows selecting intervals between aliquots of 15 to 60 minutes. Optional controller allows pacing from external flowmeter.
Power Source:	Compressed air bottle plus two 6-volt, dry-cell lantern batteries.
Sample Refrigerator:	None
Construction Materials:	Standard intake housing is aluminum alloy; stainless steel and PVC are available as alternates. Standard "duckbill" is EPT; Buna-N and Viton are available. Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.
Basic Dimensions:	Sample intake is 7.3 cm (2.875 in.) diameter x 12.7 cm (5 in.) H; case is 43 x 30 x 71 cm (17x12x28 in.); weighs 27.2 kg (60 lbs); portable.

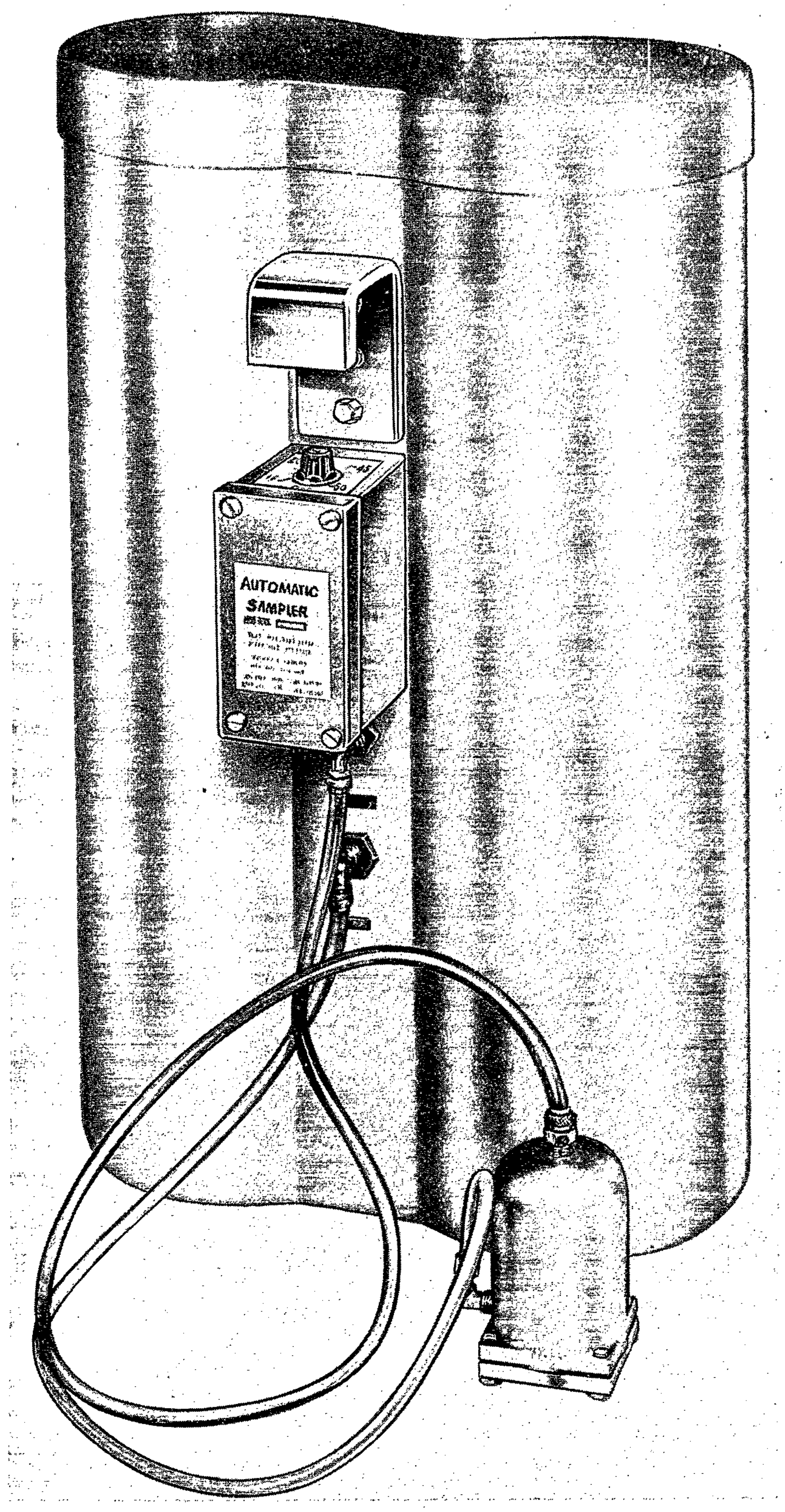


Figure 9. Markland Model 1301 Portable Sampler

Illustration Courtesy of Markland Specialty Ltd.

Base Price: $1095; add $135 for stainless steel or PVC intake, $20 for Viton "duckbill", $100 for flow proportional adapter; all prices include air freight and duty.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom and flattens out to a flaired top where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity.

Markland Model 1301 Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

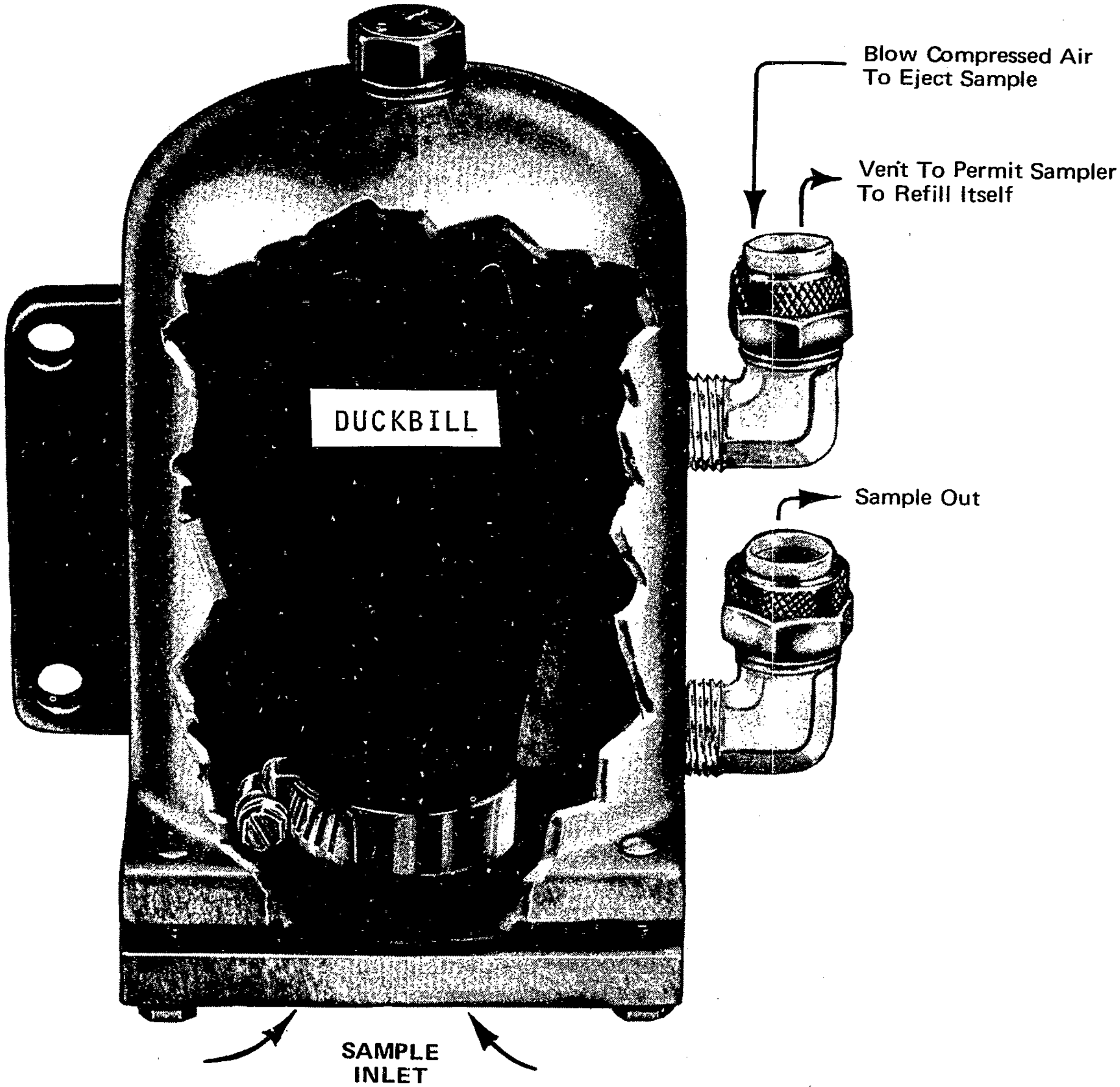


Figure 10. Markland "Duckbill" Sampler Intake

Illustration Courtesy of Markland Specialty Engineering Ltd.

5. Unit has automatic starter but no self-cleaning features.

6. Collects spot samples at either preset time intervals or paced by an external flowmeter and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. No refrigeration is provided. Cross-contamination appears likely.

9. Unit is designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. With a fully charged gas bottle, lifts in excess of 18.3m (60 ft) should be obtainable, putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 101
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Phone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	18.3m (60 ft) standard.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composites 75-mℓ aliquots into a 7.6ℓ (2 gal) bottle.
Controls:	A cycle timer with field adjustable cams allows taking an aliquot every 10, 15, 20, 30, or 60 minutes.
Power Source:	Plant air for Model 101; Model 2101 includes air compressor and motor; 110 VAC.
Sample Refrigerator:	0.17 cu m (6 cu ft) automatic refrigerator to hold either a 7.6 or 18.9ℓ (2 or 5 gal) bottle available.
Construction Materials:	Standard intake housing is aluminum alloy; stainless steel and PVC are available as alternates. Standard "duckbill" is EPT; Buna-N and Viton are available. Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle.

Basic Dimensions:	Sample intake is 7.3 cm (2.875 in.) diameter x 12.7 cm (5 in.) H; wall-mounted control box is 15 x 10 x 15 cm (6x4x6 in.); fixed installation.
Base Price:	$594 for Model 101 including control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle; $634 for Model 2101 including control box, remote sampling intake, air compressor and motor, 100 feet of tubing, and 2 gallon sample collection bottle; add $135 for stainless steel or PVC intake, $20 for Viton "duckbill", $335 for refrigerator, $11 for 5 gallon sample container; all prices include air freight and duty. Model 300 discrete 24 bottle attachment is $795.
General Comments:	The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom and flattens out to a flaired top where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample, the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity.

Markland Model 101 Evaluation

1. Sampler intake should be free from clogging; "duck-bill" will not pass any solids large enough to clog sample line; relatively high discharge pressure will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic start or self-cleaning features.

6. Collects spot samples at preset time intervals and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration is available as an option. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Lifts in excess of 18.3m (60 ft) should be obtainable, putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 102
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Phone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	18.3m (60 ft) standard.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composites 75-mℓ aliquots into a 7.6ℓ (2 gal) bottle.
Controls:	A cycle timer with field adjustable cams allows taking an aliquot every 10, 15, 20, 30, or 60 minutes.
Power Source:	Plant air plus 110 VAC.
Sample Refrigerator:	0.17 cu m (6 cu ft) automatic refrigerator to hold either a 7.6 or 18.9ℓ (2 or 5 gal) bottle available.
Construction Materials:	Standard intake housing is aluminum alloy; stainless steel and PVC are available as alternates. Standard "duckbill" is EPT; Buna-N and Viton are available. Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.
Basic Dimensions:	Sample intake is 7.3 cm (2.875 in.) diameter x 12.7 cm (5 in.) H; wall-mounted control box is 25 x 13 x 30 cm (10x5x12 in.); fixed installation.

Base Price: $894. Includes control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle. Add $135 for stainless steel or PVC intake, $20 for Viton "duckbill", $325 for refrigerator, $10 for 5 gallon sample container. All prices include air freight and duty. Model 300 discrete 24 bottle attachment is $795.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom and flattens out to a flaired top where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity. The control box has a pinch valve on the sample line which squeezes it closed and keeps the sample intake housing filled with pressurized air between aliquot ejections. This feature is useful when sampling liquids with high solids content which would tend to settle out in the intake while waiting to be ejected. Also, the air pressurization provides a reverse air purge back through the "duckbill" thereby providing a sort of self cleaning action should any solids build up in the "duckbill" inlet. The manufacturer recommends this model in particular for raw sewage or liquids with solids content over 200 PPM.

Markland Model 102 Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Representativeness of sample is questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic starter. Reverse air purge through "duckbill" provides a sort of self-cleaning action.

6. Collects spot samples at preset time intervals and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration is available as an option. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Lifts in excess of 18.3m (60 ft) should be obtainable, putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 104T
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Phone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	18.3m (60 ft) standard.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composites 75-mℓ aliquots into a 7.6ℓ (2 gal) bottle.
Controls:	Solid state predetermining digital counter accepts signals from an external flowmeter to gather samples proportional to flow. Optional solid state clock allows sampling at predetermined time intervals.
Power Source:	Plant air for Model 104T; Model 2104T includes air compressor and motor; 110 VAC.
Sample Refrigerator:	0.17 cu m (16 cu ft) automatic refrigerator to hold either a 7.6 or 18.9ℓ (2 or 5 gal) bottle available.
Construction Materials:	Standard intake housing is aluminum alloy; stainless steel and PVC are available as alternates. Standard "duckbill" is EPT; Buna-N and Viton are available. Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.

Basic Dimensions:	Sample intake is 7.3 cm (2.875 in.) diameter x 12.7 cm (5 in.) H; fixed installation.
Base Price:	$1094 for Model 104T including control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle; $1134 for Model 2104T including control box, remote sampling intake, air compressor and motor, 100 feet of tubing, and 2 gallon sample collection bottle. Add $135 for stainless steel or PVC intake, $20 for Viton "duckbill", $335 for refrigerator, $10 for 5-gallon sample container, and $215 for plug-in solid state clock module. All prices include air freight and duty. Model 300 discrete 24 bottle attachment is $795.
General Comments:	The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom and flattens out to a flaired top where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount) until the pressure is equalized. When air pressure is applied to raise the sample, the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity. The two digit counter, when connected to

an external flowmeter providing dry contact pulsing closed momentarily with frequency proportional to flow, counts down from the preset point to zero. When zero is reached, the sampling circuit latches in and extracts an aliquot while simultaneously resetting the counter back to the reset point. Pulses received while the aliquot is being ejected are counted without loss.

Markland Model 104T Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic start or self-cleaning features.

6. Collects spot samples at either preset time intervals with clock option or paced by an external flowmeter and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration is available as an option. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Lifts in excess of 18.3m (60 ft) should be obtainable putting very little restriction on operating head conditions.

Designation:	NALCO MODEL S-100
Manufacturer:	Nalco Chemical Company 180 N. Michigan Avenue Chicago, Illinois 60601 Phone (312) 887-7500
Sampler Intake:	End of 1.3 cm (1/2 in.) standard garden hose.
Gathering Method:	Forced flow from submersible pump.
Sample Lift:	Up to 7.6m (25 ft).
Line Size:	1.3 cm (1/2 in.) garden hose.
Sample Flow Rate:	28.4 ℓpm (7.5 gpm) at 6m (20 ft).
Sample Capacity:	Aliquot volume between 50 to 900 mℓ is a function of the preset diversion time (from 0.6 to 6.0 seconds); composited in user-supplied container.
Controls:	Can be used for either automatic or manual collection of samples. May be operated from a relay tripped by an external flowmeter or level switch contact or by a built-in interval timer that can be set from 3 minutes to 150 minutes.
Power Source:	115 VAC
Sample Refrigerator:	None.
Construction Materials:	Plastic or rubber hose lines; cases are plastic.
Basic Dimensions:	Control box is 29 x 22 x 25 cm (11.5x8.5x10 in.) and weighs 4.5 kg (10 lbs); carrying case is 52 x 20 x 41 cm (20.5x8x16 in.) and weighs 12.2 kg (27 lbs); portable.

Base Price: Not available at time of writing.

General Comments: Can be used portably or installed permanently in one location. Inlet connection to the pump is a standard female garden hose fitting; outlet connection is a standard male garden hose fitting. Sample container must be provided by user. Unit has a pre-flush before each sample diversion to help assure representative flow, and drainage after each sample interval helps keep system clean and free of cross-contamination.

Nalco Model S-100 Evaluation

1. Small screen over pump intake will help prevent clogging as will high flow rate; solenoid valve could be vulnerable to plugging.

2. Submersible pump offers obstruction to flow.

3. Should be capable of operation over the full range of flows.

4. Movement of small solids should not hamper operation; large objects could damage (or even physically destroy) pump unless special protection is provided by user.

5. No automatic starter. Gravity draining serves as a self-cleaning function and should help minimize cross-contamination. Pre-flush feature will also help.

6. Collects spot samples paced either by a built-in timer or external flowmeter and composites them in a user-supplied container.

7. Appears unsuitable for collection of either floatables or coarser bottom solids.

8. Sample container and protection must be supplied by user.

9. Unit is capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit is not suited for prolonged operation in freezing ambients.

12. 7.5m (25 ft) maximum lift does not place a great operating restriction on unit.

Designation:	NAPPE PORTA-POSITER SAMPLER
Manufacturer:	Nappe Corporation Croton Falls Industrial Complex Route 22 Croton Falls, New York 10519 Phone (914) 277-3085
Sampler Intake:	Provided by user; sampler has 0.64cm (1/4 in.) NPT male hose fitting.
Gathering Method:	Suction lift from self-priming positive displacement pump with flexible impeller.
Sample Lift:	1.8m (6 ft) maximum.
Line Size:	Line from petcock to sample container appears to be about 0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Pump delivers up to 11.4 ℓpm (3 gpm). Flow through by-pass to sample container depends upon petcock setting.
Sample Capacity:	Adjustable size aliquots (20 to 240 mℓ) are composited in a 3.8ℓ (1 gal) container.
Controls:	The pump is operated once every 15 minutes for a period of 20 seconds. A cycle progress indicator informs the operator of the time to next sample. There is also a manual advance to the next sample.
Power Source:	Model PPAC is 115 VAC; Model PPD is 12 VDC and Model PPU is 115 VAC or 12 VDC. The 12 VDC power must be supplied by the user and is usually a wet-cell battery.
Sample Refrigator:	None.

Construction Materials:	Sample train is bronze, brass, Buna-N, and polyethylene. Casing is 16 gauge steel with baked enamel finish.
Basic Dimensions:	Basic unit is 24 x 22 x 34 cm (9.5x8.5x13.5 in.); Models PPAC and PPD weigh 10.4 kg (23 lbs); Model PPU weighs 11.8 kg (26 lbs); portable.
Base Price:	PPAC-4 $225. PPD-4 $245. PPU-4 $285.
General Comments:	At the end of each sampling cycle, both inlet and exhaust are gravity drained. This drainage provides a sort of backwashing to help prevent clogging. Model PPU is provided with two interchangeable power cords; models PPAC and PPD have permanent power cords. A sample intake strainer is available as an option at $12.50, and a mounting base is available at $10.00. 1.3 cm (1/2 in.) I.D. polyethylene hose is available at $1.50 per foot.

Nappe Porta-Positer Model PPAC Evaluation

1. Unit would not appear to be vulnerable to clogging, especially with use of optional strainer, except perhaps at the petcock.

2. Obstruction of flow will depend upon user mounting of intake line and use of optional strainer.

3. Should operate reasonably well under all flow conditions. Although line velocity is high enough to transport suspended solids reasonably well, the tee branch and throttling effect of the petcock bypass valve may affect sample representativeness.

4. Movement of solids should not hamper operation.

5. No automatic starter. Gravity fall of liquid in lines when pump stops will provide a self-cleaning action of sorts.

6. Unit collects a simple composite sample over a 4 to 48 hour period. The 15-minute aliquot gathering frequency is non-adjustable.

7. Unsuitable for collection of samples of floatables or coarser bottom solids without specially designed intake by user.

8. No refrigeration; case offers some sample protection. Small amount of cross-contamination might be experienced.

9. Unit appears capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Not ideally suited for operation in freezing ambient conditions.

12. Maximum lift of 1.8m (5 ft) puts restrictions on use of unit.

Designation:	NAPPE SERIES 46 LIQUID SAMPLER
Manufacturer:	Nappe Corporation Croton Falls Industrial Complex Route 22 Croton Falls, New York 10519 Phone (914) 277-3085
Sampler Intake:	Provided by user; sampler has 0.95 cm (3/8 in.) NPT female pipe inlet.
Gathering Method:	Suction lift from self-priming pump with flexible impeller.
Sample Lift:	To 4.6m (15 ft) suction; to 6m (20 ft) discharge.
Line Size:	0.95 cm (3/8 in.) I.D.
Sampler Flow Rate:	Pump delivers up to 13.2 ℓpm (3.5 gpm).
Sample Capacity:	Adjustable size aliquots are composited in a 11.4ℓ (3 gal) sample container.
Controls:	Sampler can be triggered by an adjustable timer which sets the frequency between samples or by an external flowmeter for flow-proportional sampling. Pump is programmed for one of three cycles depending upon sample requirements.
Power Source:	115 VAC.
Sample Refrigerator:	Refrigeration is available and consists of a chilling coil immersed in the sample container. The compressor is housed in a compartment on top of the main sample cabinet. Temperature control is by an expansion valve that is factory set at 7°C (45°F).

Construction Materials	Pump is stainless steel with neoprene impeller. Solenoid is stainless steel and neoprene. Sample container is polyethylene. Hoses are reinforced neoprene. Sampler cabinet is primed aluminum finished in baked enamel. Hinges are stainless steel; lock is brass.
Basic Dimensions:	Non-refrigerated - 39 x 34 x 102 cm (15.4x13.5x40.1 in.); Refrigerated - 39 x 34 x 130 cm (15.4x13.5x51.1 in.); Shipping weight is 91 kg (200 lbs); designed for fixed installation.
Base Price:	$1100 to $1800 depending upon options.
General Comments:	The pump is programmed for one of three cycles. For lifts up to 3m (10 ft), the pump operates for 30 seconds prior to and during the sample diversion; for lifts from 3 to 4.6m (10 to 15 ft), the pump runs continuously and is protected by a pressure sensor; and for lifts over 4.6m (15 ft), the pump is located outside the cabinet, alongside the sampling point and runs continuously. The electrical programmer is housed on the cabinet door and is hinged to permit access. Sealed disconnect couplings are used on the refrigeration lines to permit cleaning of coils. For situations where the sampling point is not accessible to the sampler, an optional submersible pump is available.

Nappe Series 46 Liquid Sampler Evaluation

1. Unit would not appear to be vulnerable to clogging, except at hose fittings and solenoid valve.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Should operate reasonably well under all flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Gravity fall of liquid in lines when pump stops will provide a sort of self-cleaning action. Pump runs 30 seconds before extraction of each sample, keeping lines reasonably clear.

6. Can collect either timer or flowmeter paced samples and composites them in a 11.4ℓ (3 gal) container. A manual test switch operates the solenoid valve and the self-priming pump.

7. Unsuitable for collection of samples of floatables and coarser bottom solids without specially designed intake by user.

8. Refrigeration is available as an option. Cross-contamination should not be a large problem.

9. Unit not designed for manhole operation.

10. Cannot withstand immersion.

11. Thermostatically controlled heater allows operation in freezing ambients.

12. Maximum lift of 6m (20 ft) does not place severe restrictions on use of unit.

Designation:	NOASCONO AUTOMATIC SHIFT SAMPLER
Manufacturer:	Paul Noascono Company 805 Illinois Avenue Collinsville, Illinois 62234 Phone (618) 344-3706
Sampler Intake:	End of 0.48 cm (3/16 in.) I.D. suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Up to 9m (30 ft).
Line Size:	0.48 cm (3/16 in.) I.D.
Sample Flow Rate:	Up to 8 mℓ per minute.
Sample Capacity:	Ten user-supplied wide mouth, 3.8ℓ (1 gal) jars are sequentially filled from continuously running pump; one jar requires 8 hours to fill.
Controls:	On/off switch. Speed regulation is accomplished by a variable pump pulley and with a two-step motor pulley.
Power Source:	110 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampler box is "Benelex", plywood, and stainless steel. Sampling train is Mayon, teflon, and Tygon. Other parts are bronze and plastic.
Basic Dimensions:	41 x 122 x 56 cm (16x48x22 in.); weighs 39 kg (87 lbs); portable.
Base Price:	Not available at time of writing.

General Comments: Manufacturer claims that construction of box will ensure corrosion-free operation and will enable sampler to operate at subzero temperatures with the addition of user-supplied heater. Box cover is insulated with styrofoam blanket. Box is designed to hold 10 wide-mouth 3.7ℓ (1 gal) sample jars which must be supplied by the user. A threaded stainless steel driving shaft and plastic trough are used to deliver sample to jars sequentially. Manufacturer notes that samples will not be representative as regards solids content.

Noascono Automatic Shift Sampler Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; peristaltic pump can tolerate solids, but tubing is rather small.

2. Obstruction to flow will depend upon user mounting of intake line.

3. Should operate over all flow-conditions but extremely low intake velocity will affect representativeness of sample at all flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; no self-cleaning features.

6. Unit sequentially fills user supplied sample containers from very small, continuous stream. Pump speed is adjustable.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers some sample protection, but offers no refrigeration.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Unit offers reasonable protection for operation in freezing ambients due to insulated box cover if heating element is installed by user. Intake line could freeze unless also protected.

12. Maximum lift of 9m (30 ft) does not place much operating restriction on unit.

Designation:	N-CON SURVEYOR II MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	End of 1.3 cm (1/2 in.) sampling tube installed to suit by user.
Gathering Method:	Suction lift by self-priming flexible impeller pump.
Sample Lift:	1.8m (6 ft) maximum.
Line Size:	0.64 cm (1/4 in.) I.D. line connects diverter to sample container.
Sample Flow Rate:	20 ℓpm (5 gpm).
Sample Capacity:	Aliquot size adjustable from approximately 150 mℓ to 5000 mℓ; composited in user supplied container, 7.6ℓ (2 gal) jug to 208ℓ (55 gal) drum.
Controls:	Timer may be set to collect from 3 to 20 samples per hour; may also be paced by either pulse duration or totalizer signals from external flowmeter.
Power Source:	115 VAC.
Sample Refrigerator:	115 VAC/12 VDC refrigerator which can hold either one 7.6ℓ (2 gal) or two 3.8ℓ (1 gal) bottles available.
Construction Materials:	Sampling train is PVC, nylon, epoxy resin, and Buna-N.
Basic Dimensions:	28 x 20 x 25 cm (11 x 8 x 10 in); weighs 6.8 kg (15 lbs); portable.
Base Price:	$290; add $280 for refrigerator, $20 for flow proportional hook-up.
General Comments:	When sample is to be collected, the self-priming pump operates for a preset period of time which determines the volume of the sample.

Approximately 15% of the pump's throughput is diverted to the sample receiver by a fluidic diverter. When the pump stops the fall of liquid level in the exhaust line backwashes to help prevent clogging. User must supply reinforced garden hose lines for sample intake and return and sample container.

N-Con Surveyor II Model Evaluation

1. Unit would not appear to be vulnerable to clogging, except possibly at diverter fittings.

2. Will depend upon way user mounts end of sampling tube.

3. Should operate reasonably well under all flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Fall of liquid in exhaust line when pump stops will backwash giving a sort of self-cleaning action.

6. Can collect either timer or flowmeter paced samples and composite them in a suitable container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unsuitable for collection of samples of floatables and coarser bottom solids without specially designed intake by user.

8. Automatic refrigerator available as option. Small amount of cross contamination might be experienced.

9. Should be able to operate in manhole enviroment.

10. Cannot withstand immersion.

11. Not ideally suited for operation in freezing ambients.

12. Maximum lift of 6 feet limits location of unit.

Designation:	N-CON SCOUT II MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Plastic strainer approximately 5 cm (2 in.) diameter x 20 cm (8 in.) long and perforated with 0.3 cm (1/8 in.) holes.
Gathering Method:	Suction lift by peristaltic pump.
Sample Lift:	Up to 5.5 m (18 ft).
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	150 mℓ per minute.
Sample Capacity:	Aliquot size is adjustable via a solid state timer to suit hydraulics of installation and sampling programs; composited in a 3.8ℓ (1 gal) container.
Controls:	All solid state controller in moisture-proof enclosure has function switch for test, reset and set, and purge selection (before, after, or both before and after sample collection), sample volume setting knob, on/off switch, and samples per hour switch (1, 2, 4, or 8 per hour or one sample every 1, 2, or 3 hours). Float switch automatically shuts unit off when sample container is full. Unit may also be paced by any flow totalizer providing a momentary contact closure every preset number of gallons.
Power Source:	115 VAC or internal 12 VDC solid-gel battery.
Sample Refrigerator:	115 VAC/12 VDC refrigerator which can hold either one 7.6ℓ (2 gal) or two 3.8ℓ (1 gal) bottles available.

Construction Materials:	Sampling train PVC, silicone rubber, polyethylene; case is compression molded fiberglass, stainless steel hardware.
Basic Dimensions:	36 x 15 x 43 cm (14 x 6 x 17 in.); weighs 10 kg (22 lbs); portable.
Base Price:	$575; solid-gel battery is $42, charger is $38, automatic refrigerator is $280.
General Comments:	Optional refrigerator is absorption-type, measures 43 x 43 x 38 cm (17 x 17 x 15 in.), and weighs 9.5 kg (21 lbs). Case is weatherproof.

N-Con Scout II Model Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate reasonably well over all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. Three purge modes are switch-selectable to help minimize cross-contamination and offer a sort of self-cleaning.

6. Unit collects preset size aliquots at either preset time intervals or as paced by external flowmeter and composites them in container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collecting floatables or coarser bottom solids.

8. Refrigeration optional. Reasonably good sample protection (container is connected only to pump). Cross-contamination should be small.

9. Designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing environments.

12. Maximum lift of 5.5m (18 ft) places small restriction on use of unit.

Designation:	N-CON SENTRY 500 MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Plastic strainer approximately 5 cm (2 in.) diameter x 20 cm (8 in.) long and perforated with 0.3 cm (1/8 in.) holes.
Gathering Method:	Suction lift by peristaltic pump.
Sample Lift:	Up to 5.5m (18 ft).
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	150 mℓ per minute.
Sample Capacity:	Collects 24 sequential composite 500 mℓ samples made up of from 2, 4, or 8 individual aliquots over a period of 3 to 72 hours.
Controls:	Same as Scout II Model plus bottles per hour switch adjustable from 8 bottles per hour to 1 bottle in 3 hours.
Power Source:	115 VAC or internal 12 VDC solid-gel battery.
Sample Refrigerator:	Available as option.
Construction Materials:	Same as Scout II, but glass sample jars (clear styrene optional) and aluminum case with baked-on synthetic enamel finish.
Basic Dimensions:	37 x 37 x 56 cm (14.5 x 14.5 x 22 in.); weighs 17.7 kg (39 lbs) portable.
Base Price:	$1,125; solid-gel battery is $42, charger is $38.

General Comments: Similar in operation to the Scout Model except for capability to collect discrete samples. Sampler automatically shuts off after 24th bottle is filled. Twin doors provide easy access at both front and rear of case. Sample distribution tray slides out for easy cleaning without disturbing other components. A second pump head may be easily field installed, providing the ability to collect a single as well as sequential composite sample simultaneously or to sample at different levels in the flow or from two different sources simultaneously.

N-Con Sentry 500 Model Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. Three purge modes are switch-selectable to help minimize cross-contamination and offer a sort of self-cleaning.

6. Unit collects 24 sequential composite samples made up of 2 to 8 individual aliquots at preset time intervals or as paced by external flowmeter. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. Refrigeration optional. Reasonably good sample protection. Cross-contamination should be small.

9. Designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing environments.

12. Maximum lift of 5.5m (18 ft) places small restriction on use of unit.

Designation:	N-CON SENTINEL MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Provided by user; sampler has standard 5 cm (2 in.) pipe inlet.
Gathering Method:	External head to provide flow through a sampling chamber from which an oscillating dipper (after McGuire and Stormgaard) extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the sample bottle; it appears to be about 2.5 cm (1 in.).
Sample Flow Rate:	38 to 189 ℓpm (10 to 50 gpm).
Sample Capacity:	Sampling dipper collects a 25 mℓ aliquot; a 7.6ℓ (2 gal) composite container is provided.
Controls:	Constant rate sampling (between 3 and 20 samples per hour) is controlled by built-in timer; flow proportional composites are collected by connecting to the electrical output of a pulse duration or integrating external flowmeter.
Power Source:	115 VAC electricity
Sample Refrigerator:	Automatic refrigerator to maintain sample at 4° to 10°C is available.
Construction Materials:	PVC and polyethylene.
Basic Dimensions:	56 x 71 x 147 cm (22 x 28 x 58 in.). Designed for fixed installation. Weighs 83.9 kg (185 lbs).

Base Price: Around \$2,600 with refrigerator.

General Comments: Manufacturer claims representative samples assured due to design of sample chamber which causes thorough mixing of liquid before it flows over adjustable weir.

N-Con Sentinel Model Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.

2. Sampler itself offers no flow obstruction.

3. Should operate well over entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross contamination.

6. Can collect either flow proportional or fixed time interval composites. Representativeness of sample will be a function of sample intake which is not a part of this unit.

7. Collection of floatables and coarser bottom solids will depend upon design of sampling intake.

8. Automatic refrigeration maintains samples at 44° to 10°C. Offers good sample protection and freedom from precontamination.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Does not appear capable of prolonged exposure to extremely cold ambient conditions.

12. Operating head is provided by user.

Designation:	N-CON TREBLER MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Specially designed scoop.
Gathering Method:	Mechanical; oscillating scoop is lowered into the channel traversing entire depth of flow, then returned to its raised position, draining the collected sample by gravity through a swivel fitting coaxial with the hub into a sample container.
Sample Lift:	Unit must be in flow stream.
Line Size:	1.3 cm (1/2 in.) diameter pipe connects hub to sample container.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Scoop is shaped to gather a volume of liquid that is proportional to the channel flow; can vary typically from 200 to 600 mℓ when installed in a Parshall flume.
Controls:	Electric timer may be set to take from 3 to 20 samples per hour.
Power Source:	115 VAC electricity
Sample Refrigerator:	Automatic refrigerator available which provides 4° to 10°C sample storage.
Construction Materials:	Cast aluminum frame and cover; PVC scoop, plastic pipe.
Basic Dimensions:	Approximately 0.6 to 0.9m (2 to 3 ft) of headroom is required. Other dimensions depend upon size of flume or weir. Refrigerator case is 61 x 66 x 76 cm (24 x 26 x 30 in.). Designed for fixed installation.

Base Price: $1,050; add $300 for refrigerator.

General Comments: Drive mechanism and control programmer are totally enclosed and weatherproof, with no exposed chains or sprockets. Oscillating action of scoop permits installation in smaller weir boxes and manholes and lessens the chances of fouling with rags, etc., or being damaged by floating debris. Must operate in conjunction with a weir or Parshall flume.

N-Con Trebler Model Evaluation

1. Scoop is not likely to pick up any solids large enough to clog sample line.
2. Scoop presents an obstruction over the entire depth of flow during sampling cycle.
3. Scoop must be designed for range of flows anticipated in conjunction with flume. This range has certain limitations.
4. Movement of solids could interfere with scoop rotation; abrasive wear on rigid, high impact PVC scoop should not be too great.
5. No automatic starter; no self cleaning features.
6. Collects a sample for compositing from throughout the entire depth of flow that is proportional to depth and hence flow rate through the flume.
7. Will afford some capability of sampling floatables as well as bottom solids.
8. Standard unit has no sample container. Optional refrigerator would appear to offer reasonable protection.
9. Designed for operation in the flow stream, but requires a Parshall flume for best operation which would rule out most manholes.
10. Unit cannot withstand total immersion.

11. Unit is not designed to operate in freezing ambients.

12. Unit must be in flow stream to function.

Designation:	PERI PUMP MODEL 704
Manufacturer:	The Peri Pump Company Ltd. 180 Clark Drive Kenmore, New York 14223 Phone (716) 875-7955
Sampler Intake:	Weighted screen at end of 1.8m (6 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Designed to operate between 1.2 and 1.8m (4 and 6 ft); Manufacturer claims, however, that pump is capable of lifting over 7.6m (25 ft) although at reduced output.
Line Size:	Appears to be about 0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Approximately 160 mℓ per minute.
Sample Capacity:	Fixed size (approx. 40 mℓ) aliquots are taken every 15 minutes and composited in a 3.8ℓ (1 gal) container.
Controls:	On/off switch.
Power Source:	Two 12 VDC dry-cell batteries.
Sample Refrigerator:	None
Construction Materials:	Sample train is PVC and silicon. Case is aluminum with rubber sealed door and epoxy-sealed controls and is painted with an acrylic lacquer.
Basic Dimensions:	49 x 37 x 30 cm (16x12x10 in.); weighs 11.3 kg (25 lbs); portable.
Base Price:	Not available at time of writing.

General Comments: An overflow tube is connected to the container in case the unit is left longer than 24 hours. Aliquot size is a function of lift.

Peri Pump Model 704 Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon user mounting of intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not affect operation adversely.

5. No automatic starter; no self-cleaning features.

6. Unit takes fixed time interval samples paced by a built-in timer and composites them in a suitable container.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers reasonable sample protection, but offers no refrigeration. Cross-contamination appears very likely.

9. Unit is designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients.

12. Designed for operation at between 1.2 and 1.8m (4 and 6 ft) lift, which limits location of unit. Greater lifts are possible but with reduced aliquot size.

Designation:	PHIPPS AND BIRD DIPPER-TYPE
Manufacturer:	Phipps and Bird, Inc. 303 South 6th Street Richmond, Virginia 23205 Phone (703) 644-5401
Sampler Intake:	Dipping bucket.
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	Up to 3m (10 ft) standard, longer on special order.
Line Size:	Not applicable.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Dipping bucket holds 200 mℓ; user supplies sample composite container to suit.
Controls:	Sampling cycle can either be started at fixed, selected intervals from a built-in timer (15 minutes) or in response to signals from an external integrating flowmeter. Test switch.
Power Source:	115 VAC or 12 VDC electricity.
Sample Refrigerator:	Optional refrigerator, with wide mouth sample intake (to match sampler discharge trough) leading to custom sampler container, will maintain sample between 4-10°C.
Construction Materials:	Dipper and funnel are stainless steel; sprockets and chain are steel (stainless available), supports are angle iron.
Basic Dimensions:	Lower portion of unit will pass through a 30.5 cm (12 in.) diameter opening; base is 41 x 61 cm (16 x 24 in.) and entire unit will pass through a 76 cm (30 in.) diameter opening; unit extends 0.9m (3 ft) above base. Fixed installation.

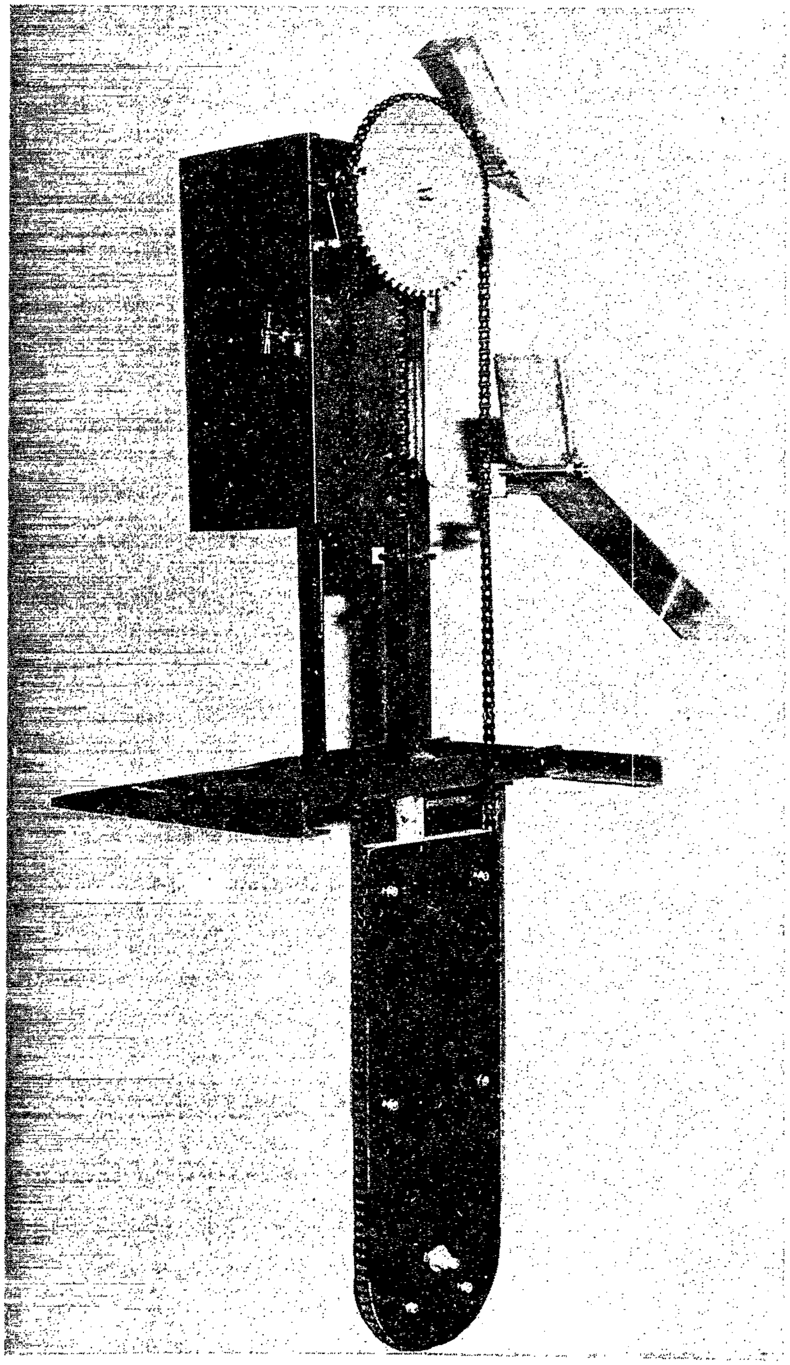


Figure 11. Phipps and Bird Dipper-Type Sampler

Photograph courtesy of Phipps and Bird, Inc.

Base Price: $725; $1,145 in stainless steel; $1,980 for explosion proof version: $2,450 for explosion proof version in stainless steel; refrigerator is $325.

General Comments: Manufacturer states unit was designed to sample trash laden streams where it is not possible to operate a pump. A circuit breaker prevents damage if unit becomes jammed.

Phipps and Bird Dipper-Type Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket drive is vulnerable to jamming by rags, debris, etc.
2. Unit provides a rigid obstruction to flow.
3. Unit should operate over full range of flows.
4. Movement of solids could jam unit.
5. No automatic starter; no self-cleaning features.
6. Collects fixed size aliquots paced by built-in timer or external flowmeter and composites them in a suitable container.
7. Does not appear well suited for collecting either floatables or coarser bottom solids.
8. No sample collector provided.
9. Unit is capable of manhole operation.
10. Unit is not weatherproof; cannot withstand total immersion.
11. Unit is not suitable for prolonged operation in freezing ambients.
12. Unit would appear impractical for very long lifts (say above 18.3m (60 ft).

Designation:	PROTECH MODEL CG-110
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-4420
Sampler Intake:	Plastic sampling chamber (about 5 cm diameter) with two rows of 0.3 cm (1/8 in.) diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 9.1m (30 ft).
Line Size:	0.32 cm (1/8 in.) I.D.
Sample Flow Rate:	Less than 1 ℓpm; depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volumes of 25, 50, 75, or 100 mℓ; composited in user supplied container.
Controls:	Sampling frequency is determined by a built-in ratemeter and fluidic accumulator timing circuit. Sampling interval adjustable from 2 to 60 minutes. On-off valve for control of external pressure source. Standard 50 mℓ sample chamber has removable 25 mℓ plug.
Power Source:	Requires external pressure source such as refrigerant type of propellant, nitrogen or compressed air.
Sample Refrigerator:	Available as an option.

Construction Materials:	All components in sampling train are TFE resins, PVC, and nylon. Case is heavy duty aluminum with baked vinyl finish.
Basic Dimensions:	33 x 23 x 30 cm (13x9x12 in.); weighs 7.3 kg (16 lbs); portable.
Base Price:	$485.
General Comments:	Model is explosion proof. No battery or electrical lines needed. Propellant consumption is approximately equivalent to 150-170 samples per 0.45 kg (1 lb) of R-12 refrigerant. Optionally available are TFE sample chamber and tubing for sampling oily or sticky liquids, puncturing valve for propellant in sealed refrigerant cans, short unweighted bottom cap for sample chamber, and a portable refrigerator.

Protech Model CG-110 Evaluation

1. Sampling train is unobstructed 0.32 cm (1/8 in.) I.D. passageway which will pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature of sorts in the sampling chamber is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle.

6. Collects spot samples at preset time intervals and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Portable refrigerator available as an option to refrigerate sample containers. Some cross-contamination appears likely.

9. Designed for manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Unit is not suited for operation in freezing ambients.

12. Upper lift limit of 9.1m (30 ft) does not pose a severe restriction on operating head conditions.

Designation:	PROTECH MODEL CG-125
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-4420
Sampler Intake:	Plastic sampling chamber (about 5 cm diameter) with two rows of 0.3 cm (1/8 in.) diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 9.1m (30 ft).
Line Size:	0.32 cm (1/8 in.) I.D.
Sample Flow Rate:	Less than 1 ℓpm (1/4 gpm); depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volumes from 25 to 250 mℓ available; sample composited in suitable container, 5.8ℓ (1.5 gal) jug available.
Controls:	Sampling frequency is determined by metering gas pressure (via a rotometer with a vernier needle valve and two float balls) into a surge tank until a preset pressure, normally 1 kg/sq cm (15 psi), is reached, whereupon a pressure controller releases the gas, a 0.14 kg/sq cm (2 psi) differential, to the sample chamber forcing the sample up to the sample bottle and blowing the lines clear. The higher the gas flow rate the higher the sampling frequency. Sampling frequency is adjustable from two minutes to one hour.
Power Source:	Three 0.45 kg (1 lb) cans of refrigerant on a common manifold inside the case is standard; compressed air or nitrogen can also be used.

Sample Refrigerator: Portable refrigerator (110 VAC or 12 VDC) with capacity for one 5.8ℓ (1.5 gal) or two 3.8ℓ (1 gal) sample containers available.

Construction Materials: All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum, gas valves and fittings are of brass and copper.

Basic Dimensions: 33 x 25 x 43 cm (13 x 10 x 17 in.) standard; deep case large enough to hold a 5.8ℓ (1.5 gal) sample container and winterizing kit is available. Standard unit weighs 14 kg (31 lbs) total; portable.

Base Price: $695 for basic unit including 50 mℓ sample chamber, 6 cans of refrigerant, and two 9m (30 ft) lengths of tubing. Add $75 for deep case; $140 for winterizing kit; $20 for 100 mℓ or $80 for 250 mℓ sample chamber; $275 for refrigerator. Two high-lift, to 91m (300 ft), models are available; CG-170 at $870 offers continuously adjustable lift, while CG-190 at $890 has convertible high/low lift.

General Comments: Standard model is explosion proof, no battery or electrical power is required. Manufacturer claims unit will sample up to 1/8" diameter solids. Check valve in sample chamber is self-cleaning. Self-cleaning feature is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle. A flow splitter provides 1 to 2, 1 to 1, or 2 to 1 ratio of sample flow to waste return flow. Three cans of refrigerant allow taking up to 250 aliquots. Winterizing is accomplished using strip heaters operated by an automatic temperature control.

Protech Model CG-125 Evaluation

1. Sampling train is unobstructed 0.32 cm (1/8 in.) I.D. passageway which will pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature of sorts in the sampling chamber is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle.

6. Collects spot samples at preset time intervals and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Refrigeration is available as an option. Deep case version offers reasonable sample protection. Some cross-contamination appears likely.

9. Unit is designed for manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Can operate in freezing ambients if fitted with optional winterizing kit.

12. Standard upper lift limit of 9.1m (30 ft) does not pose a great restriction on operating head conditions; high lift versions have virtually no restriction.

Designation:	PROTECH MODEL CG-125FP
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-4420
Sampler Intake:	Plastic sampling chamber (about 5 cm diameter) with two rows of 0.3 cm (1/8 in.) diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 9.1m (30 ft).
Line Size:	0.32 cm (1/8 in.) I.D.
Sample Flow Rate:	Less than 1 ℓpm (1/4 gpm); depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volumes from 25 to 250 mℓ available; sample composited in suitable container, 5.8ℓ (1.5 gal) jug available.
Controls:	Can take samples at preset time intervals in same way as Model CG-125. For flow proportional sampling a normally closed, solenoid operated valve in the gas inlet opens momentarily on receiving an impulse from an external flow registering device. The sampling frequency is determined by the frequency and duration of these impulses and the rotometer setting. Thus the intermittent flow signal impulses are translated into fluidic impulses that are accumulated in the surge tank which serves as a totalizer. If the flow proportional signal is supplied by a totalizer and it is desired to take one sample per impulse, a solid state timer is available

	which will hold the solenoid open long enough to accumulate the necessary pressure.
Power Source:	115 VAC or 6 VDC; three 0.45 kg (1 lb) cans of refrigerant on a common manifold inside the case is standard; compressed air or nitrogen can also be used.
Sample Refrigerator:	Optional as with CG-125.
Construction Materials:	All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum, gas valves and fittings are of brass and copper.
Basic Dimensions:	Same as Model CG-125.
Basic Price:	$925 for basic unit; add $250 for solid state timer, other accessories priced as for Model CG-125.
General Comments:	Basically a flow proportional version of Model CG-125. Completely portable in battery version. Control solenoid is certified by UL for use in hazardous areas.

Protech Model CG-125FP Evaluation

1. Sampling train is unobstructed 0.32 cm (1/8 in.) I.D. passageway which will pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature of sorts in the sampling chamber is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle.

6. Collects spot samples at either preset time intervals or paced by an external flowmeter and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Refrigeration is available as option. Some cross-contamination appears likely. Deep case version offers reasonable sample protection.

9. Unit is designed for manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Can operate in freezing ambients if fitted with optional winterizing kit.

12. Standard upper lift limit of 9.1m (30 ft) does not pose a great restriction on operating head conditions.

Designation:	PROTECH MODEL CEG 200
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-4420
Sampler Intake:	Plastic 250 mℓ sampling chamber with 4 removable 50 mℓ plugs.
Gathering Method:	Forced-flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 16.8m (55 ft).
Line Size:	Smallest line is 0.32 cm (1/8 in.) I.D.
Sample Flow Rate:	Less than 1 ℓpm (1/4 gpm); depends upon pressure setting and lift.
Sample Capacity:	Aliquots taken by 250 mℓ sample chamber with 4 removable 50 mℓ plugs are composited in a 5.8ℓ (1.5 gal) sample container.
Controls:	Sampling interval and duration are controlled individually (6 seconds to 60 hours) from panel with visible countdown. Samples can be taken by propellant from an external pressure source, or by internal air compressor for continuous use or standby. Accepts signals by preset timer or from external flowmeter signal. Purging time is controllable via sample duration timer. Higher lift than standard is available by resetting internal pressure regulator.
Power Source:	115 VAC and propellant from an external pressure source such as nitrogen, compressed air, or refrigerant.

Sample Refrigerator:	Noiseless absorption type available as an option with capacity for one 5.8ℓ (1.5 gal) or two 3.8ℓ (1 gal) sample containers. An aluminum stand is also available to support the refrigerator on a shelf below the sampler. Stationary models accommodate the refrigerator within cabinet.
Construction Materials:	All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum.
Basic Dimensions:	Portable - 33 x 48 x 43 cm (13x19x17 in.), weighs 18 kg (40 lbs) total; Stationary indoor- 69 x 66 x 127 cm (27x26x50 in.), weighs 107 kg (235 lbs) total; Stationary outdoor - 76 x 66 x 152 cm (30x26x60 in.), weighs 118 kg (260 lbs) total.
Base Price:	$1,345 (portable), $1,990 (stationary indoor), and $2445 (stationary outdoor); all include 250 mℓ sample chamber, 15.2m (50 ft) each of 0.64 cm (1/4 in.) O.D. and 1.3 cm (1/2 in.) O.D. tubing, and 5.8ℓ (1.5 gal) sample container. For portable model add $275 for refrigerator, $140 for winterizing kit, and $75 for aluminum stand to hold sampler above container or refrigerator.
General Comments:	Manufacturer claims unit has high-solids capability for sampling industrial and sewage wastes. Sample lines are purged of liquid after each sample is taken. A seven-day programming clock for stationary models programs operation in selected 15-minute increments; available at $195.

Protech Model CEG 200 Evaluation

1. Sampling train is unobstructed 0.32 cm (1/8 in.) I.D. passageway which will pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. Self-cleaning in the sampling chamber is somewhat accomplished by the two-way flushing action which occurs during each filling and pressuring cycle.

6. Collects spot samples at either preset time intervals or paced by an external flowmeter and composites them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Portable top-opening, absorption-type refrigerator available as an option to maintain sample compartment at desired temperature. Some cross-contamination appears likely.

9. Portable unit can be used for manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Can operate in freezing ambients if fitted with optional winterizing kit.

12. Upper lift limit of 16.8m (55 ft) poses little restriction on operating head conditions.

Designation: PROTECH MODEL CEL-300

Manufacturer: Protech, Inc.
Roberts Lane
Malvern, Pennsylvania 19355
Phone (215) 644-3854

Sampler Intake: Plastic cylindrical (about 10 cm diameter x 20 cm long) screen perforated with over 500-0.5 cm (3/16 in.) diameter ports over pump inlet.

Gathering Method: Forced flow from submersible pump.

Sample Lift: Standard maximum is 9.1m (30 ft.)

Line Size: 1.3 cm (1/2 in.) I.D. inlet hose.

Sample Flow Rate: 3.8 to 7.6 ℓpm (1 to 2 gpm) recommended.

Sample Capacity: Aliquot volume (2 to 65 mℓ) is a function of the preset diversion time; 5.8ℓ (1.5 gal) composite container is standard.

Controls: Unit operates on continuous-flow principle, returning the uncollected sample to waste. Sample is pumped through a non-clogging flow-diverter type chamber. Upon receiving a signal from either an external flow registering device or the built-in timer, the unit diverts the flow for a preset period of time (adjustable from 0.06 to 1.0 second) to the sample container. When operating in the timed sampling mode, the sampling frequency can be set for 1, 2, or 5 minutes. When operating in the flow-proportional mode the sampler may accept either a timed pulse signal which can be accumulated (totalized) by the built-in timer, or a single totalized signal whereupon the sampler will be fired directly.

Power Source: 115 VAC.

Sample Refrigerator: Available as an option in portable model. Stationary models have automatic refrigerated sample compartment.

Construction Materials: Sampling train; PVC, nylon, stainless steel, and TFE resins; case is aluminum with baked vinyl finish.

Basic Dimensions: Portable - 33 x 48 x 43 cm (13 x 19 x 17 in.), weighs 31.8 kg (70 lbs) total; Stationary indoor - 69 x 66 x 127 cm (27 x 26 x 50 in.), weighs 113 kg (250 lbs) total; Stationary outdoor - 76 x 66 x 152 cm (30 x 26 x 60 in.), weighs 125 kg (275 lbs) total.

Base Price: $1,495 portable, $2,205 stationary indoor, $2,750 stationary outdoor; all include 11m (36 ft) of 1.3 cm (1/2 in.) I.D. inlet hose, 6.1m (20 ft) of 2.5 cm (1 in.) waste return hose, clamps, submersible magnetic-drive pump, motor, and sample container. Alternative pumps are direct-drive submersible (add $10), flexible-impeller positive-displacement (add $25), progressive-cavity positive-displacement (add $185), open-impeller centrifugal (add $145), and closed-impeller centrifugal (add $175).

General Comments: Model DEL-400S is essentially similar except that it takes up to 24 discrete samples in separate 500 mℓ containers. It is housed in a stationary outdoor cabinet measuring 76 x 81 x 183 cm (30 x 32 x 72 in.) and total weight is 154 kg (340 lbs). Aluminum cabinet version weighs 93 kg (205 lbs). Standard model costs $3,995 and aluminum version is $4,765.

Protech Model CEL-300 Evaluation

1. Large sampling screen chamber over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.

2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flow conditions.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter since designed for continuous flow. Continuous flow serves a self cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flowmeter and composites them in a suitable container. DEL-400 collects 24 discrete samples.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Absorption type refrigerator available as an option in portable version. Stationary units have automatic refrigerated sample compartment. Cross-contamination should not be too great.

9. Portable unit is designed for manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients unless fitted with optional winterizing kit.

12. Upper lift limit of 9.1m (30 ft) does not pose a great restriction on operating head conditions.

Designation:	QCEC MODEL CVE
Manufacturer:	Quality Control Equipment Company P.O. Box 2706 Des Moines, Iowa 50315 Phone (515) 285-3091
Sampler Intake:	End of suction line installed to suit by user.
Gathering Method:	Suction lift from vacuum pump.
Sample Lift:	6m (20 ft.) maximum.
Line Size:	0.64 cm (1/4 in.) I.D.
Sample Flow Rate:	Depends upon lift, but under 3 ℓpm (0.8 gpm).
Sample Capacity:	Adjustable aliquots of from 20 to 50 mℓ are composited in a 1.9ℓ (1/2 gal) jug (standard) or 3.8ℓ (1 gal) jug (optional).
Controls:	Sampling cycles can either be started at fixed, selected intervals by a built-in timer or in response to signals from an external flowmeter.
Power Source:	115 VAC standard; 12 VDC optional.
Sample Refrigerator:	Standard model has insulated case with built-in ice chamber; automatic refrigeration is available as an option.
Construction Materials:	Sampling train is tygon, polypropylene, polyethylene, and glass; case is fiberglass.
Basic Dimensions:	38 x 38 x 61 cm (15 x 15 x 24 in.) portable.
Base Price:	$570 for base unit with timer only. Add $175 for control to allow pacing by external flowmeter, $250 for mechanical refrigeration, $35 for electric heater.

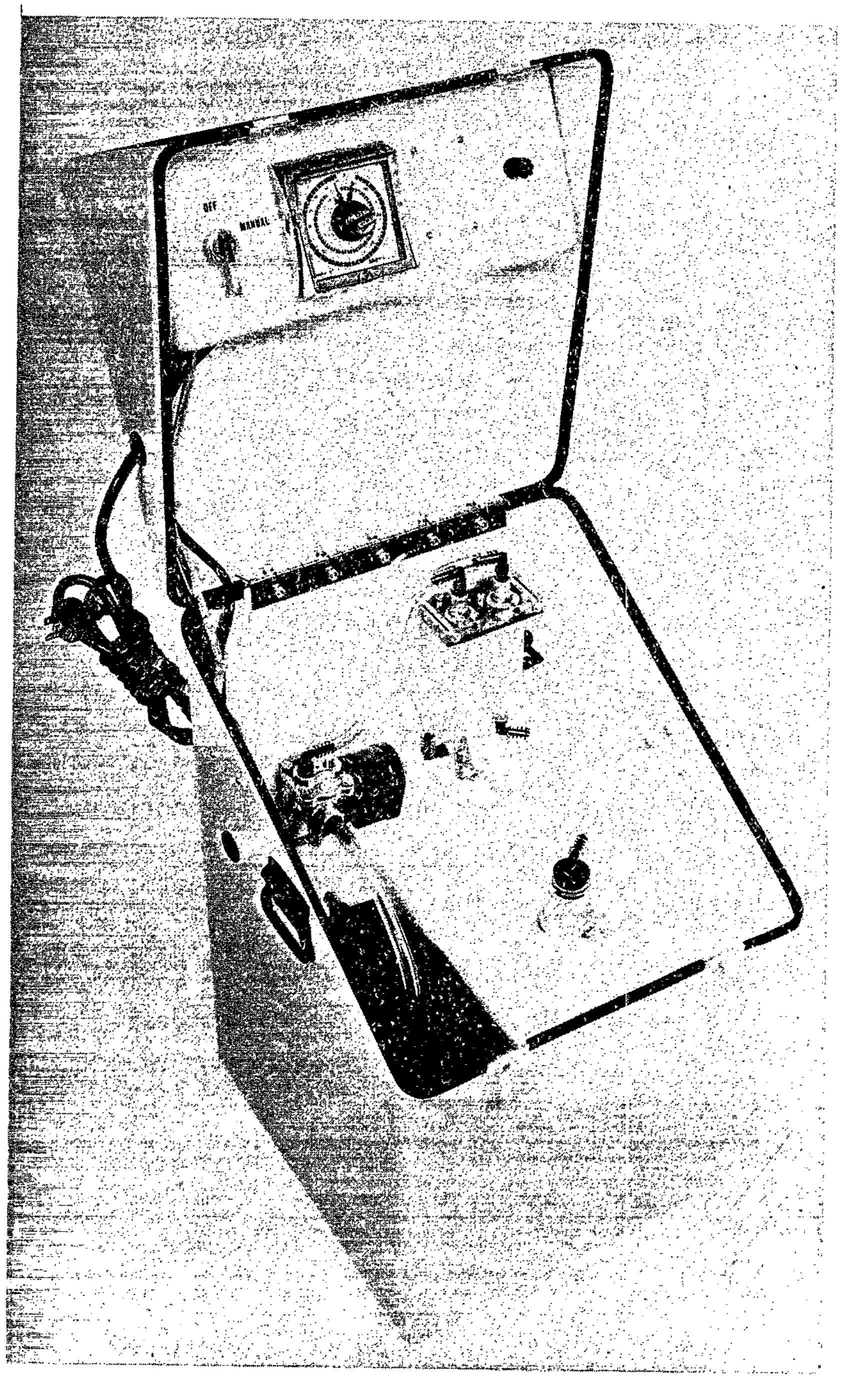


Figure 12. Quality Control Equipment Company Model CVE Sampler

Photograph courtesy of Quality Control Equipment Company

General Comments: Unit was developed by Dow Chemical and is manufactured under license. It uses a patented vacuum system which delivers a volumetrically controlled sample on signal. Liquid is lifted through suction tube into a sample chamber (which is connected to the sample container) with a float check valve. When the chamber is filled to the desired level it is automatically closed to vacuum, the pump shuts off, and the sample is forcibly drawn into the sample container. The suction line drains by gravity to the source. An option provides an 5.6 kg/sq cm (80 psi) blow-down of the sampling train just prior to sampling assuring that no old material remains in the submerged lower end of the suction tube, helps clean the lines of any accumulations which might clog or plug, and provides a fresh air purge of the entire system.

QCEC Model CVE Evaluation

1. Should be relatively free from clogging due to lack of bends and fittings in sample train and optional 5.6 kg/sq cm (80 psi) purging feature.

2. Obstruction of flow will depend upon way user mounts end of sampling tube.

3. Should operate fairly well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Optional purge serves a self-cleaning function.

6. Can collect samples paced by either built-in timer or external flowmeter and composite them in a suitable container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. Standard unit has insulated sample container with ice chamber; automatic refrigeration is optional. Appears to offer good sample protection and freedom from precontamination.

9. Unit would appear to function satisfactorily in a manhole environment.

10. Cannot withstand total immersion.

11. Thermostatically controlled heater is available for applications in freezing ambients.

12. Maximum lift of 6m (20 ft) does not place too severe a restriction on use of the unit.

Designation: QCEC MODEL CVE II

Manufacturer: Quality Control Equipment Company
P.O. Box 2706
Des Moines, Iowa 50315
Phone (515) 285-3091

Sampler Intake: End of suction line installed to suit by user.

Gathering Method: Suction lift from vacuum pump.

Sample Lift: 6m (20 ft) maximum.

Line Size: 0.64 cm (1/4 in.) I.D.

Sample Flow Rate: Adjustable up to 3 ℓpm (0.8 gpm).

Sample Capacity: Adjustable aliquots of from 20 to 50 mℓ are composited in a 3.8ℓ (1 gal) jug.

Controls: New all solid state control system with interval timing module will accept signals from external flowmeters and perform its own integration to provide flow proportional sampling. It will also accept external time pulse signals, or signals from sampling switches, or operate on a straight timed interval basis. Sample flow rate is also adjustable.

Power Source: 115 VAC standard; 12 VDC optional, including internal gel-cell battery.

Sample Refrigerator: Standard model has insulated case with built-in ice chamber; automatic refrigeration is available as an option.

Construction Materials: Sampling train is tygon, polypropylene, polyethylene, and glass; case is fiberglass.

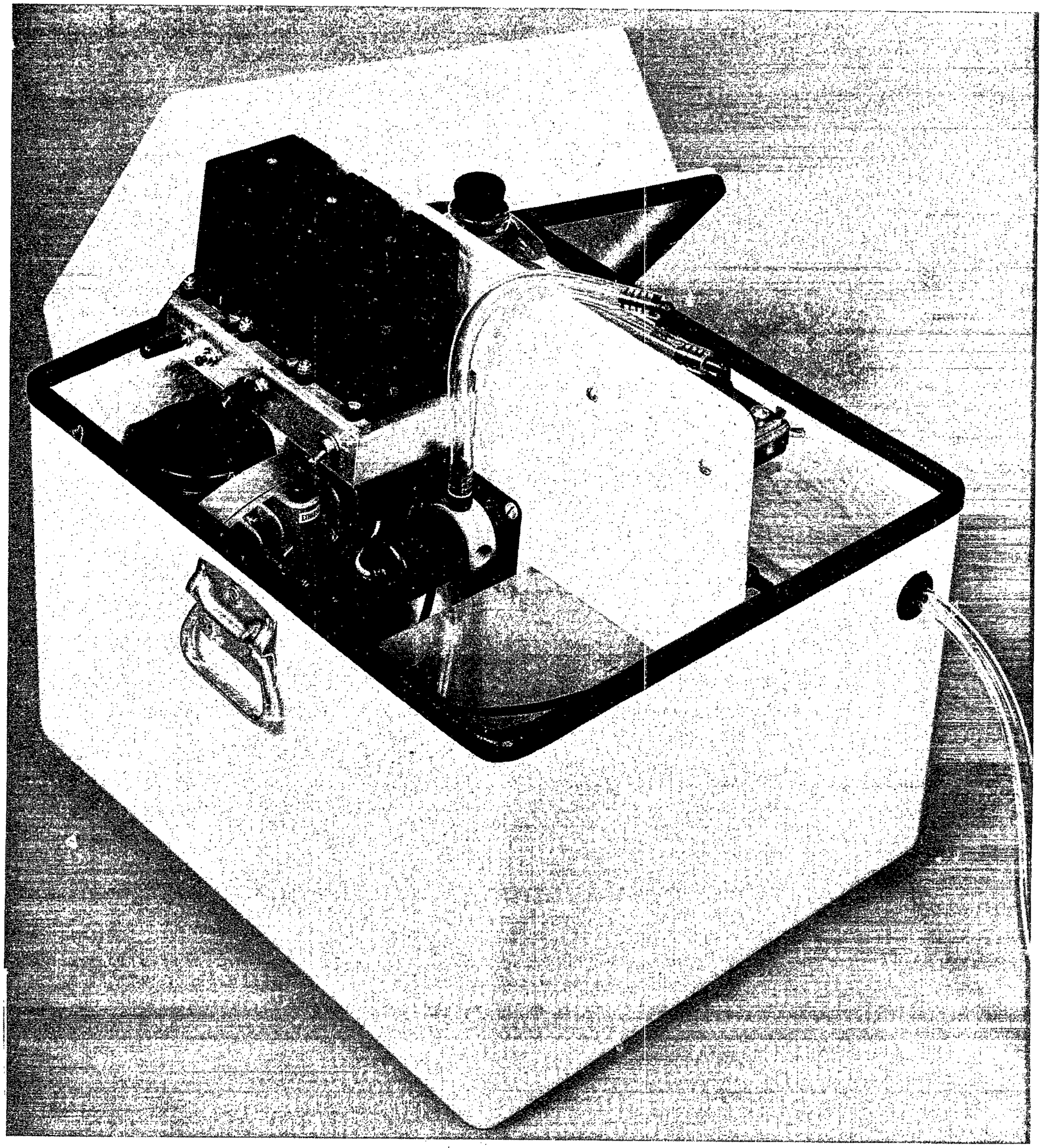


Figure 13. Quality Control Equipment Company Model CVE II Sampler

Photograph courtesy of Quality Control Equipment Company

Basic Dimensions: About 43 x 38 x 51 cm (17x15x20 in.); portable.

Base Price: Approximately $1,000 for basic unit.

General Comments: This unit is essentially an improved version of the older CVE. Its internal battery will last up to 4 days on a single charge. Up to two weeks operation is possible with automotive type batteries. Unit has built-in charger. The new solid state control system allows the double blow-down feature to operate in all control modes. Sample intake velocity is now adjustable. In both the standard case and a specially designed housing for suspension in manholes, the sample container and battery are easily removable from the top.

QCEC Model CVE II Evaluation

1. Should be relatively free from clogging due to lack of bends and fittings in sample train and optional 5.6 kg/sq cm (80 psi) purging feature.

2. Obstruction of flow will depend upon way user mounts end of sampling tube.

3. Should operate fairly well over the entire range of flow conditions; sample intake velocity is adjustable.

4. Movement of solids should not hamper operation.

5. May be triggered by external signal. Optional purge serves a self-cleaning function.

6. Can collect samples paced by either built-in timer or external flowmeter and composite them in a suitable container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. Standard unit has insulated sample container with ice chamber; automatic refrigeration is optional. Appears to offer good sample protection and freedom from precontamination.

9. Unit would appear to function satisfactorily in a manhole environment.

10. Cannot withstand total immersion.

11. Thermostatically controlled heater is available for applications in freezing environments.

12. Maximum lift of 6m (20 ft) does not place too severe a restriction on use of the unit.

Designation:	QCEC MODEL E
Manufacturer:	Quality Control Equipment Company P.O. Box 2706 Des Moines, Iowa 50315 Phone (515) 285-3091
Sampler Intake:	Dipping bucket.
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	To suit; manufacturer claims no reasonable limit to working depth.
Line Size:	Not applicable.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Dipping bucket holds 60 mℓ; user supplies sample composite container to suit.
Controls:	Sampling cycles can either be started at fixed, selected intervals by a built-in timer or in response to signals from an external flowmeter.
Power Source:	115 VAC Electricity
Sample Refrigerator:	None
Construction Materials:	Dipper is stainless steel; sprockets and chain are corrosion-resistant cast iron (stainless available), supports are provided by user.
Basic Dimensions:	Upper unit is 20 x 39 x 36 cm (8 x 15.5 x 14 in.); lower unit is 7.6 x 11.4 cm (3 x 4.5 in.).
Base Price:	$965 plus $25 per foot beyond 6'; add $400 for stainless steel sprockets and chain plus $45 per foot beyond 6', $175 for control to allow pacing by external flowmeter.

General Comments: Manufacturer states that unit was designed as a permanently installed sampler for the most difficult applications such as packing houses, steel mills, pulp mills, and municipal applications. Unit must be custom installed by user. Minimum water depth required is 10 cm (4 in.).

QCEC Model E Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket drive is vulnerable to jamming by rags, debris, etc.

2. Unit provides a rigid obstruction to flow.

3. Unit should operate over full range of flows.

4. Movement of solids could jam or physically damage unit.

5. No automatic starter; no self cleaning features.

6. Collects fixed size aliquots paced by built-in timer or external flowmeter and composites them in a suitable container.

7. Does not appear well suited for collecting either floatables or coarser bottom solids.

8. No sample collector provided.

9. Unit is capable of manhole operation.

10. Unit is weatherproof; cannot withstand total immersion.

11. Unit is not suitable for prolonged operation in freezing ambients.

12. Unit would appear impractical for very long lifts, say above 18m (60 ft).

Designation:	RICE BARTON EFFLUENT SAMPLER
Manufacturer:	Rice Barton Corporation P.O. Box 1086 Worcester, Massachusetts 01601 Phone (617) 752-2821
Sampler Intake:	Open end of rigid pipe extending from below expected low water level to above sample container.
Gathering Method:	Suction lift from vacuum pump.
Sample Lift:	Around 3.7m (12 ft) maximum.
Line Size:	Smallest line appears to be about 2.5 cm (1 in.)
Sample Flow Rate:	Will vary with lift.
Sample Capacity:	Adjustable size aliquots of from 200 to 500 mℓ are composited in a user-supplied container.
Controls:	Panel offers selection of manual, timed sequence, or automatic remote modes. Timing cycles can be varied from one to ten minutes, or longer if necessary.
Power Source:	110 VAC.
Sample Refrigerator:	None.
Construction Materials:	Sampling train has all non-corrosive effluent contact surfaces.
Basic Dimensions:	Draw pipe, sample discharge tube and valve unit are sample lift plus about 0.9m (3 ft) long; motor, pump, and control unit appear to be about 0.6 x 0.1 x 0.9m (2x1x3 ft); appears best suited for fixed installations.
Base Price:	Not available at time of writing.

General Comments: Large diameter sample draw pipe is normally pressurized with zero effluent level. On signal, an air control valve is shifted to vacuum and the effluent rises in the draw pipe until the sample discharge pipe is full. A liquid probe contact signal shifts the air control valve to pressure, leaving sample discharge pipe full. Timer signal opens sample discharge valve and sample is discharged to container. Valve closes and unit is ready for next cycle. Unit was designed for sampling of effluents with high solids content.

Rice Barton Effluent Sampler Evaluation

1. Only the sample discharge valve offers any vulnerability to clogging.

2. Draw pipe offers a rigid obstruction to flow.

3. Should operate reasonably well over all flow conditions. Representativeness may be questionable at high flow rates.

4. Movement of small solids should not hamper operation; large objects could damage (or even physically destroy) the intake pipe.

5. Accepts remote triggering; no self-cleaning features.

6. Unit essentially collects aliquots at fixed time periods and composites them in a user-supplied container.

7. Appears unsuitable for collection of either floatables or coarser bottom solids.

8. No refrigeration. Sample protection must be provided by user. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Maximum lift of 3.7m (12 ft) puts some restriction on use of unit.

Designation:	SERCO MODEL NW-3
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	24-0.64 cm (1/4 in.) I.D. vinyl sampling lines are connected to individual ports in a stainless steel sampling head (approx 10 cm dia) and protected by a stainless steel shroud.
Gathering Method:	Suction lift from vacuum in evacuated sample bottles.
Sample Lift:	0.9m (3 ft) standard; sample size reduced as lift increases; about 3m (10 ft) appears practical upper limit.
Line Size:	0.64 cm (1/4 in.) inside diameter.
Sample Flow Rate:	Varies with filling time, atmospheric pressure, bottle vacuum, sample lift, etc.
Sample Capacity:	24-473 mℓ French square glass bottles are provided. Sample sizes up to 400 mℓ can be obtained depending upon lift, bottle vacuum and atmospheric pressure; 200 mℓ is typical.
Controls:	A spring driven clock via a changeable gearhead rotates an arm which trips line switches at a predetermined time interval triggering sample collection. Sampling intervals of 2, 3, or 8 hours and 5, 10 or 30 minutes are available in addition to the standard one hour interval.
Power Source:	Spring driven clock.
Sample Refrigerator:	Has ice cavity for cooling:

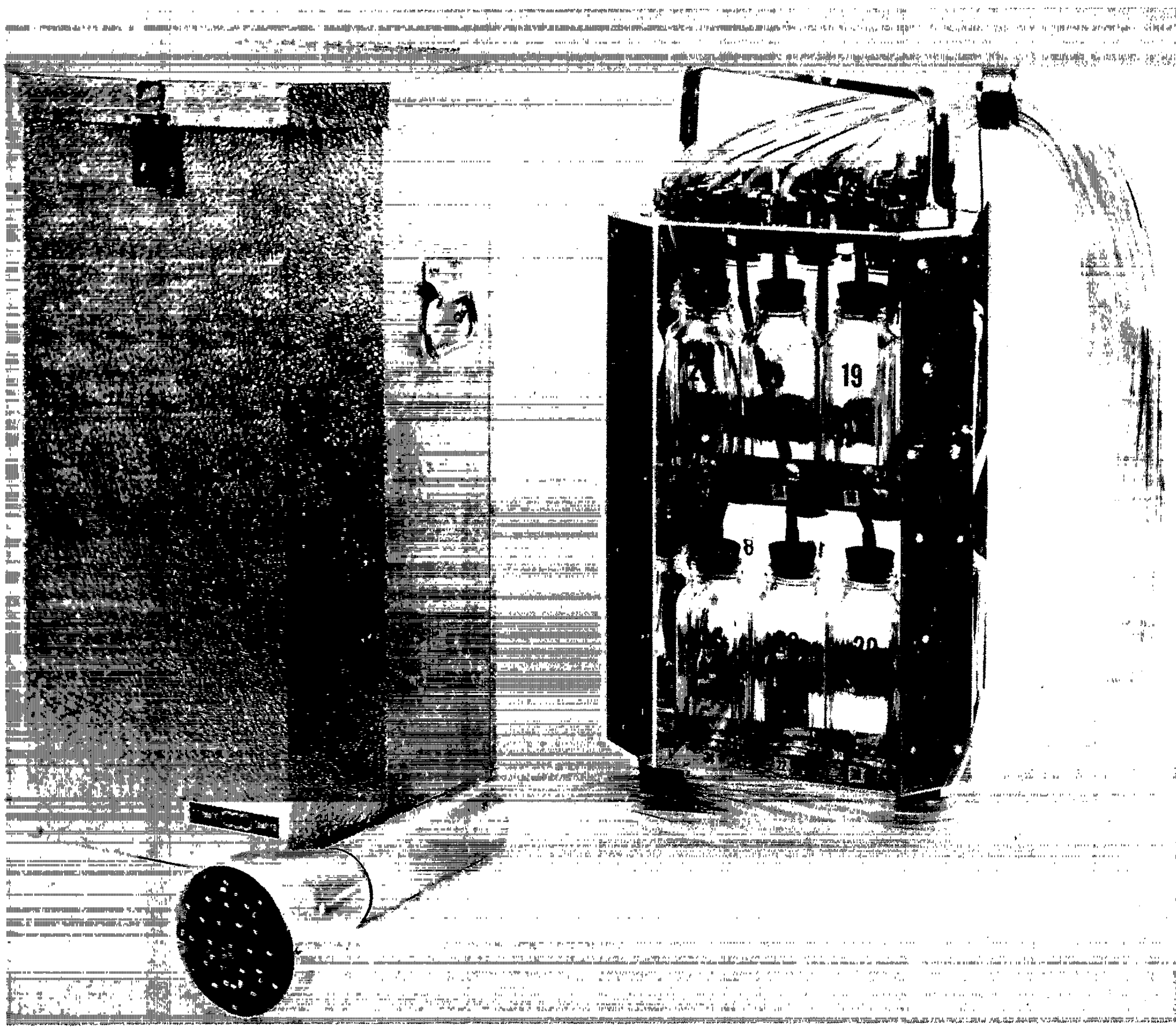


Figure 14. SERCO Model NW-3 Sampler

Photograph courtesy of Sonford Products Corp.

Construction Materials:	Aluminum case with rigid polystyrene insulation; aluminum bottle rack; glass bottles with rubber stoppers and rubber lines through switch plate, plastic connectors and vinyl lines to stainless steel sampling head.
Basic Dimensions:	39 x 39 x 68 cm (15.5 x 15.5 x 26.8 in.) empty weight is 25 kg (55 lbs; portable.
Base Price:	$920 including vacuum pump.

Serco Model NW-3 Evaluation

1. Sampling head is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is an unobstructed 0.64 cm (1/4 in.) passageway which will pass small solids. No pump to clog.

2. Sampling head and shroud are simply dangled in the flow stream to be sampled. No rigid obstruction.

3. Low sampling velocities make representativeness of samples questionable at high flow rates. Length of protective shroud limits immersion to about 0.3m (1 ft) before vinyl sampling tubes are exposed to flow.

4. Sampling head would appear to be vulnerable to clogging if in bed load. Stainless steel shroud offers good protection against movement of solids in flow stream.

5. Optional automatic starter available which allows remote starting by either clock or float mechanism. Otherwise must be started manually. No self cleaning features. Proper cleaning of all 24 sampling lines would be difficult and time consuming in the field.

6. Collects discrete samples at preset times.

7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. Provision for ice cooling affords some sample protection for a limited time. Limited lift may require

placing sampler case in a vulnerable location. Use of individual sampling lines eliminates cross contamination possibility.

9. Unit will pass through a 51 cm (20 in.) diameter circle. Case has base opening where sampling line bridle emerges. Should be capable of manhole operation.

10. Case will fill with fluid if submerged. Spring clock and drive mechanism then becomes vulnerable, especially if fluid contains solids.

11. No standard provision for heating case. Freezing of sampling lines appears a distinct possibility.

12. Practical upper lift limit of 3m (10 ft) poses restrictions on operating head conditions.

Designation:	SERCO MODEL TC-2
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	Provided by user; sampler has standard 5 cm (2 in.) pipe inlet.
Gathering Method:	External head to provide flow through a sample reservoir from which a mechanical arm actuated by an air cylinder with a dipper cup extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the tube leading to the sample bottle; it appears to be about 2 cm (3/4 in.).
Sample Flow Rate:	Recommended flow rate through sampler is 38 to 47 ℓpm (10 to 15 gpm). Reservoir is designed so that sufficient velocity and turbulence will prevent settling or separation.
Sample Capacity:	Sampling dippers are available in either 10 or 20 mℓ capacity; a two gallon sample composite container is provided.
Controls:	Takes samples either on signal from a preset timer or from signals originating from an external flowmeter.
Power Source:	115 VAC electrical plus low pressure plant air.
Sample Refrigerator:	Automatic refrigeration unit thermostatically controlled to maintain sample temperature at 4° to 10°C.

Construction Materials: Sampling arm is all brass and stainless steel; dipper cup is plastic; cabinet is stainless steel with zinc plated framing and porcelain interior.

Basic Dimensions: 97 x 61 x 88 cm (38 x 24 x 35 in.) plus sampling arm which extends up 60 cm (23.5 in.) and back about 0.3m (1 ft). Designed for fixed installation.

Base Price: $2,495

General Comments: A permanent installation for continuous composite sampling. The actual sampling device is simply an open cup which is large enough to permit sampling all sizes of suspended solids normally encountered in wastewater flows. Because the cup is emptied by turning it over completely, the entire sample is removed and there is little likelihood of solids being retained in the cup.

Serco Model TC-2 Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.

2. Sampler itself offers no flow obstruction.

3. Should operate well over entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross-contamination.

6. Can collect either flow proportional composite or fixed time interval composite. Representativeness of sample will be a function of sampling intake which is not a part of this unit.

7. Collection of floatables and coarser bottom solids will depend upon design of sampling intake.

8. Automatic refrigeration maintains samples at 4° to 10°C. Offers good sample protection and freedom from precontamination.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Not designed for use in freezing ambient conditions.

12. Operating head is provided by user.

Designation:	SIGMAMOTOR MODEL WA-1
Manufacuter:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 7.6m (25 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from nutating-type peristaltic pump.
Sample Lift:	6.7m (22 ft) maximum lift.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	60 mℓ per minute.
Sample Capacity:	Adjustable size aliquots of from 60 to 1,800 mℓ are composited in a 5.8ℓ (2.5 gal) sample container.
Controls:	Built-in timer triggers unit once every 30 minutes. Model WA-2 has an adjustable timer allowing sampling interval to be set from 1 to 30 minutes.
Power Source:	115 VAC. Model WD-1 comes with a N. Cad battery pack and charger.
Sample Refrigerator:	None. Model WA-2R has an automatic refrigeration unit for cooling sample compartment.
Construction Materials:	Sample train is tygon and polyethylene; case is ABS plastic.
Basic Dimensions:	WA-1, WA-2, WD-1, WD-2 - 34 x 25 x 36 cm (13.5 x 10 x 14 in.) WA-2R - 53 x 53 x 86 cm (21 x 21 x 34 in.); weights are WA-1 8.2 kg (18 lbs) WA-2 8.6 kg (19 lbs), WD-1 12.7 kg (28 lbs), WD-2 13.2 kg (29 lbs), WA-2R 40.8 kg (90 lbs); all portable.
Base Price:	$430 WA-1; $600 WD-1 $480 WA-2; $650 WD-2; $730 WA-2R

General Comments: Charge time for battery operated models is 16 hours. On model WA-2R the pump automatically purges the tubing at the end of each sampling cycle to help prevent bacterial growth in the line.

Sigmamotor Model WA-1 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; the peristaltic pump can tolerate solids but the 0.3 cm (1/8 in.) I.D. tubing size is rather small.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter. Only the refrigerated model has an automatic purging feature for self-cleaning.

6. Unit takes fixed time interval samples paced by a built-in timer and composits them in a suitable container.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Units offer reasonable sample protection; a refrigerated model is available to maintain sample at a preset temperature.

9. Unit appears capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients.

12. Maximum lift of 6.7m (22 ft) does not place a great operating restriction on unit. All but the refrigerated model will pass through a standard manhole.

Designation:	SIGMAMOTOR MODEL WAP-2
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 7.6m (25 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from nutating-type peristaltic pump.
Sample Lift:	6.7m (22 ft) maximum lift
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	60 mℓ per minute
Sample Capacity:	Unit takes a 5.8ℓ (2.5 gal) composite sample.
Controls:	Models WAP-2, WAP-2R and WDP-2 vary the number of samples in response to a varying signal from a user-supplied flow transmitter. The unit will deliver a 30 second sample (nominally 30 mℓ) every 4 minutes at a maximum signal strength, every 8 minutes at one-half signal strength, etc. Models WAPP-2, WAPP-2R and WAPP-2 respond to a switch closure from an external flow meter and take an adjustable size aliquot variable from 36 to 640 cc per switch closure.
Power Source:	Models WAP-2, WAP-2R, WAPP-2R and WDPP-2 operate on 115 VAC. Models WDPP-2 and WDP-2 operate on 115 VAC or 12 VDC and are supplied with a NiCad battery pack and charger.
Sample Refrigerator:	None. Models WAP-2R and WAPP-2R have an automatic refrigeration unit for cooling sample compartment.

Construction Materials:	Sample train is tygon and polyethylene. Case is ABS plastic.
Basic Dimensions:	Models WAP-2, WAPP-2, WDP-2 and WDPP-2 are 34 x 30 x 37 cm (13.5x10x14.5 in.); Models WAP-2R and WAPP-2R are 53 x 56 x 86 cm (21x22x34 in.); weights are WAP-2 and WAPP-2 8.6 kg (19 lbs), WAP-2R and WAPP-2R 44.5 kg (98 lbs), WDP-2 and WDPP-2 13.2 kg (29 lbs); portable.
Base Price:	WAP-2 \$650 WAP-2R \$870 WAPP-2 \$500 WAPP-2R \$800 WDP-2 \$820 WDPP-2 \$700
General Comments:	All models come with 1.8m (6 ft) of 3-wire cord; charge time for battery operated models is 16 hours. A winterizing kit is available at \$95 to allow effective operation at temperatures to -23°C (-10°F). A stainless steel strainer anchor intake is available, at \$15, to prevent plugging of sampling tubes.

Sigmamotor Model WAP-2 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line and use of the optional strainer intake. The peristaltic pump can tolerate solids but the tubing size is rather small.

2. Obstruction of flow will depend upon user mounting of intake lines and/or use of optional strainer intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter. No self-cleaning features. Small amount of cross-contamination is possible.

6. Unit takes composite samples paced by external flow-meter.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers reasonable sample protection from damage and deterioration. Models WAP-2R and WAPP-2R have refrigerated units to store samples.

9. All but refrigerated units appear capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients unless winterized.

12. Lift of 6.7m (22 ft) does not place a severe operating restriction on unit. All but the refrigerated models will pass through a standard manhole.

Designation:	SIGMAMOTOR MODEL WM-3-24
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 7.6m (25 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from nutating-type peristaltic pump.
Sample Lift:	6.7m (22 ft) maximum lift.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	60 mℓ per minute
Sample Capacity:	Unit takes 24 discrete 450 mℓ samples.
Controls:	Sampling frequency adjustable from one every ten minutes to one every hour.
Power Source:	115 VAC for models WM-2-24, WM-3-24 and WM-1-24R; 12 VDC or 115 VAC for Model WM-4-24, which comes with a wet-type lead-acid battery (35 amp hours capacity) and charger; 12 VDC or 115 VAC for Model WM-2-24 which comes with a NiCad battery pack and charger.
Sample Refrigerator:	None. Model WM-1-24R has an automatic refrigerated case for entire sampler and collection unit.
Construction Materials:	Sample train is tygon and polyethylene; tygon and glass for Model WM-2-24.
Basic Dimensions:	WM-3-24 and WM-4-24 are 61 x 37 x 64 cm (20x14.5x25 in.); WM-2-24 is 37 x 34 x 62 cm (14.5x13.5x24.5 in.); and WM-1-24R is 53 x 56 x 86 cm (21x22x34 in.).

	Weights are WM-2-24 and WM-3-24, 16.3 kg (36 lbs); WM-4-24, 25.4 kg (56 lbs); and WM-1-24R, 56.7 kg (125 lbs). Portable.
Base Price:	WM-3-24 $975 WM-4-74 $1,075 WM-2-24 $1,200 WM-1-24R $1,525
General Comments:	Ten meters (10 ft) of 3-wire retractable power cord is supplied with WM-3-24 and WM-4-24; 1.8m (6 ft) of 3-wire power cord is supplied with WM-1-24R. At the end of each sampling cycle, the pump automatically reverses, purging the sample line and tending to make each sample completely discrete. On Models WM-3-24 and WM-4-24, the sample line feeds into a funnel attached to a rotating nozzle which is automatically positioned to fill the next sample container. A one-piece deep-drawn plastic distribution plate is used to route the sample from the nozzle to the containers, which are in a rectangular array. On Models WM-1-24R and WM-2-24, an indexing arm positions the pump discharge tubing sequentially over each filling nozzle, each of which is connected by a separate piece of tubing to its individual sample container. Model WM-4-24 is supplied with a 6 amp automatic battery charger which adjusts charging rate to battery condition. This may be left connected for trickle charge. Charge time is 3-1/2 to 4-1/2 hours. Charge time for the NiCad battery pack of Model WM-2-24 is 16 hours. A winterizing kit for Models WM-3-24 and WM-4-24 is available, at $95, for effective operation to temperatures of -23°C (-10°F).

A strainer-anchor is available for $15. to prevent plugging of sampling tubes.

Sigmamotor Model WM-3-24 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line and use of the optional strainer intake. The peristaltic pump can tolerate solids but the tubing size is rather small.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Should operate reasonably well under all flow conditions but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter. At the end of each cycle the pump automatically reverses, purging the sample line to help prevent cross-contamination.

6. Unit takes 24 discrete samples at preset time intervals paced by a built-in timer and deposits them in individual containers.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers reasonable sample protection; Model WM-1-24R has a refrigerator unit to maintain samples at a preset temperature.

9. Models WM-2-24, WM-3-24 and WM-4-24 appear capable of manhole operation, but Model WM-1-24R does not.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients unless winterized.

12. Maximum lift of 6.7m (22 ft) does not place a great operating restriction on units. All but the refrigerated model will pass through a standard manhole.

Designation: SIGMAMOTOR MODEL WA-5

Manufacturer: Sigmamotor, Inc.
14 Elizabeth Street
Middleport, New York 14105
Phone (716) 735-3616

Sampler Intake: End of 7.6m (25 ft) long suction tube installed to suit by user.

Gathering Method: Suction lift from finger-type peristaltic pump.

Sample Lift: 5.5m (18 ft) maximum lift with 0.64 cm (1/4 in.) tubing; 3m (10 ft) with 0.95 cm (318 in.) tubing; 1.5m (5 ft) with 1.3 cm (1/2 in.) tubing.

Line Size: 0.64 cm (1/4 in.) I.D. standard. Also available in 0.5 cm (3/16 in.), 0.95 cm (3/8 in.), or 1.3 cm (1/2 in.) I.D.

Sample Flow Rate: 80 mℓ per minute.

Sample Capacity: Adjustable size aliquots are composited in a 19ℓ (5 gal) sample container. Aliquots for Model WA-5 are from 80 mℓ to 2400 mℓ; Model WD-5 from 80 mℓ to 4800 mℓ and Model WA-5R from 60 to 1800 mℓ.

Controls: Adjustable timer for Models WA-5 and WA-5R allows sampling interval to be set from one to thirty minutes, and for Model WD-5 from one to 60 minutes.

Power Source: 115 VAC for Models WA-5 and WA-5R; 115 VAC or 12 VDC for Model WD-5. WD-5 comes with a wet type lead-acid battery (35 amp-hours capacity) and charger.

Sample Refrigerator: None. Model WA-5R has an automatic refrigeration unit for cooling sample compartment.

Construction Materials: Sample train is tygon, and polyethylene; case is fiberglass.

Basic Dimensions: Models WA-5 and WD-5 are 51 x 37 x 64 cm (20x14.5x25 in.); Model WA-5R is 53 x 56 x 150 cm (21x22x59 in.); weights are WA-5 18.1 kg (40 lbs), WD-5 27.2 kg (60 lbs), WA-5R 56.7 kg (125 lbs); all portable.

Base Price: $750 WA-5
$900 WD-5
$990 WA-5R

General Comments: Unit comes with 3m (10 ft) of 3-wire retractable power cord; Model WA-5R comes with 1.8m (6 ft) of 3-wire power cord. A 6-amp automatic battery charger is included with Model WD-5. Unit adjusts charging rate to battery condition. Charge time is 3-1/2 to 4-1/2 hours and may be connected for trickle charge. A winterizing kit is available for Models WA-5 and WD-5, at $95, for effective operation to temperatures of -23°C (-10°F). A stainless steel strainer-anchor intake is available for $15 to prevent plugging of sampling tubes.

Sigmamotor Model WA-5 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line and use of the optional strainer intake. The unobstructed sampling line and the peristaltic pump should tolerate solids fairly well.

2. Obstruction of flow will depend upon user mounting of intake line and/or use of optional strainer intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; no self-cleaning feature.

6. Unit takes simple composite samples paced by a built-in timer.

7. Unit does not appear suitable for collecting either floatable or coarser bottom solids.

8. Unit offers reasonable sample protection from damage and deterioration. Model WA-5R has a refrigeration unit to store sample.

9. Models WA-5 and WD-5 appear capable of manhole operation; Model WA-5R does not.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients unless winterized.

12. Lift capacity will depend upon tubing size. All but the refrigerated model will pass through a standard manhole.

Designation:	SIGMAMOTOR MODEL WAP-5
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 7.6m (25 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from finger-type peristaltic pump.
Sample Lift:	5.5m (18 ft) maximum lift with 0.64cm (1/4 in.) tubing; 3m (10 ft) with 0.95 cm (3/8 in.) tubing; 1.5m (5 ft) with 1.3 cm (1/2 in.) tubing.
Line Size:	0.64 cm (1/4 in.) I.D. standard. Also available in 0.5 cm (3/16 in.), 0.95 cm (3/8 in.), or 1.3 cm (1/2 in.) I.D.
Sample Flow Rate:	80 mℓ per minute; other flows depending on tubing size. Model WAC-5R is 13 mℓ per minute at maximum signal.
Sample Capacity:	Adjustable size aliquots are composited in a 19ℓ (5 gal) sample container. Aliquots for Models WAP-5, WAP-5R and WDP-5 are to 40 mℓ. For Models WAPP-5, WAPP-5R and WDPP-5, aliquot is 640 mℓ, and for Model WAC-5R, flow is continuous.
Controls:	Models WAP-5, WAP-5R, and WDP-5 vary the number of samples in response to a varying signal from a user supplied transmitter. The units will deliver a 30-second sample every 4 minutes at maximum signal strength, every 8 minutes at one-half strength, etc.

Models WAPP-5, WAPP-5R, and WDPP-5 respond to a switch closure from an external flowmeter and take an adjustable size aliquot. Model WAC-5R varies flow rate in proportion to strength of external signal.

Power Source:	Models WAP-5, WAP-5R, WAPP-5, WAPP-5R and WAC-5R operate on 115 VAC. Models WDP-5 and WDPP-5 operate on 115 VAC or 12 VDC and are equipped with a wet type lead-acid battery (35 amp-hours capacity) and charger.
Sample Refrigerator:	None. Models WAP-5R, WAPP-5R and WAC-5R have an automatic refrigeration unit for cooling sample compartment.
Construction Materials:	Sample train is tygon and polyethylene. Case is fiberglass.
Basic Dimensions:	Models WAP-5, WAPP-5, WDP-5, and WDPP-5 are 51 x 37 x 64 cm (20x14.5x25 in.); Models WAP-5R, WAPP-5R, and WAC-SR are 53 x 56 x 124 cm (21x22x49 in.). Weights are WAP-5 and WAPP-5 18.6 kg (42 lbs), WDP-5 and WDPP-5 27.2 kg (60 lbs), WAP-5R, WAPP-5R, and WAC-5R 44.4 kg (98 lbs); all portable.
Base Price:	WAP-5 $850, WAP-5R $1,100 WAPP-5 $780, WAPP-5R $1,080 WDP-5 $$1,050, WDPP-5 $ 980 WAC-5R $1,215
General Comments:	Models WAP-5, WAPP-5, WDP-5 and WDPP-5 come with 3m (10 ft) of 3-wire retractable cord. Models WAP-5R and WAPP-5R come with 1.8 cm (6 ft) of 3-wire cord. Charge time for battery-operated models is 3-1/2 to

4-1/2 hours. A winterizing kit is available for Models WAP-5, WAPP-5, WDP-5 and WDPP-5 at $95 for effective operation to temperatures of -23°C (-10°F). A stainless steel strainer-anchor intake is available at $15 to prevent plugging of sampling tubes. Model WAC-5R is a continuous sampler with flow rate directly proportional to a 4-20 milliamp input signal.

Sigmamotor Model WAP-5 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line, and use of the optional strainer intake. The unobstructed sampling line and the peristaltic pump should tolerate solids fairly well.

2. Obstruction of flow will depend upon user mounting of intake line and/or use of optional strainer intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; no self-cleaning or purging feature.

6. Unit takes composite samples paced by an external flowmeter.

7. Unit does not appear suitable for collecting either floatable or coarser bottom solids.

8. Unit offers reasonable sample protection from damage and deterioration. Models WAP-5R, WAPP-5R and WAC-5R have refrigerator units to store samples.

9. Models WAP-5, WAPP-5, WDP-5 and WDPP-5 appear capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients unless winterized.

12. Lift capacity will depend upon tubing size. All but the refrigerated models will pass through a standard manhole.

Designation:	SIGMAMOTOR MODEL WM-5-24
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 7.6m (25 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift from finger-type peristaltic pump.
Sample Lift:	5.5m (18 ft) maximum lift with 0.64 cm (1/4 in.) tubing; 3m (10 ft) lift with 0.95 cm (3/8 in.) tubing; and 1.5m (5 ft) lift with 1.3 cm (1/2 in.) tubing.
Line Size:	0.64 cm (1/4 in.) I.D. standard. Also available in 0.5 cm (3/16 in.), 0.95 cm (3/8 in.), and 1.3 cm (1/2 in.) I.D.
Sample Flow Rate:	80 mℓ per minute.
Sample Capacity:	Unit takes 24 discrete 450-mℓ samples.
Controls:	Sampling frequency adjustable from one every ten minutes to one every hour.
Power Source:	115 VAC for Model WM-5-24 and WM-5-24R; 12 VDC or 115 VAC for Model WM-6-24, which comes with a wet-type lead acid battery (35 amp hours capacity) and charger.
Sample Refrigerator:	None. Model WM-5-24R has an automatic refrigeration unit for cooling sample compartment.
Construction Materials:	Sample train is tygon and polyethylene; case is fiberglass.

Basic Dimensions:	Models WM-5-24 and WM-6-24 are 51 x 37 x 64 cm (20x14.5x25 in.); Model WM-5-24R is 53 x 56 x 150 cm (21x22x59 in.). Weights are: WM-5-24 20.0 kg (44 lbs), WM-6-24 27.2 kg (60 lbs), WM-5-24R 56.7 kg (125 lbs); portable.
Basic Price:	WM-5-24 $1,225. WM-6-24 $1,325. WM-5-24R $1,775.
General Comments:	A 3m (10 ft) length of 3-wire retractable power cord is supplied with Models WM-5-24 and WM-6-24; 1.8m (6 ft) of 3-wire power cord is supplied for Model WM-5-24R. At the end of each cycle, the pump automatically reverses, purging the sample line and tending to make each sample completely discrete. Sample line feeds into a funnel attached to a rotating nozzle which is automatically positioned to fill the next sample container. A one-piece deep-drawn plastic distribution plate is used to route the sample from the nozzle to the containers, which are in a rectangular array. Model WM-6-24 comes with a 6-amp automatic battery charger which adjusts to battery condition automatically. This may be left connected for trickle charge. Charge time is 3-1/2 to 4-1/2 hours. A winterizing kit is available for Models WM-5-24 and WM-6-24 at $95 for effective operation to temperatures of -10°F. A stainless steel strainer-anchor intake is available at $15 to prevent plugging of sampling tubes.

Sigmamotor Model WM-5-24 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line and use of optional strainer intake. The unobstructed sampling line and the peristaltic pump should tolerate solids fairly well.

2. Obstruction of flow will depend upon user mounting of intake line and/or use of the optional strainer intake.

3. Should operate reasonably well under all flow conditions; however, fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; at the end of each cycle the pump automatically reverses, purging the sample line to help prevent cross-contamination.

6. Unit takes 24 discrete samples at preset time intervals paced by a built-in timer and deposits them in individual containers.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Unit offers reasonable sample protection from damage and deterioration. Model WM-5-24R has a refrigeration unit to maintain samples at a preset temperature.

9. Models WM-5-24 and WM-6-24 appear capable of manhole operation. Model WM-5-24R does not.

10. Unit cannot withstand total immersion.

11. Unit cannot withstand freezing ambients unless winterized.

12. Lift capacity will depend upon tubing size. All but the refrigerated model will pass through a standard manhole.

Designation:	SIRCO SERIES B/ST-VS
Manufacturer:	Sirco Controls Company 8815 Selkirk Street Vancouver, B.C. Phone 261-9321
Sampler Intake:	Weighted end of 7.6m (25 ft) sampling tube installed to suit by user. May also sample from 2 or 3 different points.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	Up to 6.7m (22 ft) vertical and 30.5m (100 ft) horizontal.
Line Size:	0.95 cm (3/8 in.) I.D. standard, larger sizes available.
Sample Flow Rate:	Up to 12 ℓps (3.2 gpm) depending upon lift.
Sample Capacity:	Sample volume is adjustable between 10 to 1000 mℓ (repeatable to within ±0.5 mℓ); either composited in 7.6, 11.4, or 18.9ℓ (2, 3, or 5 gal) jars or sequential or discrete in either 12 or 24 jars of either 1/2 or 1 liter capacity.
Controls:	"Metermatic" chamber (adjustable) controls sample volume. Available with built-in timer for preset time inteveral (3 min to 45 hr) sampling or for connection to external flowmeter for flow proportional sampling or both. Purge timer, automatic jar full shut-off.
Power Source:	Either 110 VAC or 12 VDC level zinc or nickel cadmium battery or combination.
Sample Refrigerator:	Available with thermostatically controlled refrigerated sample compartment.

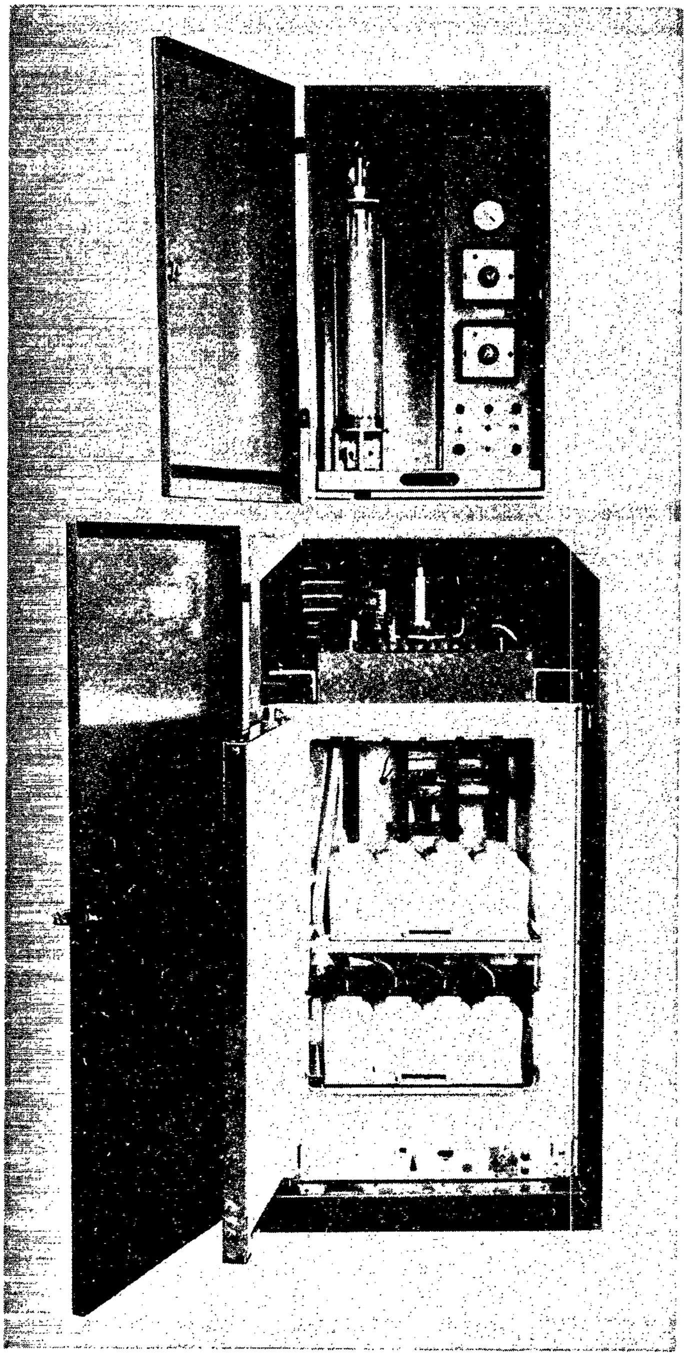


Figure 15. Sirco Series B/ST-VS Sampler

Photograph courtesy of Sirco Controls Company

Construction Materials: PVC sampling tube, weatherproof steel enclosure standard; all stainless steel construction available.

Basic Dimensions: Sampler only - 41 x 36 x 81 cm (16 x 14 x 32 in.), weighs 45 kg (100 lbs); Sampler with container - 41 x 36 x 163 cm (16 x 14 x 64 in.) weighs 68 kg (150 lbs); Refrigerated model - 58 x 71 x 152 cm (23 x 28 x 60 in.), weighs 91 kg (200 lbs); designed for fixed installation.

Base Price: Varies, depending upon what combination of features are desired, from under $1,900 to over $3,000.

General Comments: Signal from flowmeter or timer starts vacuum/compressor pump as well as purge timer. Compressor side of pump purges sample pick-up tube until purge timer times out. Sequence changes and vacuum side of pump evacuates metering chamber and draws sample in to the desired capacity. After obtaining the desired amount of sample, the compressor side of pump is used to forcibly discharge sample from metering chamber into sample collector.

Should plugging of the sample pick-up tube occur, an automatic timer switch uses the compressor side to blow out the tube. This sequence repeats itself as often as needed to obtain the exact amount of sample required. Purging also takes place before and after each sample is taken.

Manufacturer states this unit is especially designed to sample untreated raw sewage or high consistency industrial waste as it is capable of taking solids up to 3/8" in diameter including rags, fibers, and similar. The only wetted parts are the sample tubing and volume control chamber.

Sirco Series B/ST-VS Evaluation

1. Should be relatively free from clogging due to lack of bends and fittings in sample train and high pressure purging feature.

2. Obstruction of flow will depend upon way user mounts the end of the sampling tube.

3. Should operate well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. Automatic starter available. Power purge serves a self-cleaning function. Cross-contamination should be minimal.

6. Can collect external flowmeter or built-in timer paced samples either discrete, sequential, or composite. Representativeness of sample will depend upon user mounting of intake tube.

7. Unsuitable for collection of floatables or coarser bottom solids without specially designed intake by user.

8. Automatic refrigeration (adjustable temperature) available. Offers good sample protection and freedom from precontamination.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Thermostatically controlled heaters and fans are available for applications in freezing ambients.

12. Maximum lift of 6.7m (22 ft) does not place too severe a restriction on use of the unit.

Designation:	SIRCO SERIES B/IE-VS
Manufacturer:	Sirco Controls Company 8815 Selkirk Street Vancouver, B.C. Phone 261-9321
Sampler Intake:	5 cm (2 in.) I.D. guide pipe for sampling cup with perforations in lower end to maximum flow level.
Gathering Method:	Mechanical; a weighted sampling cup is lowered through a guide pipe into the effluent by a hoist mechanism powered by a reversing gear motor. At the upper travel stop the cup empties sample into a sample container by gravity.
Sample Lift:	Up to 61m (200 ft).
Line Size:	Smallest line in sampling train appears to be about 0.95 cm (3/8 in.) tube connecting collection funnel to sample reservoir.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Sample cup has 100 mℓ capacity; either composited in 7.6, 11.4 or 18.9ℓ (2, 3, or 5 gal) jars or sequential in either 12 or 24 jars of either 1/2 or 1 liter capacity.
Controls:	Available with built-in timer for pre-set time interval sampling or for connection to external flowmeter for flow proportional sampling or both.
Power Source:	Either 110 VAC or 12 VDC lead zinc or nickel cadmium battery or combination.
Sample Refrigerator:	Available with thermostatically controlled refrigerated sample compartment.

Construction Materials:	PVC sampling cup and guide tube, weatherproof steel enclosure standard; all stainless steel construction available.
Basic Dimensions:	About 0.6 x 0.6 x 1.5m (2 x 2 x 5 ft); designed for fixed installation.
Base Price:	Varies from under $1,500 to around $3,000 depending upon features desired.
General Comments:	This unit was designed for high lift applications. According to the manufacturer it is not recommended for high consistency industrial effluent or raw sewage where large pieces of fiber, rags papers, etc. are present.

Sirco Series B/IE-VS Evaluation

1. Cup in guide pipe appears susceptible to sticking and clogging. Guide pipe perforations are vulnerable to obstruction and clogging.

2. The 5 cm (2 in.) inside diameter guide pipe must pass completely through the flow stream to be sampled presenting a serious rigid obstruction to flow.

3. Does not appear capable of uniform operation over full range of flow conditions.

4. Solids could collect in guide pipe and hamper cup travel.

5. No automatic starter. No self cleaning features.

6. Can collect flowmeter or timer paced samples either sequential or composite. Representativeness of sample will be dependent upon conditions at end of guide tube but appear highly variable and questionable.

7. Not suitable for collection of floatables or coarser bottom solids.

8. Automatic refrigerator (adjustable temperature) available. Offers good sample protection but vulnerable to cross contamination in sequential mode.

9. Not designed to operate in manholes.

10. Cannot withstand total immersion.

11. Thermostatically controlled heaters and fans are available for applications in freezing ambients.

12. 61m (200 ft) lift gives this unit virtually unrestricted use.

Designation:	SIRCO SERIES B/DP-VS
Manufacturer:	Sirco Controls Company 8815 Selkirk Street Vancouver, B.C. Phone 261-9321
Sampler Intake:	Provided by user. Sampler has 5 cm (2 in.) inlet pipe.
Gathering Method:	External head to provide flow through sampler and back to sewer. On signal a liquid diverter mechanism is energized and sample is drawn into a metering chamber. After the desired amount of sample is obtained, a solenoid pinch valve at the bottom of the metering chamber is actuated and the sample is discharged by gravity into the sample jar.
Sample Lift:	Not applicable.
Line Size:	Smallest line size appears to be about 0.95 cm (3/8 in.) tube leading to sample jar.
Sample Flow Rate:	Depends upon user's installation; no recommended minimum.
Sample Capacity:	Sample metering chamber adjustable from 50 to 500 mℓ (500 to 1000 mℓ optional); either composited in 7.6, 11.4, or 18.9ℓ (2, 3, or 5 gal) jars or sequential in either 12 or 24 jars of either 1/2 or 1 liter capacity.
Controls:	Available with built-in timer for pre-set time interval (3 min to 45 hrs) sampling or for connection to external flowmeter for flow proportional sampling or both. Automatic jar full shut-off.
Power Source:	Either 110 VAC or 12 VDC lead zinc or nickel cadmium battery or combination.

Sample Refrigerator:	Available with thermostatically controlled refrigerated sample component.
Construction Materials:	Sampling train is stainless steel and plastic; weatherproof steel enclosure standard; all stainless steel construction available.
Basic Dimensions:	Same as B/ST-VS.
Base Price:	Varies from under $1,600 to around $3,000 depending upon features desired.
General Comments:	This unit was designed for installations where the sampler must be some distance, say more than 100 feet, from the sample pick-up point. It is recommended by the manufacturer for treated sewage or final effluent.

Sirco Series B/DP-VS Evaluation

1. Diverter mechanism could be subject to clogging (manufacturer only recommends unit for treated sewage or final effluent). Sampling intake must be designed by user.

2. Sampler itself offers no flow obstruction.

3. Should be capable of operating over entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Continuous flow serves a self-cleaning function and should reduce cross-contamination.

6. Can collect flowmeter or timer paced samples either discrete, sequential, or composite. Representativeness of sample will depend upon design of sampling intake which is not a part of this unit.

7. Unsuitable for collection of floatables or coarser bottom solids.

8. Automatic refrigerator (adjustable temperature) available. Offers good sample protection but vulnerable to slight cross-contamination in sequential mode.

9. Specifically designed for installation remote from sample pick-up point. Not suitable for manhole operation.

10. Cannot withstand total immersion.

11. Thermostatically controlled heater and fans are available for applications in freezing ambients.

12. Operating head is provided by user.

Designation:	SIRCO MODEL MK-VS
Manufacturer:	Sirco Controls Company 8815 Selkirk Street Vancouver, B.C. Phone 261-9321
Sampler Intake:	Weighted end of sampling tube installed to suit by user.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	Up to 6.7m (22 ft).
Line Size:	0.95 cm (3/8 in.) I.D.
Sample Flow Rate:	Up to 6 ℓps (1.6 gpm) depending upon lift.
Sample Capacity:	Sample volume adjustable between 25 to 500 mℓ (repeatable to within ±0.5 mℓ); composited in 15.1ℓ (4 gal) container or sequential or discrete in 24 500 mℓ containers.
Controls:	Adjustable chamber slide electrode controls sample volume. Built-in timer allows adjusting sample cycle from 3 minutes to 45 hours. Option allows pacing by external flowmeter. Automatic shut-off.
Power Source:	110 VAC or 12 VDC lead-acid or nickel cadmium battery.
Sample Refrigerator:	Ice compartment allows some sample cooling. Automatic refrigerator available.
Construction Materials:	Sample train is PVC, plexiglass, and stainless steel. Case is weatherproof aluminum.
Basic Dimensions:	41 x 41 x 56 cm (16 x 16 x 22 in.); weighs 16.8 kg (37 lbs) without battery. Portable.
Base Price:	Around $1,300 and up depending upon features desired.

General Comments:

Signal from timer starts vacuum/compressor pump. Compressor side of pump purges sample intake tube, sequence changes and vacuum side of pump evacuates metering chamber and draws desired amount of sample. Compressor side of pump then discharges sample into sample container. Should plugging of the sampling tube occur, the pump is switched to the compressor side to blow out the tube. This sequence is repeated until the desired amount of sample is collected. Purging also takes place before and after each sample is taken.

Manufacturer states that the unit is especially designed to sample untreated raw sewage or high consistency industrial waste containing rags, fibers, etc.

A low cost Model MK-5, which collects up to 150 adjustable size (25 to 150 mℓ) aliquots and composites them in a 3.8ℓ (1 gal) jug, is also available. It does not have power-purge but uses similar controls as MK-VS units. Measuring 43 x 25 x 56 cm (17 x 10 x 22 in.) and weighing 19 kg (42 lbs), the unit can lift up to 6m (20 ft) through its 0.64 cm (1/4 in.) I.D. intake tube.

Sirco Model MK-VS Evaluation

1. Should be fairly free from clogging due to lack of bends and fittings in sample train and high pressure purging feature.
2. Obstruction of flow will depend upon way user mounts the end of the sampling tube.
3. Should operate equally well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. Automatic starter available. Power purge serves a self-cleaning function. Cross-contamination should be minimal.

6. Can collect external flowmeter or built-in timer paced samples either composite or discrete or sequential. Representativeness of sample will depend upon user mounting of intake tube.

7. Unsuitable for collection of floatables or coarser bottom solids without special designed intake by user.

8. Unit affords good sample protection; case has ice cavity which will provide cooling for a limited time; automatic refrigerator available. High pressure purge features should offer reasonable protection against cross-contamination.

9. Designed to operate in manhole area.

10. Cannot be totally immersed.

11. Cannot withstand freezing ambient.

12. Maximum lift of 6.7m (22 ft) does not place a severe restriction on use of unit.

Designation:	SONFORD MODEL HG-4
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	Parabolic port in a 1.9 cm (3/4 in.) I.D. rigid tube.
Gathering Method:	Mechanical; sampling tube is rotated down into the flow where it fills through the port by gravity; an electric motor rotates the tube up and the sample flows by gravity into the container.
Sample Lift:	Telescoping sampling tubes may be adjusted to reach down to 53 cm (21 in.) from the bottom of sampler.
Line Size:	1.9 cm (3/4 in.) I.D.
Sample Flow Rate:	Varies with tube angle.
Sample Capacity:	Varied aliquot sizes of 10, 20 or 30 mℓ are composited in a single 3.8ℓ (1 gal) container.
Controls:	Sampling cycle may be triggered at preset time intervals from built-in electrical timer or on signal from external flowmeter.
Power Source:	110 VAC standard; battery optional.
Sample Refrigerator:	Has ice cavity for cooling.
Construction Materials:	Aluminum outer case with rigid insulation.
Basic Dimensions:	33 x 31 x 33 cm (13 x 12 x 13 in.) plus clearance for oscillating sampling tube which varies depending upon telescoping adjustment. Portable.
Base Price:	$325 electric; $495 with battery.

Sonford Model HG-4 Evaluation

1. Does not appear capable of sampling a particle large enough to clog it; could be affected by rags or paper; no pump to clog.

2. Sampling tube presents a flow obstruction during sampling period only.

3. Low sampling velocities make representativeness of samples questionable at high flow rates. Does not appear tolerant of variable depth flows.

4. Unless mounted so that sampling tube oscillates in flow direction, large solids could cause damage. Appears susceptible to fouling by stringy materials which could wrap around sampling tube.

5. No provision for automatic starting. No self-cleaning features.

6. Collects fixed size samples at either preset time intervals or on signal from external flowmeter and composites them in a single container.

7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. Provision for ice cooling affords some sample protection for a limited time. Limited lift may require placing sampler in a vulnerable location. Cross contamination appears very likely.

9. Unit has a small case but requires clearance for oscillating sampling tube. Case has unsealed opening for movement of same.

10. Unit cannot tolerate submersion.

11. No standard provision for heating case. Ice buildup in sampling tube appears a real possibility.

12. Limited lift and restrictions on liquid level variations severely limit range of operating head conditions

Designation:	STREAMGARD DISCRETE SAMPLE ATTACHMENT MODEL DA-24S1
Manufacturer:	Fluid Kinetics, Inc. 3120 Production Drive Fairfield, Ohio 45014 Phone (513) 874-5120
Sampler Intake:	Not applicable.
Gathering Method:	Pump or liquid composite sampler provided by user.
Sample Lift:	Not applicable.
Line Size:	0.6 cm (1/4 in.) I.D.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Twenty-seven, 473-mℓ bottles are sequentially filled at hourly intervals.
Controls:	None.
Power Source:	Spring driven clock.
Sample Refrigerator:	Refrigerated sample storage optional.
Construction Materials:	Sampling train is all plastic, mostly PVC; case is aluminum with epoxy paint finish.
Basic Dimensions:	48 x 30 x 50 cm (18x12x20 in.); portable.
Base Price:	$775.
General Comments:	This unit is actually a sample delivery subsystem rather than a complete sampler. The sample container tray slides easily out of the cabinet and the tray cover, which has a carrying handle, seals the containers when snapped into position. Since the tray is provided with segmented dividers,

individual bottles may be removed during the sampling period without disturbing the sequence of the other containers. Since it is not a complete sampler, no evaluation will be given.

Designation:	TMI FLUID STREAM SAMPLER
Manufacturer:	Testing Machines, Inc. 400 Bayview Avenue Amityville, New York 11701 Phone (516) 842-5400
Sample Intake:	Stainless steel hollow cylindrical body with a 2.5 cm (1 in.) inlet and mounted submerged in the stream either on four legs mounted to a bottom plate or suspended from above if in a weir or flume.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Over 7.6m (25 ft); depends upon air pressure.
Line Size:	1.3 cm (1/2 in.) O.D.
Sample Flow Rate:	Depends upon air pressure and lift.
Sample Capacity:	Aliquots of approximately 1/2 liter are composited in a suitable container provided by user.
Controls:	User must provide air pressure regulator if plant air supply is not regulated; sampling interval timer is adjustable to allow from one minute to one month to elapse between aliquots; manual on-off switch.
Power Source:	Compressed air supply of at least 1.4 kg/sq cm (20 psi), 7 kg/sq cm (100 psi) maximum; 110 VAC.
Sample Refrigerator:	None
Construction Materials:	Stainless steel and plastic.
Basic Dimensions:	Largest element will be user supplied sample container; sampling intake 10 x 23 x 20 cm (4 x 9 x 8 in.); timing controller 30 x 18 x 38 cm (12 x 7 x 15 in.).

Base Price: Around $800.

General Comments: Sampler developed by International Paper Company for use in the paper industry for checking the loss of useable fiber in effluent, taking consistency samples, etc. Sampler has performed well in flows to 6,800 ℓpm (1800 gpm) and consistencies to 3.5%.

TMI Fluid Stream Sampler Evaluation

1. Sampler should be free from clogging.
2. Sampler intake offers rigid obstruction to flow.
3. Sampling chamber will fill immediately following end of previous sample. Circulation through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of next triggering signal.
4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.
5. No automatic starter; no self-cleaning features.
6. Collects fixed size spot samples and composites them in a suitable container; a three minute cycle interval will deliver approximately 230ℓ (60 gal) in 24 hours.
7. Unsuitable for collection of either floatables or coarser bottom solids without special intake designed by user.
8. Sample container provided by user.
9. Not designed for manhole operation.
10. Cannot withstand total immersion.
11. Unit should be capable of operation in freezing ambients.
12. Upper lift limit determined by air supply pressure.

Designation:	TMI MARK 3B MODEL SAMPLER
Manufacturer:	Testing Machines, Inc. 400 Bayview Avenue Amityville, New York 11701 Phone (516) 842-5400
Sampler Intake:	Twelve 0.64 cm (1/4 in.) I.D. vinyl sampling lines are connected to individual ports in a stainless steel sampling head (approx. 10 cm dia) fitted with a stainless steel filter having approximately 930 0.3 cm (1/8 in.) diameter holes.
Gathering Method:	Suction lift from vacuum in evacuated sample bottles.
Sample Lift:	Sample size reduced as lift increases; 3m (10 ft) appears practical upper limit with 592 mℓ (20 oz) bottles.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	Varies with filling time, atmospheric pressure, bottle vacuum, sample lift, etc.
Sample Capacity:	12 "Medicine Flat" glass bottles are provided. Sample sizes up to 400 mℓ can be obtained depending upon lift, bottle vacuum and atmospheric pressure; 300 mℓ is typical.
Controls:	A spring driven clock rotates an arm which trips line switches at a predetermined time interval triggering sample collection. Sampling intervals of 1/2 to 8 hours are available.
Power Source:	Spring driven clock.
Sample Refrigerator:	None.
Construction Materials:	PVC coated, light alloy case with; glass bottles with rubber stoppers and rubber lines through switch

	plate, plastic connectors and vinyl lines to stainless steel sampling head.
<u>Basic Dimensions</u>:	37 cm (14.5 in.) diameter x 66 cm (26 in.), empty weight is 14.5 kg (32 lbs); portable.
<u>Base Price</u>:	$595 including vacuum pump. Mark 4B model has 24 bottles at $685 for 592 mℓ (20 oz) size and $695 for 1 liter size.
<u>General Comments</u>:	This unit was originally developed by the Water Pollution Research Laboratory in England and is manufactured by North Hants Engineering Co. Ltd. under license from the National Research Development Corporation.

<u>TMI Mark 3B Model Sampler Evaluation</u>

1. Sampling head is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is an unobstructed 0.64 cm (1/4 in.) passageway which will pass small solids. No pump to clog.

2. Sampling head and shroud are simply dangled in the flow stream to be sampled. No rigid obstruction.

3. Low sampling velocities make representativeness of samples questionable at high flow rates. Vinyl sampling tubes are exposed to flow.

4. Sampling head would appear to be vulnerable to clogging if in bed load. Stainless steel filter offers some protection against movement of solids in flow stream.

5. No automatic starter; clocks allow setting a time delay before sampling commences. No self-cleaning features. Proper cleaning of all 24 sampling lines would be difficult and time consuming in the field.

6. Collects discrete samples at preset times from a fixed point intake only.

7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. No sample refrigeration. Limited lift may require placing sampler case in a vulnerable location. Use of individual sampling lines eliminates cross-contamination possibility.

9. Unit will pass through a 38 cm (15 in.) diameter circle. Case has base opening where sampling line bridle emerges.

10. Case will fill with fluid if submerged. Spring clock and drive mechanism then becomes vulnerable, especially if fluid contains solids.

11. No standard provision for heating case. Freezing of sampling lines appears a distinct possibility.

12. Practical upper lift limit of 3m (10 ft) poses restrictions on operating head conditions.

Designation:	TRI-AID SAMPLER SERIES
Manufacturer:	Tri-Aid Sciences, Inc. 161 Norris Drive Rochester, New York 14610 Phone (716) 461-1660
Sampler Intake:	End of suction tube installed to suit by user; manufacturer recommends using a large area screen with openings approximately 0.16 cm (1/16 in.) smaller than intake tube I.D.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Up to 7.6m (25 ft).
Line Size:	0.95 cm (3/8 in.) I.D. standard; 1.3 cm (1/2 in.), or 1.9 cm (3/4 in.) I.D. optional.
Sample Flow Rate:	500 mℓ per minute.
Sample Capacity:	Adjustable size aliquots (based upon diversion time of continuous flow from pump) are composited in a suitable container.
Controls:	Two built-in adjustable timers control sample interval (3 to 40 minutes) and diversion time (3 to 40 seconds); alternately, unit may be paced by external flowmeter.
Power Source:	115 VAC.
Sample Refrigerator:	Available as option for foot-mount models.
Construction Materials:	Sample train is tygon, silicone, PVC; case is fiberglass for portable models, weatherproof steel for wall and foot-mount models.

Basic Dimensions: 38 x 25 x 51 cm (15x10x20 in.) for basic unit without sample container; typical foot-mount outdoor model is 91 x 51 x 173 cm (36x20x68 in.); weights are 15.9 kg (35 lbs) and up.

Base Price: $650 either portable or wall mount for use with external Tri-Aid controller; add $115 for 1.3 cm (1/2 in.) I.D. tubing, $160 for built-in timer, $60 for foot mount.

General Comments: Units are usually sold in conjunction with flowmeters (and possibly on-line moniters) as a complete system. Diverter valve is solenoid-actuated, three-way squeeze-tube type.

Tri-Aid Sampler Series Evaluation:

1. Peristaltic action of pump and relatively large line size should reduce probability of clogging.

2. Obstruction of flow will depend upon user design and mounting of intake.

3. Should operate reasonably well over all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter since it is continuous flow type; this will provide some self-cleaning and help minimize cross-contamination.

6. Unit collects preset size aliquots as paced by either built-in timer or external flowmeter and composites them in a user-supplied container.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. User must provide sample containers and protection for basic unit; automatic refrigeration optional.

9. Not specifically designed for manhole operation. Portable units could be so used with proper precautions.

10. Cannot withstand total immersion.

11. Not suited for prolonged operation in freezing ambients.

12. Maximum lift of 7.6m (25 ft) does not place great restriction on use of unit.

Designation:	WILLIAMS OSCILLAMATIC SAMPLER
Manufacturer:	Williams Instrument Co., Inc. P.O. Box 4365, North Annex San Fernando, California 91342 Phone (213) 896-9585
Sampler Intake:	Small diameter slitted strainer installed to suit by user.
Gathering Method:	Suction lift from diaphragm pump.
Sample Lift:	Up to 3.6m (12 ft).
Line Size:	Appears to be 0.64 cm (1/4 in.) I.D. or larger.
Sample Flow Rate:	60 mℓ per minute maximum.
Sample Capacity:	Composite container must be supplied by user. Sample volume is about one mℓ per stroke.
Controls:	Sampling rate may be adjusted from one sample per second to one every 10 minutes during operation.
Power Source:	Can be operated from any air or gas supply of 1.8 kg/sq cm (25 psi) or more or from a self-contained CO_2 bottle.
Sample Refrigerator:	None.
Construction Materials:	Sampling train is PVC, viton, and stainless steel.
Basic Dimensions:	Not in a case; largest item is gas bottle.
Base Price:	$438; includes pump, mounting bracket, tubing with strainer and fittings, and 6.8 kg (15 lbs) CO_2 bottle.

General Comments: Maximum discharge head is 36.6m (120 ft). The only moving part is a viton diaphragm which is operated by a pneumatic oscillator to create variable sample frequency.

Williams Oscillamatic Sampler Evaluation

1. Should be relatively free from clogging.

2. Obstruction of flow will depend upon user mounting of intake.

3. Low sampling velocities make representativeness of samples questionable at high flow rates.

4. Movement of solids should not affect operation adversely.

5. No automatic starter. No self-cleaning feature. Cross-contamination appears likely.

6. Unit takes continuous composite samples paced by the Oscillamatic pulse controller and composites them in a user-supplied container.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. No refrigeration. No sample collector provided.

9. Unit appears suitable for manhole operation; however, mounting may prove difficult.

10. Unit cannot withstand submersion.

11. Unit does not appear suitable for use in freezing ambient conditions.

12. Lift limit of 3.7m (12 ft) places some restrictions on use of unit.

SECTION VII

REVIEW OF CUSTOM DESIGNED SAMPLERS

INTRODUCTION

As was noted in section VI, it has been the practice of many project engineers to custom design one-of-a-kind samplers for use in their projects due to a lack of availability of suitable commercial equipment. In this section several examples of such equipment are reviewed. Inasmuch as there is no dearth of examples, it was necessary to be rather selective in order to keep the overall size of this report within manageable bounds. Several practical considerations also favor less than 100 percent coverage. For example, no attempt has been made to dig back into history in order to examine older concepts and notions. It is felt that any good features in older designs, having proved themselves to be effective, would be incorporated in present day equipment. Furthermore, the major emphasis has been placed in recent EPA project experience.

DESCRIPTIVE FORMS AND EVALUATIONS

The same description and evaluation formats that were used for reviewing the commercially available samplers in section VI are used here with one exception. For these custom designed one-of-a-kind samplers, prices in terms of today's dollars are generally not available and, furthermore, the inevitable engineering changes that one would introduce in building equipment following a prototype would have cost impacts that are not easily assessed.

The samplers have been given names to correspond with either the developer or the project location. The descriptive forms and evaluations presented on the following pages are arranged roughly in chronological order of development, and an index is provided on page xiii.

Designation:	AVCO INCLINED SEQUENTIAL SAMPLER
Project Location:	Tulsa, Oklahoma
EPA Report No.:	11034 FKL 07/70
Sampler Intake:	Inlet tube passes through an aluminum tube which is hinged at the top of the storm drainage structure and has a polyethylene float at the other end where the inlet tube terminates with a sampling probe.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Not stated, but probably under 6m (20 ft.).
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	Not stated, but must be fairly low for inclined sequential filling scheme to be meaningful.
Sample Capacity:	Unit sequentially fills a 60 $m\ell$ sample bottle, then a 2,000 $m\ell$ sample bottle, and repeats this 6 times, i.e., until it has filled six 60-$m\ell$ and six 2,000-$m\ell$ bottles; then it collects a composite sample in a 18.9ℓ (5 gal) overflow bottle.
Controls:	A limit switch on the hinged float arm starts the pump when the flow level exceeds a preset value. When the flow level subsides the pump is shut off.
Power Source:	12 VDC marine battery.
Sample Refrigerator:	None.
Construction Materials:	Polypropylene pick-up tube, tygon and polyethylene connecting tubes, polyethylene bottles; aluminum frame, wood case.

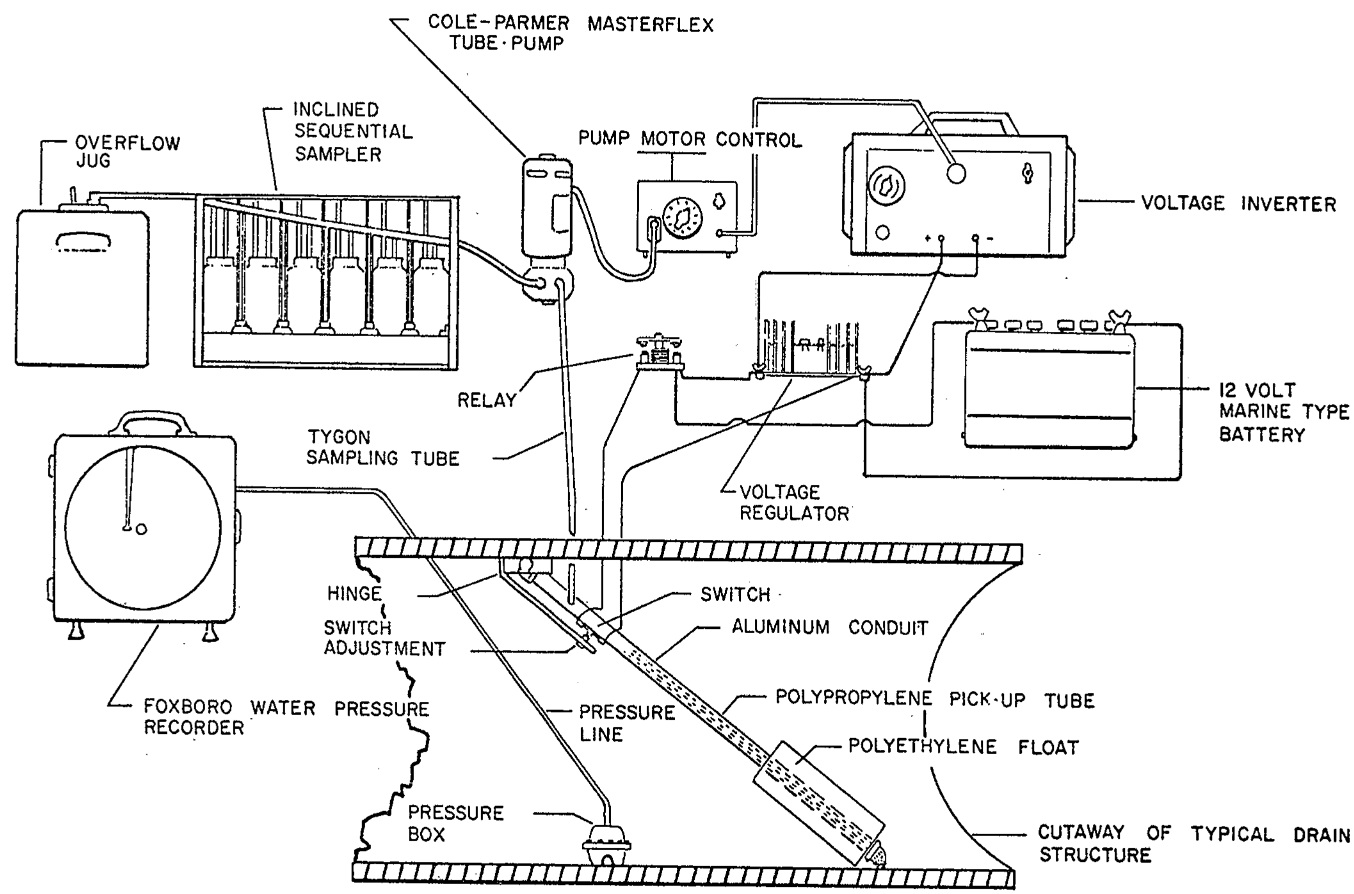


Figure 16. AVCO Inclined Sequential Sampler

Taken from EPA Report No. 11034 FKL 07/70.

Basic Dimensions: Bottle rack is 71 x 15 x 41 cm (28x6x16 in.). Both semi-stationary and portable configurations were assembled.

General Comments: A pressure box in the flow and connected to a Foxboro water pressure recorder was used. Components included a Cole-Parmer Masterflex tube pump, Model No. 7015 and a Terado power inverter (Allied No. 21f4499). The sequential filling of the sample bottles is simply performed by arranging their inlet tubes in order along an inclined manifold.

AVCO Inclined Sequential Sampler Evaluation

1. Clogging is likely in samples with high solids content due to numerous 0.3 cm (1/8 in.) obstructions in sampling train unless a filter is used; sampling probe points downstream and is near the surface due to float, but could possibly be affected by paper, plastic, etc.

2. Float and arm will be completely submerged in a full pipe flow situation and present an obstruction to flow.

3. Unit should operate over full range of flows, but low sample flow rate makes representativeness questionable for high stream flows.

4. Movement of solids in the flow stream could hamper operation.

5. Unit starts automatically when flow level rises above a preset height; no self cleaning features.

6. Sequentially fills sample bottles from output of a continuously running pump. Flow rate provides the only timing function. Samples will be representative of the near-surface water at best.

7. Unit may collect some floatables but is totally unsuited for collecting coarser bottom solids.

8. No refrigeration. Some cross-contamination is guaranteed due to filling stem arrangement, especially for 60-mℓ bottles.

9. Unit does not appear ideally suited for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit is unsuitable for use in freezing ambients.

12. A 15 to 20 foot lift limit puts slight restriction on operating head conditions.

Designation:	SPRINGFIELD RETENTION BASIN SAMPLER
Project Location:	Springfield, Ill.
EPA Report No.:	11023 - - - 08/70.
Sampler Intake:	End of 280m (920 ft.) long influent line suspended 15 cm (6 in.) below water surface from a float.
Gathering Method:	Suction lift from a screw rotor pump.
Sample Lift:	Less than 4.3m (14 ft.) required in this application.
Line Size:	3.8 cm (1.5 in.) diameter lagoon influent sample intake line, 10 cm (4 in.) diameter lagoon effluent sample intake line.
Sample Flow Rate:	Approximately 15 ℓpm (4 gpm).
Sample Capacity:	Intake lines diacharged into 61ℓ (16 gal) sampling tanks. A constant volume aliquot was obtained each 30 minutes and composited in a 18.9ℓ (5 gal) container.
Controls:	A Lakeside Trebler scoop sampler was used to remove aliquots from sampling tanks. See discussion of that sampler for details.
Power Source:	115 VAC electricity.
Sample Refrigerator:	Automatic thermostatically controlled refrigerators were used to house sample containers.
Construction Materials:	ABS plastic intake lines, PVC sample bottles, sampling tank appears to be metal, pump materials not given.

__Basic Dimensions:__ Components are distributed within a general purpose equipment building; fixed installation.

__General Comments:__ Moyno pumps operating on a continuous basis were used to provide sample flow through a 61ℓ (16 gal) sampling tank. Two samplers were constructed, one for the lagoon influent and one for the effluent. Since the Lakeside Trebler sampler is evaluated elsewhere, no further evaluation of this installation will be made.

Designation: MILK RIVER SAMPLER

Project Location: Grosse Point Woods, Mich.

EPA Report No.: 11023 FBD 09/70

Sampler Intake: Overflow system influent sampler intake was simply inlet of submersible pump suspended beyond the bar screens within the transition structure between sewer and wet well. Effluent sampler intake was four 2.5 cm (1 in.) vertical suction lines spaced evenly along the 64m (210 ft.) long effluent weir which drew their samples from points between the skimming baffle and weir at a depth above the bottom of the baffle and just below the outlet weir.

Gathering Method: Forced flow from submerged pump for influent sampler; suction lift from centrifugal pump for effluent sampler.

Sample Lift: Not stated.

Line Size: Except for 2.5 cm (1 in.) diameter inlet lines leading to effluent sampler header, all sampling lines were 5 cm (2 in.) diameter.

Sample Flow Rate: Not stated.

Sample Capacity: Samplers collect adjustable grab samples from the continuously flowing 5 cm (2 in.) pipe streams, composite them for variable periods and hold them in a refrigerated compartment for periods up to about three hours.

Controls: The size of each grab sample is controlled externally. Otherwise, the sampling program is controlled by a continuous punched paper tape program which varies the collection time of each composite, the number of grab samples in each composite, and each of the variables from one sampling time to another.

Power Source:	115 VAC electricity.
Sample Refrigerator:	Automatic thermostatically controlled refrigerated sample compartments.
Construction Materials:	Metal, plastic, and wood were used in construction; no details were given.
Basic Dimensions:	Indoor portion of sampler is large, perhaps 1.8x0.9x1.5m (6x3x5 ft.) or so; fixed installation.
General Comments:	This unit apparently functioned fairly well on the project for which it was designed. Since it is a custom designed, fixed installation unit no complete evaluation will be made.

Designation:	ENVIROGENICS BULK SAMPLER
Project Location:	San Francisco, California
EPA Report No.:	11024 FKJ 10/70
Sampler Intake:	A metal container resembling an inverted roadside mail box approximately 37 cm (14.5 in.) long and 36 cm (14 in.) deep with a 15 cm (6 in.) radius; hinged covers at each end are mechanically connected to function integrally upon activation of an air cylinder.
Gathering Method:	Mechanical; the sampler intake assembly is designed to fit a special support structure which must be installed in the manhole chosen for sampling. It is lowered to the bottom of the invert whereupon the covers are closed thereby trapping a plug of the combined sewage inside the sampler. The filled sampler was then raised by winch to the surface.
Sample Lift:	Depth of manhole in question. No real limit.
Line Size:	Not applicable.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Roughly 34ℓ (9 gal) maximum.
Controls:	Manually operated.
Power Source:	Compressed air.
Sample Refrigerator:	None.
Construction Materials:	Aluminum.
Basic Dimensions:	37 x 31 x 36 cm (14.5x12x14 in.) plus brackets and supporting structure, etc.

Envirogenics Bulk Sampler Evaluation

1. Unit should be free from clogging except for possibility of large debris interfering with flap closure.

2. Unit will completely obstruct flow the instant the covers are closed, but will clear as raised.

3. Since sampler must be designed for the specific manhole invert size in which it is to be used, it is suitable for all flow conditions.

4. Movement of solids in flow will not affect operation except where a significant bed load would prevent sampler from coming to rest on the invert.

5. Unit is manually operated. Cleaning is accomplished by the running sewage.

6. Sampler removes a "plug" of the sewage flow covering the entire flow cross-section.

7. Unit should sample both floatables and coarser bottom solids.

8. Unit is not suitable for sample storage.

9. Unit is designed for manhole operation, but also requires clear area above manhole for hoist and personnel.

10. Unit operates totally immersed; if manhole is surcharging sample might be less representative.

11. Unit should operate in freezing ambients.

12. Unit is indifferent to operating head conditions.

Designation:	ROHRER AUTOMATIC SAMPLER
Project Location:	Sandusky, Ohio
EPA Report No.:	11022 ECV 09/71
Sampler Intake:	Not clearly stated but presumably the end of the suction line mounted in the overflow conduit just beyond the leaping weir.
Gathering Method:	Suction lift from diaphragm pump.
Sample Lift:	Not stated but probably good for at least 6m (20 ft.).
Line Size:	Smallest line would appear to be the one connecting the diverter head to the sample container, but size is not given.
Sample Flow Rate:	Not stated but presumably rather large.
Sample Capacity:	Unit collects 24 0.47ℓ (1 pt.) discrete samples plus a flow proportional composite of up to 18.9ℓ (5 gal).
Controls:	Sampling is automatically started when the leaping weir diverts flow into the overflow flume. Discrete samples were collected every 5 minutes paced by a built-in timer adjustable from 5 to 60 minutes. Constant volume composite aliquots are added for each 37,854ℓ (10,000 gal) of flow through the overflow flume.
Power Source:	115 VAC electricity.
Sample Refrigerator:	None
Construction Materials:	Not stated.
Basic Dimensions:	None given but a fixed installation located in a building specially erected for the project.

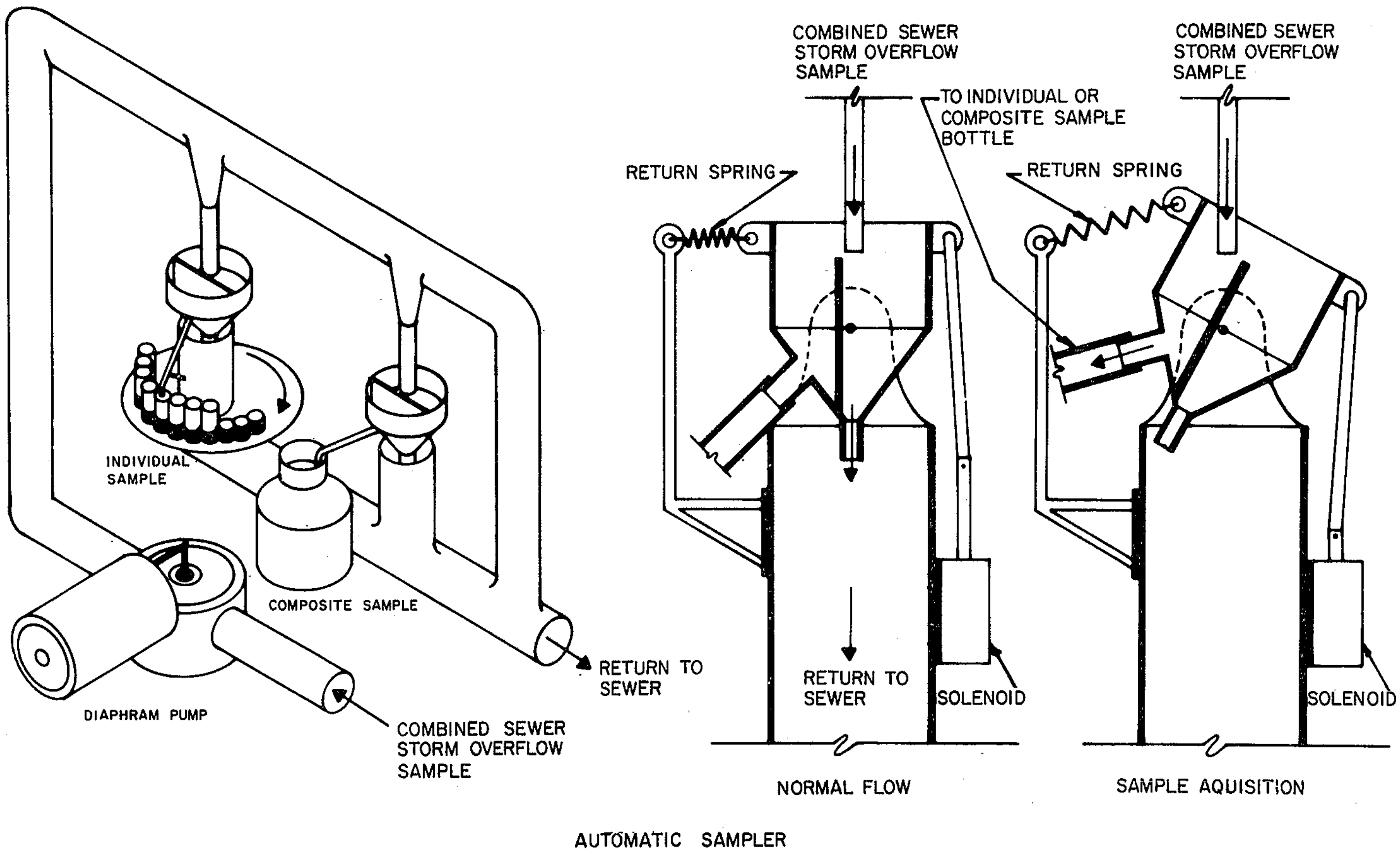


Figure 17. Rohrer Automatic Sampler

Taken from EPA Report No. 11022 ECV 09/71

General Comments: The pump produces a continuous flow of sewage through the sampling header pipe and back to the sewer. Two taps are provided to allow continuous flow through diversion nozzles for the individual and composite sample collection stations and return to sewer. When it is desired to collect a sample, a solenoid is actuated operating a linkage which mechanically rotates the diversion nozzle causing the flow to enter a chamber connected to the sample bottle rather than the sewer return. A spring assures return of the diversion nozzle to its original position after the sample is taken. The time of solenoid activation governs the size of the sample. The 24 discrete sample bottles are mounted on a turntable which indexes upon each sampling cycle to place an empty bottle under the filling spout.

Rohrer Automatic Sampler Evaluation

1. Should be relatively free from clogging.
2. Unit would not appear to offer any significant obstruction to flow.
3. Unit should be operable over the full range of flow conditions.
4. Movement of solids in the flow should not hamper operations.
5. Automatic operation. Continuous flow serves a self cleaning function.
6. Collects 24 discrete samples at pre-set time intervals and a flow proportional composite.
7. Ability to collect floatables and coarser bottom solids will depend upon details of sampling intake.
8. No refrigeration, but otherwise unit would appear to afford reasonable sample protection.

9. Unit was not designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear capable of operation in freezing ambients.

12. Relatively high lift should allow operation over a fairly wide range of operating head conditions.

Designation: WESTON AUTOMATIC SAMPLER

Project Location: Washington, D.C.

EPA Report No.: 11024 EXF 08/70

Sampler Intake: Details of intake to submersible sewage pump and of sampling head to vacuum-charged sampler not stated.

Gathering Method: Forced flow to a retention tank by a sewage pump anchored to the sewer floor, thence, by vacuum, from the retention tank to sample bottles.

Sample Lift: Not stated.

Line Size: Not stated.

Sample Flow Rate: Not stated.

Sample Capacity: Collects 24 discrete samples.

Controls: Wastewater is pumped continuously to the retention tank. The vacuum tank is triggered by the increased back-pressure of a bubbler line resulting from the increased depth of sewer flow. The discrete interval is adjusted by an electric timer to a minimum period of 5 minutes.

Power Source: 115 VAC electricity.

Sample Refrigerator: Sample bottles, sampling lines, and control switches installed in a refrigerated enclosure.

Construction Materials: Not stated.

Basic Dimensions: The wastewater retention tank, the refrigerated sampler, and the piping are all housed in 2.1 x 1.6 x 2.0m (7x5.2x6.5 ft.) metal shed.

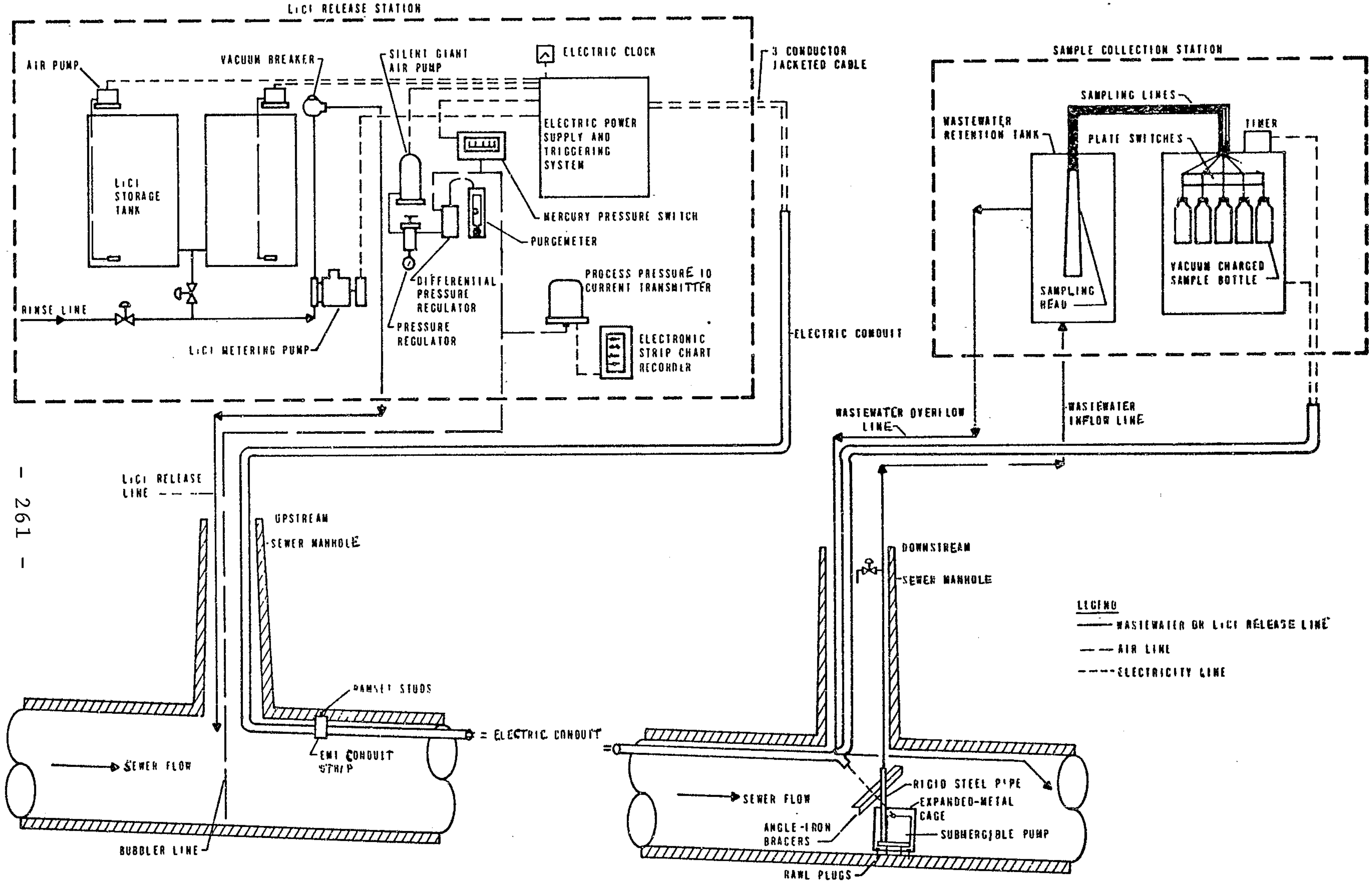


Figure 18. Weston Automatic Sampler

Taken from EPA Report No. 11024 EXF 08120.

General Comments:

A submersible, heavy-duty manually-controlled sewage pump delivers wastewater continuously to a retention tank having a normal retention time of less than 1 minute. The pump is anchored to the sewer bottom in a metal cage.

During a storm, an increase of water depth in the sewer applies back pressure to an air-bubbling system, thus activating a mercury switch and triggering the system which collects samples from the retention tank. The 24 sample bottles are vacuum charged prior to the storm by use of a portable vacuum pump. The bottles are in a fixed position in the refrigerated enclosure, and each sample is drawn into its bottle by vacuum when a control switch is released by a tripper arm operated in conjunction with a timer.

Weston Automatic Sampler Evaluation

1. The submersible pump anchored to the bottom of the sewer is often clogged by solid wastes such as cans, rags, wire, wood chips, tree stems, gravel, sand, etc.

2. The submersible pump with its metal cage and angle iron braces offers a significant obstruction to flow.

3. Pump stoppages have occurred during low-intensity storms, probably because of insufficient water depth in the sewer.

4. Movement of heavy solids has caused severe damage to the equipment, to the extent that pumps have washed away.

5. Automatic operation of sampler above retention tank. Continuous flow from pump to retention tank assists in self cleaning.

6. Collects 24 discrete samples at preset time intervals. Synchronized recorded flow data permit flow proportional compositing. Samples are collected from a single elevation in the sewer.

7. Ability of unit to collect floatables or coarser bottom solids will depend upon elevation of pump intake.

8. Refrigerated sample container protects samples from damage and deterioration. Continuous flow from sewer to retention tank will help minimize cross-contamination. Sampling head and lines may be susceptible to precontamination.

9. Unit was not designed for manhole operation.

10. Unit cannot operate under a condition of total immersion.

11. Not suitable for operation under freezing ambient conditions. Could be made to operate during freezing weather by heating the metal shed housing the unit.

12. Relatively high discharge pressure would allow operation over a wide range of operating head conditions.

Designation:	PAVIA-BYRNE AUTOMATIC SAMPLER
Project Location:	New Orleans (Lake Pontchartrain), Louisiana
EPA Project No.:	11020 FAS. Final report should be available soon.
Sampler Intake:	Saran wrapped, galvanized sheet metal air diffuser about 76 cm (30 in.) long, placed about 20 cm (8 in.) below the water surface. Polyethylene tubing from intake to sampler.
Gathering Method:	Positive displacement, screw type, Moyno or Aberdenffer pump operated with a 0.56 KW (3/4 HP) motor.
Sample Lift:	Maximum suction lift about 6m (20 ft.).
Line Size:	Minimum 1.9 cm (3/4 in.) line from canal to sampler. Intake pipe to sampler manifold 1.9 cm (3/4 in.). Manifold to each row of sampler bottles, 1.3 cm (1/2 in.). Line from solenoid valve to sampler, 0.64 cm (1/4 in.).
Sample Flow Rate:	Under 11.4 ℓpm (3 gpm).
Sample Capacity:	Unit collects 36 discrete samples in bottles of about 1.2ℓ (40 oz) capacity each.
Controls:	Sampler operation initiated with manually operated switch. Filling of sample bottles controlled by a motor driven timer, through relays, to a solenoid valve at each sample bottle. Time interval between sample collections not stated.
Power Source:	Sample pump operates through a 220 volt, 60 Hz, external power source. Electrical control equipment is on a 120 volt, 60 Hz, power source.

Sample Refrigerator: Sample bottles, solenoid valves to each bottle, and sampler manifold, are installed in a Shaefer Cooler Model MC-1600, with cooling units built in its walls.

Construction Materials: Sampler piping and fittings are of PVC. Grating and supports within the cooler are aluminum.

Basic Dimensions: Outside dimensions of cooler in which sampler is installed are about 79 x 155 x 89 cm (31x61x35 in.). All equipment is installed in a 1.8 x 2.4m (6x8 ft.) shed.

General Comments: The pump produces a continuous flow of sewage to the sampler. When the sampler has been placed in operation, individual solenoid valves from the sampler manifold are opened one at a time to the 36 sample bottles by an electrically operated timer. A combination standpipe and overflow line is used to maintain pressure on the solenoid valves.

Pavia-Byrne Automatic Sampler Evaluation

1. Most clogging would be at the air diffuser inlet. Its extent would depend on the size and shape of openings in the diffuser.

2. The air diffuser intake would present some obstruction of flow, depending on where it is placed in the sewer. This would not be significant in the very large canal where the existing samplers have been installed.

3. Probably would operate at the full range of flow conditions, except at very low stages, when the air diffuser may not provide satisfactory inlet conditions.

4. Damage to the air diffuser intake may occur in storm or combined sewers of high flow velocity and heavy debris load.

5. Operation is automatic after initial startup at the beginning of a storm. Continuous flow promotes self cleaning.

6. Representativeness of sample depends on placement and configuration of the air diffuser intake. Discrete samples of uniform size collected at constant time intervals. Flow proportional compositing not possible unless time-synchronized with a recording flow meter.

7. Does not collect floatable material because the intake is set below the water surface.

8. Cooled sample container protects samples from damage and deterioration. Continuous flow from sewer to sampler minimizes precontamination.

9. Unit was not designed for manhole operation.

10. Not designed to operate under total immersion or flooding.

11. Continuous flow and insulated cooler would help permit continued operation under ambient freezing.

12. Relatively high lift would allow operation over a fairly wide range of operating head conditions.

Designation:	REX CHAINBELT, INC. AUTOMATIC SAMPLER
Project Location:	Kenosha, Wisconsin
EPA Project No.:	11023 EKC. Final report should be available soon.
Sampler Intake:	Pipe drilled with 0.63 to 0.95 cm (1/4 to 3/8 in.) holes.
Gathering Method:	Uses a "Hushpuppy" positive pressure pump. Cost of pump about $30. Operates only during a 2-3 minute purging period and during actual filling of sample bottle.
Sample Lift:	Suction lift about 4.6m (15 ft.).
Line Size:	1.3 cm (1/2 in.) Tygon tubing and garden hose.
Sample Flow Rate:	Approximately 11.4 ℓpm (3 gpm).
Sample Capacity:	Unit collects 18 discrete samples in bottles of 1-liter capacity.
Controls:	Sampler operation started by manually operated control. Thereafter, flow to sample bottles is regulated by an electric timer and solenoid valve. Time interval between filling of bottles can be adjusted between 3 minutes and one hour.
Power Source:	Not stated.
Sample Refrigerator:	None provided.
Construction Materials:	Sampling lines are composed of Tygon tubing and garden hose; pump is plastic and Buna N.
Basic Dimensions:	Not stated.

General Comments: After manual starting, the pump runs for 2 to 3 minutes to purge the sampler lines. The pump then operates only while each sample bottle is filled through a revolving solenoid valve regulated by an electric timer. Apparently, the pump operation is stopped automatically after 18 sample bottles have been filled.

Rex Chainbelt Automatic Sampler Evaluation

1. Experience has been only in sewage which has been comminuted and passed through a grit chamber, but unit should be fairly free from clogging.

2. The pipe sampler intake would present some obstruction of flow, the extent of obstruction depending on the method used for maintaining the position of the pipe in the flow.

3. Does not collect enough samples at short time intervals to include the entire storm period at many locations.

4. Operation impediment by the movement of solids will depend on the method used for installation of the sampler intake pipe.

5. Operation is automatic after initial startup at the beginning of a storm. Self cleaning limited to initial purging of lines.

6. Representatitiveness of sample depends on placement, and specifications of the intake pipe. Discrete samples of uniform size are collected at constant time intervals. Flow proportional compositing not possible unless time-synchronized with a recording flow meter.

7. Unit could provide some capability for floatables and bottom solids depending upon positioning and length of sampler pipe.

8. No provision for refrigeration of samples provided. Purging of lines prior to sample collection serves to reduce precontamination; cross-contamination will probably occur.

9. Unit was not designed for manhole operation.

10. Not designed to operate under total immersion or flooding.

11. Unit not designed to operate under freezing conditions.

12. Relatively high lift would allow operation over a fairly wide range of operating head conditions.

Designation: COLSTON AUTOMATIC SAMPLER

Project Location: Durham, North Carolina

EPA Report No.: EPA-670/2-74-096.

Sampler Intake: Direct intake to sump pump set on piling at stream bed. Intake from sampling flume is a standard Serco Model NW-3 sampling head.

Gathering Method: Water pumped from stream to sampling flume with an Enpo-Cornell sump pump, Model No. 150A. Pump is placed inside a 61 x 46 cm (24x18 in.) metal box, all within a woven wire frame. A standard Serco Model NW-3 vacuum sampler gathers samples from the 91 x 27 cm (36x10.5 in.) Plexiglas flume.

Sample Lift: About 3.3m (11 ft.) from the pump to the sampling flume. No lift from the flume to the Serco sampler.

Line Size: Line from pump to flume is 3.8 cm (1.5 in.) fire hose. Serco sampler lines are 0.63 cm (1/4 in.) inside diameter.

Sample Flow Rate: Flow rate from pump to flume is about 189 ℓpm (50 gpm). Flow rate from flume to Serco sampler is variable.

Sample Capacity: 24-500 mℓ bottles are provided in the Serco sampler. Actual sample sizes are about 400 mℓ.

Controls: Operation of pump starts and stops when float in an offstream stilling well reaches specified stages. For Serco Model NW-3 sampler controls, see page 193.

Power Source: Pump operates on 110 VAC. Serco sampler is powered with a spring driven clock.

Sample Refrigerator: None provided.

Construction Materials: Sampling train composed of fire hose, Plexiglas flume, stainless steel sampling head, vinyl lines, and glass bottles with rubber stoppers.

Basic Dimensions: Not a concentrated unit. Serco sampler 39 x 39 x 68 cm (15.5x.5.5x26.7 in.).

Colston Automatic Sampler

1. Because of large diameter hose from the pump to the sampling flume, and continuous flow during the period of operation, clogging is infrequent. Experience has been in an urban stream which has the characteristics of a storm sewer.

2. The pump and covering, as placed on the stream bed, would create a significant obstruction to flow, particularly in a sewer of ordinary dimensions.

3. May not operate during very low flows, depending upon height of pump inlet above stream bed.

4. Heavy bed loads could render the pump inoperable.

5. Pump starts and stops automatically in accordance with specified water stages. Continuous flow to sampling flume provides self cleaning, but the Serco sampler has no self cleaning features.

6. Collects discrete samples at preset times from a fixed point intake only. Flow proportional compositing is possible when time is synchronized with recording flow measurement equipment.

7. Unsuitable for collection of samples of floatables or coarser bottom solids.

8. No refrigeration provided. Use of individual sampling lines in the Serco sampler eliminates cross-contamination possibility.

9. Not designed for operation in sewer manholes or other confined spaces.

10. Not operable under conditions of total immersion or flooding.

11. Would not operate under freezing conditions.

12. Sample lift of about 3.3m (11 ft.) to the sampling flume, and a potential lift of 3m (10 ft.) for the Serco sampler, indicates capability for operation under a fairly wide range of operating head conditions.

Designation:	ROHRER AUTOMATIC SAMPLER MODEL II
Project Location:	To be used in Akron, Ohio
EPA Report No.:	None
Sampler Intake:	Not clearly stated but presumably the end of the 5 cm (2 in.) I.D. suction line mounted directly in the flow stream to be sampled.
Gathering Method:	Suction lift from diaphram pump.
Sample Lift:	Not stated but probably good for at least 6.1m (20 ft).
Line Size:	1.9 cm (3/4 in.) I.D.
Sample Flow Rate:	Depends upon lift; could exceed 76 ℓpm (20 gpm).
Sample Capacity:	Unit collects twenty-four 1.9ℓ (1/2 gal) discrete samples plus an 18.9ℓ (5 gal) composite.
Controls:	Has a provision for automatic starting. Discrete samples and composite aliquots can be collected every 5 minutes paced by a built-in timer adjustable from 5 to 60 minutes. Switches automatically stop diversion to composite bottle when it is full and shut sampler off when last discrete bottle has been filled.
Power Source:	115 VAC
Sample Refrigerator:	None
Construction Materials:	Tygon and PVC tubing; aluminum diverter, nozzle, etc.; "Nalgene" sample bottles; aluminum frame.
Basic Dimensions:	137 x 76 x 150 cm (54 x 30 x 59 in.) including mounting dolly. Can be wheeled about, but appears too heavy to lift without assistance.

General Comments: The pump produces a continuous flow of sewage through the sampler diverter and back to the sewer. Two solenoids are provided to allow diversion of flow to either the discrete or composite sample container for a preset time period. They tip a nozzle inside a diversion chamber and thus direct the flow as commanded by the timing cams. The nozzle is spring loaded to return to its null position which directs flow back to the sewer. A rotating nozzle is indexed over one of 24 funnels, each connected by a piece of 1.9 cm (3/4 in.) I.D. tygon tubing to one of the wide mouth discrete sample bottles which are in a rectangular array.

Rohrer Automatic Sampler Model II Evaluation

1. Should be relatively free from clogging, except perhaps the tubes connecting the distribution funnels to the discrete sample bottles.

2. Unit would not appear to offer any significant obstruction to flow.

3. Units should be operable over the full range of flow conditions.

4. Movement of solids in the flow should not hamper operations, except for possible diaphram wear.

5. Capable of automatic operation. Continuous flow serves a self cleaning function.

6. Collects 24 discrete samples at preset time intervals and a simple composite.

7. Ability to collect floatables and coarser bottom solids will depend upon details of sampling intake.

8. No refrigeration, but otherwise unit would appear to afford reasonable sample protection.

9. Unit was not designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear capable of operation in freezing ambients.

12. Relatively high lift should allow operation over a fairly wide range of operating head conditions.

Designation:	NEAR SEWER SAMPLER
Project Location:	Tested at San Jose Water Pollution Control Plant.
EPA Report No.:	None. Not developed under EPA sponsorship.
Sampler Intake:	Small hole approximately 1.3 cm (1/2 in.) diameter in the side of a traversing pick-up tube.
Gathering Method:	Mechanical; pick-up tube with piston is lowered and fills through intake near its lower end as it traverses the stream to be sampled. Sample is ejected through a hole near the top of the tube by raising the piston inside the tube.
Sample Lift:	Will depend upon pick-up tube length; 2.4m (8 ft) would appear to be a practical maximum.
Line Size:	Smallest line (possibly 1/2") would appear to be the one connecting the sample bottle to the pick-up tube outlet.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Developer simply states that either a composite sample or a number of discrete samples can be provided.
Controls:	An upper piston was added to allow varying the quantity of samples gathered during the stream depth traverse in a controlled way. It is activated by a water surface sensor located on the bottom of the pick-up tube. The water sensor provides the capability (in conjunction with a small memory and logic unit) of gathering flow-proportional samples, at least to the extent that flow is

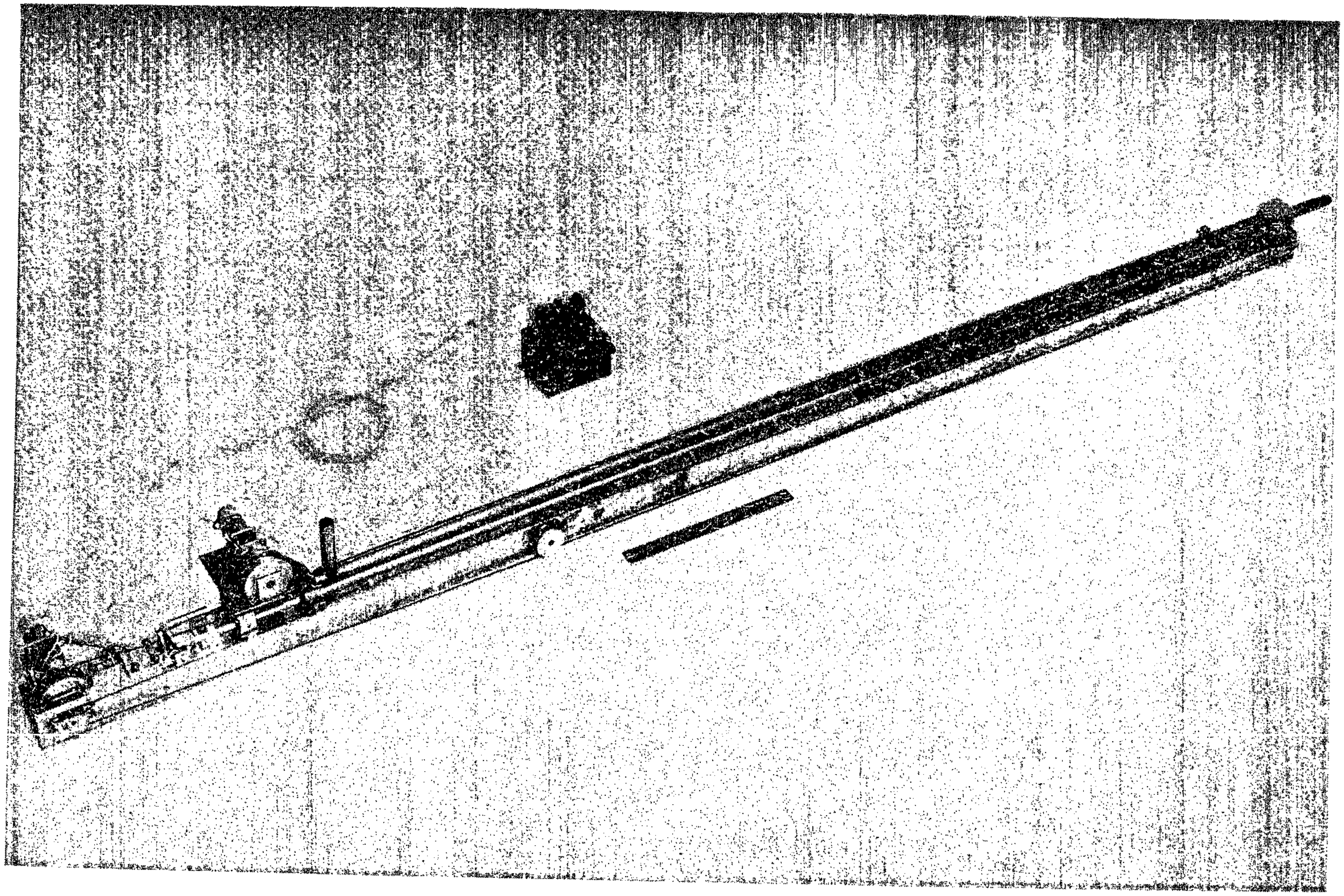


Figure 19. NEAR Sewer Sampler

Photograph courtesy of Nielsen Engineering and Research, Inc.

proportional to water depth. Otherwise samples could be paced by a timer or arranged to accept signals from an external flowmeter.

Power Source: Basic unit could be battery powered. External controls could require alternating current.

Sample Refrigerator: None

Construction Materials: Stainless steel and plastic.

Basic Dimensions: Will depend upon length of pick-up tube; say approximately 0.3 x 0.3 x 2.4m (1 x 1 x 8 ft) plus a sample container rack. Unit must be mounted in manhole or otherwise near the flow stream. Basic unit would appear to weigh 13-18 kg (30-40 lbs).

General Comments: Sampler is out of the main flow except when taking a sample. Developer claims sampler can pick-up a representative sample of surface oil film. Both an initial model and an improved prototype have been fabricated and tested to demonstrate the basic concepts involved, but the unit has not been made commercially available as yet. A patent has been granted for the sampler and its concept. Any requests for further information should be directed to:

S. B. Spangler, Vice President
Nielsen Engineering & Research, Inc.
850 Maude Avenue
Mountain View, California 94040
Telephone (415) 968-9457

NEAR Sewer Sampler Evaluation

1. Pick-up tube might collect debris (rags, paper, etc.) during traverse which could clog inlet port; otherwise should be relatively free from clogging.

2. Pick-up tube offers a rigid obstruction to flow while sample is actually being collected.

3. Unit would appear vulnerable to damage due to Strouhal vibration at high flow rates.

4. Movement of large objects in the flow at the time a sample is being taken could damage or even physically destroy the pick-up tube assembly.

5. Prototype does not have an automatic start feature. No self cleaning. Cross contamination appears very likely.

6. Prototype is amenable to several types of control systems, but none has been demonstrated as yet.

7. Preliminary test results indicate a capability of collecting surface oil films. Unit is unsuitable for collecting coarse bottom solids.

8. Sample container case not designed. Since unit mounts in manhole near flow surface, samples are vulnearable, and refrigeration does not appear reasonable.

9. Unit is designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear to have difficulty operating in freezing ambients.

12. Unit has design capability of operating over a fairly wide range of operating head conditions.

Designation:	FREEMAN AUTOMATIC SAMPLER
Project Location:	Columbia, Maryland
EPA Report No.:	None
Sampler Intake:	Provided by user.
Gathering Method:	External head to provide flow to sampling equipment shed. Fluidic diverters are controlled by solenoid valves by timer signals and divert flow to discrete sample containers, the flow otherwise returning to waste.
Sample Lift:	Not applicable.
Line Size:	The smallest passage in the sampling train is the 0.63 x 0.63 cm (0.25 x 0.25 in.) throat of the diverter.
Sample Flow Rate:	5.7 ℓpm (1.5 gpm).
Sample Capacity:	Modularized construction allows as many 0.9ℓ (1 qt) discrete sample containers to be used as desired. For this installation, 6 modules were arranged vertically in a single cascade, and two cascades were employed.
Controls:	Timer-actuated solenoid valves open and close the diverter control ports causing a sample to be taken at preset time intervals. Volume of sample is adjusted by positioning the vent tube in the sample jar.
Power Source:	110 VAC
Sample Refrigerator:	None
Construction Materials:	PVC pipe, fluidic diverters molded from PVC, sample containers are glass Mason jars, metal and plywood frame.

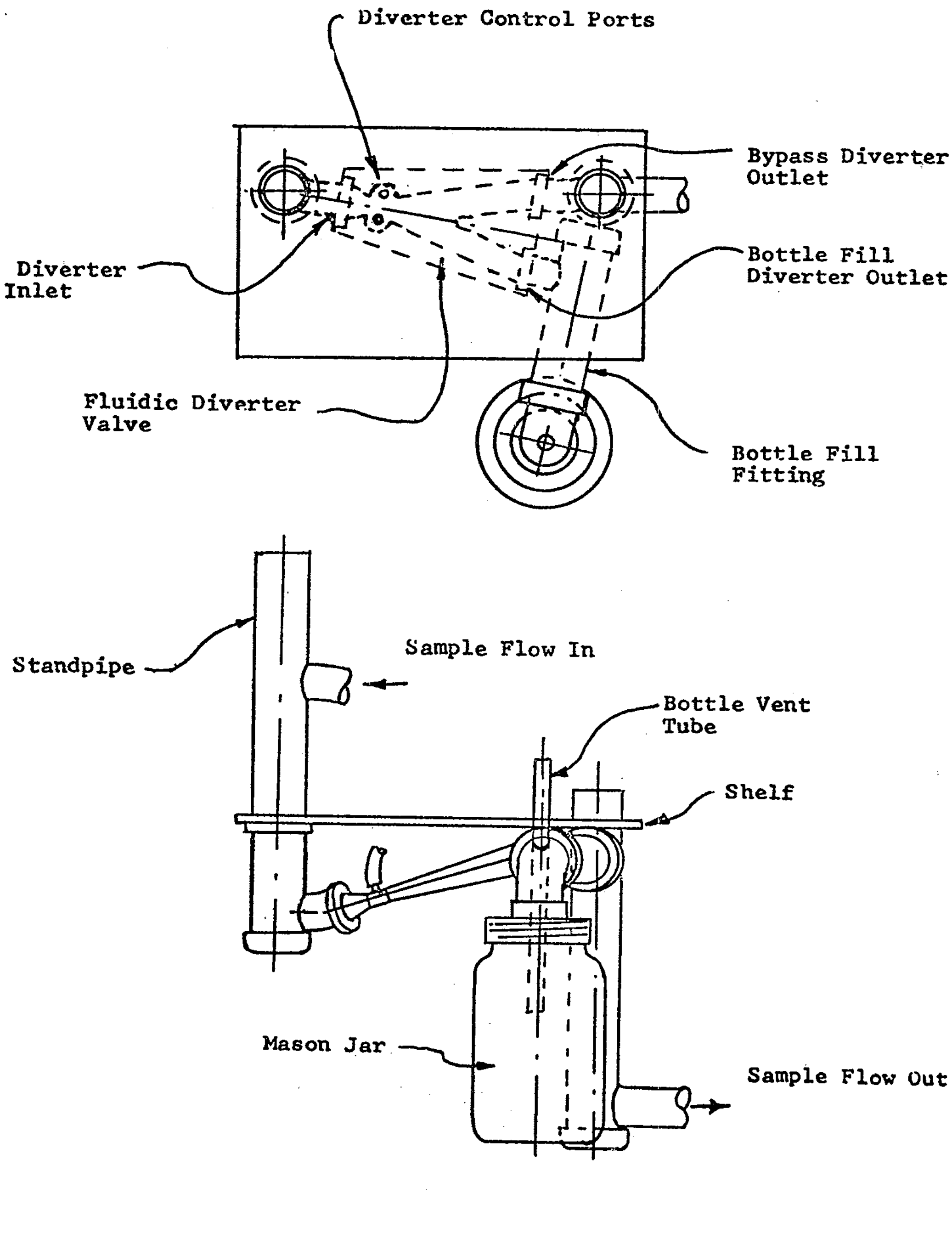


Figure 20. Freeman Automatic Sampler Module

Sketch courtesy of Peter A. Freeman Associates, Inc.

Basic Dimensions: Each 6 module cascade appears to be about 0.5 x 0.3 x 1.5m (1.5 x 1 x 5 ft). Minimum height of a module is 15.2 cm (6 in.) head required for diverter operation plus sample bottle height.

General Comments: The complete absence of moving parts in the flow stream is a distinct advantage. With the use of a bias orifice in one control port, only one control line need be blocked to obtain diversion. The possibility of using such an arrangement with the control lines sequenced vertically in a timing jar that is fed fluid by a calibrated wick would allow a sampler with absolutely no moving parts and requiring no power other than from the fluid flow itself.

Freeman Automatic Sampler Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Continuous flow serves a self cleaning function. No cross-contamination.
6. Collects adjustable size (up to 1 liter) discrete samples at preset time intervals.
7. Ability to collect samples of floatables and coarser bottom solids will depend upon design of sampling intake.
8. No refrigerator. Adequate sample protection for this installation.
9. Not designed for manhole operation as presently configured.

10. Cannot withstand total immersion.

11. Unit should be able to operate in freezing ambients.

12. Operating head is provided by user.

Designation:	PS-69 PUMPING SAMPLER
Project Location:	Columbia, Maryland
EPA Report No.:	None. Not developed under EPA sponsorship.
Sampler Intake:	Provided by user.
Gathering Method:	Suction lift from progressive cavity screw-type pump.
Sample Lift:	6.1m (20 ft) recommended maximum.
Line Size:	Pump will pass 0.5 cm (3/16 in.) solids.
Sample Flow Rate:	Approximately 26 ℓpm (7 gpm).
Sample Capacity:	Adjustable size discrete samples are collected in seventy-two 0.5ℓ (1 pt) glass bottles or 0.9ℓ (1 qt) plastic containers.
Controls:	Sample size is adjusted by potentiometer setting; under timer operation samples may be taken as often as every 2 minutes or as infrequently as one a day; may be paced by optional stage-discharge computer or external flowmeter. Has automatic starter and event marker.
Power Source:	36 VDC (three 12V automobile batteries of 55 amp-hr. capacity or greater) for pump motors; one standard D dry cell battery for clock.
Sample Refrigerator:	None.
Construction Materials:	Intake tubing is user-supplied; pump is Buna-N, stainless steel, carbon and ceramic; also PVC and vinyl in sampling train.

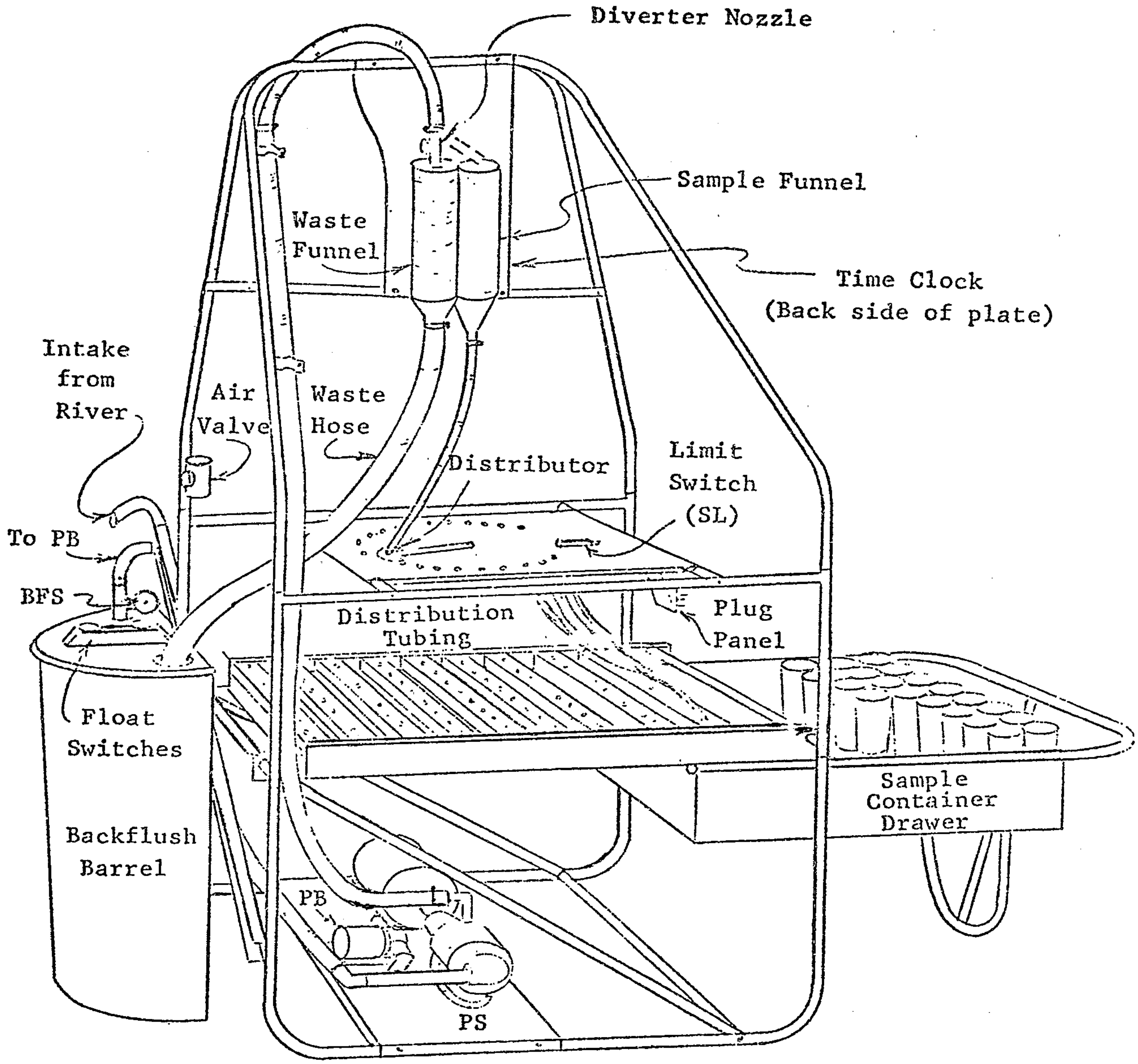


Figure 21. PS 69 Pumping Sampler

Basic Dimensions: 96 x 147 x 183 cm (38x58x72 in.); weighs 77 kg (170 lbs) without batteries or tubing; designed for fixed installation.

General Comments: This sampler was designed for sediment transport studies in rivers. A typical cycle begins with a small pump taking water from a backflush barrel and backflushing the intake, priming the line and removing any grass or trash from the intake proper. This operation continues until a bottom float in the barrel drops. When the large (sampling) pump starts, a solenoid on the backflush barrel closes the backflush pump intake and the distribution arm advances one hole. The sampling pump feeds into a solenoid operated diverter that normally feeds the backflush tank. About 20 seconds after the sampling pump starts, the diverter switches for a preset period and the sample is routed via the distributer arm and an individual plastic hose to the next sample container. The sampling pump is shut off when the top float in the backflush barrel lifts. A smaller, portable version designated PS-73 and taking 36 discrete samples is also available. Any requests for further information should be directed to:

John V. Skinner
Hydrologist-in-Charge
Federal Inter-Agency
Sedimentation Project
St. Anthony Falls Hydraulic
Laboratory
Hennepin Island and Third Ave.
S.E.
Minneapolis, Minnesota 55414

PS-69 Pumping Sampler Evaluation

1. Should be relatively free from clogging, except perhaps the tubes connecting the distribution funnels to the discrete sample bottles.

2. Obstruction to flow will depend upon way user designs and installs sampler intake.

3. Unit should be operable over the full range of flow conditions.

4. Movement of solids should not hamper operation.

5. Automatic starter; backflush of intake and inlet line provides partial self-cleaning.

6. Collects 72 discrete samples (either 0.5ℓ or 0.9ℓ) paced by interval timer, optional proportional frequency controller (stage-discharge computer), or external flowmeter.

7. Ability to collect floatables or coarser bottom solids will depend upon details of sampling intake, but anything larger than 0.5 cm (3/16 in.) will jam pump.

8. No refrigeration, but otherwise unit would appear to offer reasonable sample protection when installed in recommended shelter.

9. Unit was not designed for manhole operation.

10. Unit cannot withstand total immersion.

11. The use of a heated shelter is recommended for cold-weather operation.

12. Relatively high lift should allow operation over a fairly wide range of operating head conditions.

Designation:	RECOMAT SAMPLER
Project Location:	Paris, France (Department De Seine Saint-Denis)
EPA Report No.:	None. Not developed under EPA sponsorship.
Sampler Intake:	Four 120 mℓ tanks, each with an 8 cm (5/16 in.) diameter hole in the bottom and protected by a plastic bell, which can be positioned vertically anywhere within the flow stream.
Gathering Method:	Forced-flow due to pneumatic ejection.
Sample Lift:	10m (33 ft) maximum.
Line Size:	Smallest line is 0.6 mm (1/4 in.).
Sample Flow Rate:	Depends upon pressure and lift.
Sample Capacity:	Collects 24 sequential composite samples (1.6ℓ maximum) made up of an undisclosed (but fixed) number of aliquots of less than 120 mℓ per intake.
Controls:	The design is such that it takes 5 minutes to collect each sequential composite sample. The only control is an operator setting (η) that causes the sampler to fill the first η bottles one after the other (essentially continuous operation), after which the remaining 24-η bottles are filled at 10 minute time intervals. Thus, the total sampling period can range from 2 to 4 hours.
Power Source:	Electricity required for air compressor motor and refrigerator.

Sample Refrigerator: Entire sample distribution and storage assembly is inside an automatic refrigerator set to maintain a 4°C internal temperature.

Construction Materials: Sampling train is plastic and rubber.

Basic Dimensions: Sample intake is 8 cm (3.1 in.) diameter x 15 cm (5.9 in.) H; control box is 60 x 30 x 80 cm (23.6x11.8x31.5 in.); refrigerator is 100 x 100 x 120 cm (39.4x39.4x47.2 in.); each compressor is 50 x 50 x 20 cm (19.7x19.7x7.9 in.); fixed installation.

General Comments: This sampler was designed by RECOMAT to meet specifications written by Coyne and Bellier consulting engineers. Each intake is gravity filled, via its bottom hole, through an elastic rubber truncated cone inside its tank. The release of air pressure pinches the edges of the rubber hole and forces the sample up the line, through the distribution arm, and into the sample container. Due to air losses associated with the rubber cones (and piping), due in part to failure to shut off because of obstruction by heavy particles, only 500 mℓ or so of sample is typically obtained (rather than the 1.6ℓ design capacity). A separate air compressor is used to move the distribution arm.

RECOMAT Sampler Evaluation

1. Should be relatively free from clogging except for possibly the elastic rubber cone in the intake.

2. Sampler intakes and supporting structure present a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, but the use of several aliquots to obtain each sample minimizes adverse effects of this. Representativeness is questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intakes. Small solids could prevent rubber intake cone from sealing, resulting in reduced or no sample from that intake.

5. Apparently has no automatic start or self-cleaning features.

6. Collects sequential composite samples made up of a number of aliquots of possibly varying size.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for its 2-4 hour duty cycle life.

12. Maximum lift of 10m (33 ft) puts little restriction on operating head conditions but is less than in many pneumatic ejection designs.

Designation:	EG&G PROTOTYPE SEWER SAMPLER
Project Location:	Rockville, Maryland
EPA Report No.:	EPA-670/2-75-XXX to be issued soon.
Sampler Intake:	Four intakes of present configuration can be located anywhere within the flow stream. Presently consists of 4 plastic nozzles, each with three 0.5 cm (3/16 in.) diameter ports in line with the flow, mounted to a streamlined stainless steel strap around the inside periphery of the sewer pipe.
Gathering Method:	Suction lift from separate high capacity 3-rotor peristaltic pump heads for each intake, driven by a common electric motor through keyed connecting shafts.
Sample Lift:	Submersible pump box is designed to be located within 3m (10 ft) or so of the flow. Discharge heads of over 15m (50 ft) are possible.
Line Size:	Smallest line is 0.95 cm (3/8 in.) I.D.
Sample Flow Rate:	9.5 ℓpm (2.5 gpm) through each line for 37.9 ℓpm (10 gpm) total flow in present configuration.
Sample Capacity:	Collects 12 discrete 2ℓ (0.53 gal) samples per storage module.
Controls:	May be set to take a sample as often as every minute or as infrequently as once every 9 hours, in 200 millisecond increments when paced by internal timer; may also be paced by suitable external flowmeter; has automatic start connection; all solid state design. Backflush and blowdown

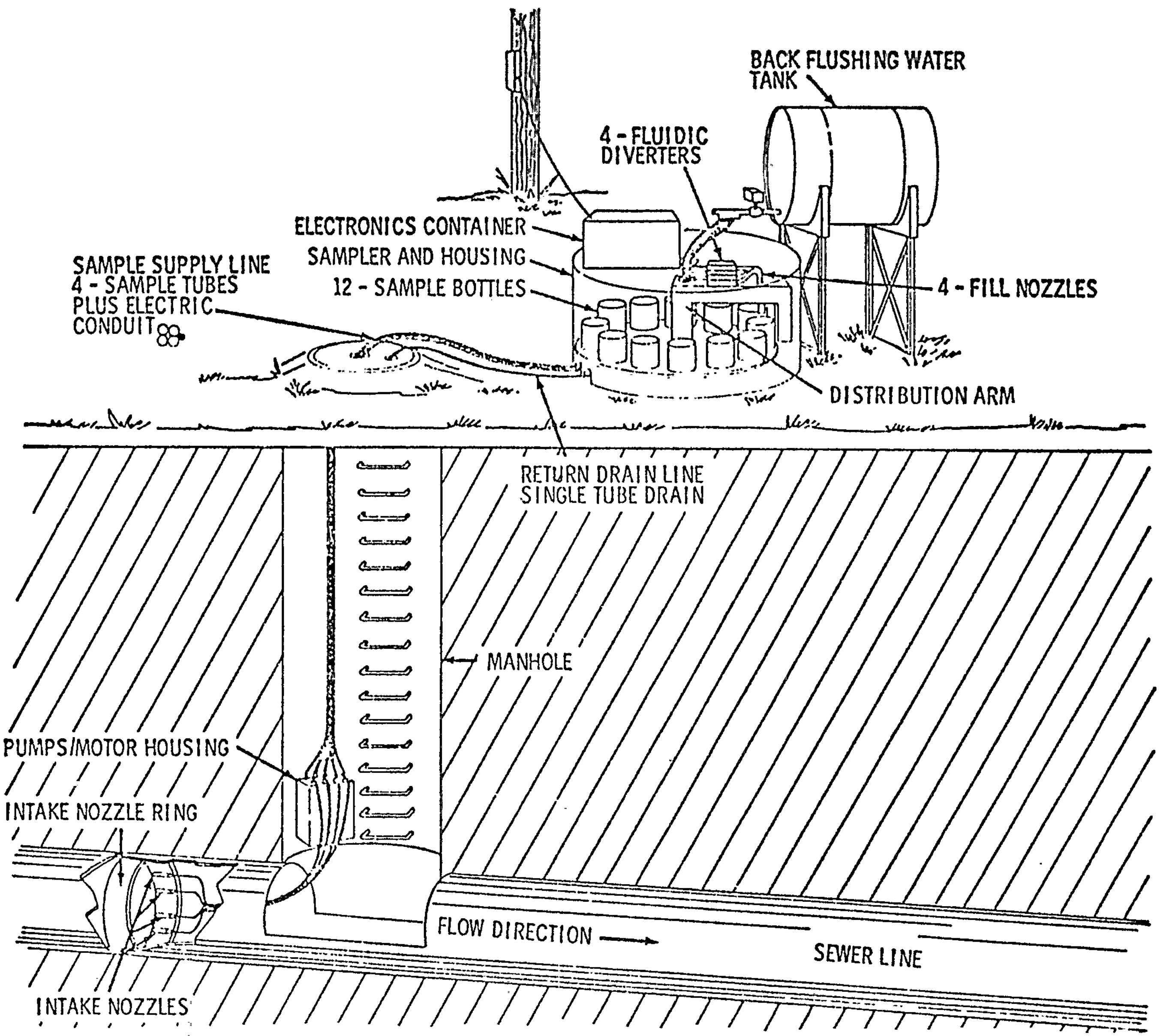


Figure 22. EG&G Prototype Automatic Sewer Sampling System Schematic

time periods are also adjustable. Can be programmed or run manually in any fashion for test purposes.

Power Source: 110 VAC electricity.

Sample Refrigerator: Entire sample distribution and storage assembly can be fitted with an insulated, refrigerated cover, but none is provided at present.

Construction Materials: Sampling train is PVC, tygon, silicone, plexiglass, and polyethylene.

Basic Dimensions: Not an integrated unit. Largest components are a standard 55-gallon drum and distributor and storage assembly which is approximately 1.2m (4 ft) in diameter and 0.9m (3 ft) H; electronics box is 47 x 39 x 30 cm (18.5x15.5x12 in.); fixed installation.

General Comments: This automatic sampler is a prototype design incorporating several previously untried features in five modular subsystems, including all solid-state electronics, a clock to allow time-of-day correlation, high sample intake and transport velocities, large high-capacity peristaltic pumps and fluidic diverters avoiding any moving parts in the sampling train, return of the first flow to waste, fresh water or chemical purge and backflush and high pressure air blowdown after each sample is taken, multilevel sample intakes with non-intrusive mounting, and large sample capacity with the quantity of each sample determined by weight. The modular subsystem approach allows the basic design implementation to be tailored to suit a wide variety of sampling program and site requirements.

EG&G Prototype Sewer Sampler Evaluation

1. Should be relatively free from clogging due to design of intake, lack of constrictions and moving parts in the sampling train, the fact that the sample flows under pressure from the pump all the way to the sample container, and the backflush and blowdown features.

2. Non-intrusive intake ring presents virtually no obstruction to the flow.

3. Should be capable of operating over the entire range of flow conditions.

4. Movement of solids should not hamper operations.

5. Has connection for automatic starting on signal from external sensor. Backflush, purge, and blowdown self-cleaning features should minimize cross-contamination.

6. Collects discrete samples from a multi-level intake paced by built-in timer or external flowmeter.

7. Separate intake designs required for sampling floatables or coarser bottom solids.

8. No refrigeration in present form.

9. Submersion proof pump box is designed to operate in a surcharged manhole; intake can be installed in entry line to manhole in less than 15 minutes; no other subsystems are intended to be down in the manhole; transformer isolated to prevent shock hazard if pump box is physically destroyed by accident.

10. Manhole components can withstand complete immersion.

11. Freshwater tank would require heater or antifreeze for cold weather operation. Collected samples would freeze if left for prolonged periods without a heated cover.

12. Combined lift of over 18m (60 ft) puts little restriction on operating head conditions.

SECTION VIII

EXPERIENCE WITH COMBINED SEWER SAMPLERS

In order to assess the efficacy of both standard commercially available samplers and custom engineered units in actual field use, a survey of recent EPA projects in the storm and combined sewer pollution control area was conducted. Final reports were obtained where available, but for some projects only interim reports existed and, in a few instances, telephone conversations had to be relied on. In each project, the research and development contract or grant was for an activity which also required determination of water quality. No projects had been undertaken solely to compare or evaluate samplers for use in storm and combined sewers.

STRAINER/FILTER TREATMENT OF COMBINED SEWER OVERFLOWS

Reference 9 is the final report for a project to examine strainer/filter treatment of combined sewer overflows. Although automatic sampling equipment was not used in this project, several interesting observations were made. It is stated in the conclusions that "this feasibility study has shown that sampling methods commonly used in evaluating the effect of combined sewer overflows on receiving streams cannot be considered reliable. The results indicate that most of the calculated loads that are based on automatic sampling stations have most likely understated the actual case". Particular criticism is leveled against the small diameter, low velocity probes which are characteristic of most present-day automatic sampling units. In this project the sampling was performed manually by a technician at the overflow site. Samples were taken at 15-minute intervals during the first 2 hours of flow and thereafter at 30-minute intervals for 2 hours. The samples were discrete in nature, not composites over each time interval, and were taken in two quantities: a) a 7.6ℓ (2 gal) sample taken with a 3.8ℓ (1 gal) pail, and b) a 3.8ℓ (1 gal) sample taken with a 0.5ℓ (1 pt) wide mouth cup. The samples were brought to the analytical laboratory within 6 hours of the initial sampling time.

It is noted on page 18 that visual observation of several overflows conclusively showed the presence of fresh human feces (larger than one-half inch) and whole pieces of toilet paper. Samples were also collected using a wire mesh screen with one-quarter inch openings. Comparison of the suspended solids in the usual pail samples with those collected on wire mesh strainers consistently showed a variation in particle size. Only when a sample was taken at the surface of the flowing stream did the maximum particle size obtained with the pail equal that found with the wire mesh strainer.

In one instance a set of samples was taken by two people simultaneously at the same surface depth. The pail sample was found to have consistently higher values than the scoop sample for each variable tested. These variables included BOD, COD, suspended solids, total solids, volatile solids and settleable solids. In some instances the analyses of the scoop obtained samples resulted in values less than half of those obtained from pail-collected samples. Although whole sections of toilet paper were noted in the overflow, the sampling technique used did not produce or yield any paper in the samples.

STREAM POLLUTION ABATEMENT FROM COMBINED SEWER OVERFLOWS

Reference 10 contains the results of a detailed engineering investigation and comprehensive technical study to evaluate the pollution effects from combined sewer overflows on the Sandusky River at Bucyrus, Ohio. The overflows from many storms were sampled during the study period to determine the quality of the overflow and pollution loads. For about 6 months samples were collected manually. After February 1, 1969, Serco automatic samplers, Model NW-3, were installed in the instrument shelters at the overflows. These samplers collected a 300 ml sample every 5 minutes for 2 hours during overflow. If the overflow continued longer than 2 hours, samples were collected manually at less frequent intervals.

It is noted on page 15 that an automatic starter was devised for the samplers that started the clocks when the water level reached a pre-determined height behind the weirs. The samplers could therefore be left unattended prior to and during an overflow. The samplers required a vacuum to be maintained in the sample bottles. Because the samplers would lose vacuum after 1 or 2 days, they had to be installed in the 24 hours preceeding the overflow.

Except for these comments regarding difficulty with automatic starters and vacuum leaks, no other in-service related problems were mentioned.

CONTROL OF POLLUTION BY UNDERWATER STORAGE

Reference 11 contains the results of a demonstration project for the control of pollution by underwater storage. A pilot plant was designed, constructed and operated to assess the feasibility of providing a facility for the collection, treatment, storage and final disposition of storm overflow from a combined sewer system. A Serco Model NW-3 automatic sampler was located at the Parshall Flume. It was found to be inadequate for the requirements of the testing laboratories. The sampling quantities required were four times greater than that originally contemplated. As a result, samples were taken partly with the automatic sampler, but primarily by hand. No other comments of the suitability of this sampler for its application or experience with it were made.

ENGINEERING INVESTIGATION OF SEWER OVERFLOW PROBLEMS

Reference 12 contains the results of an engineering investigation of sewer overflow problems in Roanoke, Virginia. Both manual and automatically gathered samples were obtained during storm events to assess the quality of sewer overflows and storm runoff. Serco automatic samplers were used in this program. The problems encountered during sampling primarily involved the equipment. It is noted on page 149 that the automatic samplers worked rather well, except that some precautions had to be taken. In the streams the nozzle could not be rested on the bottom, or sand and grit would be drawn in the sample bottle. Rags from the sanitary sewers would block several of the tube openings during a 24-hour sampling program. Occasionally a clock would stop and a complete rainfall would be missed. The automatic starting devices proved to be inadequate; therefore, the samplers had to be started manually at the beginning of each rainfall which proved to be time-consuming.

MICROSTRAINING AND DISINFECTION OF COMBINED SEWER OVERFLOWS

Reference 13 contains the results of an investigation of microstraining and disinfection of combined sewer overflows. On page 20 it is noted that composite samples of the raw and strained water were extracted automatically by two N-Con Surveyor model samplers and stored in refrigerated containers. The samplers were adjusted to withdraw portions of the flows at a fixed rate every 6 minutes. The only comments made about the sampling equipment were that composite sampling is not so representative of variations within a storm and discrete samples would be more desirable, and a complaint about the low suction lift which restricted operations.

In Phase II of this project reported in (14) automatic vacuum-type discrete samplers (Serco Model SG-15) were used. The samplers collected discrete 300 mℓ samples of influent and effluent every 2 minutes. The data on organic content and coliform from 14 storms were rendered useless due to improper sterilization of the samplers in the field. Sampler failures were noted but not discussed.

STORMWATE" POLLUTION FROM URBAN LAND ACTIVITY

Reference 15 presents the results of an investigation of the pollution concentrations and loads from storm water runoff in an urban area of Tulsa, Oklahoma. Standard procedures for manual sampling were used when baseline samples or stormwater runoff samples were collected. The stationary automatic sampling method was used when a time series of samples was desired. The sampling apparatus employed was unique and custom-designed for this project by the contractor. Five semi-stationary automatic sampling stations and three portable automatic samplers were fabricated and used in this project. The only problems noted were due to vandalism. Several of the semi-stationary sampling stations were broken open and some of the equipment was damaged. This caused important data losses on some watersheds.

RETENTION BASIN CONTROL OF COMBINED SEWER OVERFLOWS

Reference 16 contains an evaluation of the control of combined sewer overflows by retention in an open basin in Springfield, Illinois. It is interesting to note that the instrumentation subcontract cost was $31K, while the subcontract for construction of the basin itself only cost $77K. A rather large scale fixed installation, automatic sampling system was designed for this project. Originally 10 cm (4 in.) diameter influent and effluent sampling lines were used. Pumps took suction from the sampling lines and discharged in the sampling tanks. A Trebler scoop-type sampler was provided in each tank to take the samples. Samples of equal volume were taken at 30-minute intervals with the automatic samplers and composited over a 24-hour period The composite bottles were located in a refrigerator and were kept under mechanical refrigeration at all times.

Problems were experienced with operation of the samplers during early months of the operation. This was particularly true of the influent sampler. The influent sampling line was over 274m (900 ft) long. It was concluded that this 10 cm (4 in.) diameter line was much too large for the size pump taking suction from it and, as a result, considerable amounts of solids settled in the line. This provided a non-representative sample of the influent. There were also difficulties associated with the location of the influent sampler probe. As a solution, the 10 cm (4 in.) influent sampling line was replaced with a 3.8 cm (1.5 in.) diameter line. This provided better velocities in the line and minimized settling of solids in it. A listing of maintenance items required over a 1-year period of operation is given on page 31. It is noted that there was one instance of repair on the flowmeter, seven instances of influent sampling line repair, one instance of effluent sampling pump repair, one instance of influent sampler motor burnout and replacement, three instances of repair for both pumps, and eight instances when the influent sampling line needed to be unclogged.

CHEMICAL TREATMENT OF COMBINED SEWER OVERFLOWS

Reference 17 contains the results of a study of flocculant treatment and disinfection of combined sewer overflows at Grosse Point Woods, Michigan. It is noted on page 48 that one of the most difficult problems was that of sampling. Flow rates varied from 8.6 to 69.4 cu m (305 to 2,450 cu ft.) per second. Influent sewage depths varied from 0.6 to 5.2m (2 to 17 ft.) with no dry well available for positive head devices, and a representative effluent sample had to be obtained from an inaccessible weir approximately 64m (210 ft.) in length.

All main sampling lines in the final design were 5 cm (2 in.) in diameter and flowed constantly during the sampling period. Because of the importance of sampling, automatic samplers were designed and constructed specifically for work on this project. These samplers were designed to collect adjustable grab samples from the continuously flowing 5 cm (2 in.) pipe stream, composite them for various periods, and hold them in a refrigerated compartment for periods up to about 3 hours. No discussion of problems encountered with these sampling devices was given.

COMBINED SEWER TEMPORARY UNDERWATER STORAGE FACILITY

Reference 18 contains the results of a demonstration of the feasibility of utilizing a temporary underwater storage facility as a means of abating pollution resulting from storm overflow from a combined sewer. Conclusion number 5 is especially interesting: "The samplers utilized on the project are not recommended for the sampling of sewage from combined sewers. A more advanced and efficient sampling method should be developed for future programs." On page 32 it is noted that "the required volume per sample was 1,020 mℓ to perform all required analyses. The standard Serco Model NW-3 automatic sampler would collect approximately 330 mℓ of sample per bottle when operated with a 1.5m (5 ft) lift, and 66 cm (26 in.) mercury internal vacuum and an atmospheric pressure of 76 cm (30 in.) mercury. Therefore, it was necessary to fill four bottles at a time for adequate sample volume". A newly designed and fabricated tripper arm was installed on the Serco sampler. The tripper arm simultaneously actuated four sampling line switches. A 15-minute gearhead was utilized for the tests to provide a sampling interval that would not overtax the field laboratory beyond its capacity.

URBAN RUNOFF CHARACTERISTICS

Reference 19 is an interim report on investigations for the refinement of a comprehensive EPA stormwater management model in which urban runoff characteristics are to be depicted. As a part of this program, automatic equipment for sequential sampling of water quality was installed for five separate sewer locations in the Bloody Run Sewer Water Shed in Cincinnatti, Ohio. N-Con Sentry Sequential Effluent Samplers were used in this program. The large amount of data given in the report indicates a generally satisfactory collection of samples but no operational comments are given.

IN-SEWER FIXED SCREENING OF COMBINED SEWER OVERFLOWS

Reference 20 reports on a project to examine the feasibility of in-sewer fixed screening of combined sewer overflows. As a part of this effort, a field sampling and analysis program supplemented with laboratory studies was conducted to characterize combined sewage contributory to combined sewer overflows, and to ascertain the removal of floatables and solid materials that could be effected by the placement of the screening devices in these systems. For this program special sampling equipment and supporting structures were designed and manufactured in order to assure representative collection of combined sewage samples. The equipment consisted of two types of samplers: a bulk liquid sampler and a screening sampler. Both employed the same support structure and the same sampling manhole. These are essentially bulk grab samplers which allowed removal of an entire 30.5 cm (1 ft) long section of combined sewage flow in the sewer. The sampler is lowered by hand and raised by a winch. Samples were collected on an hourly basis. No comments are made about the operational experience with these samplers, but apparently no difficulties were encountered.

STORM AND COMBINED SEWER POLLUTION SOURCES AND ABATEMENT

Reference 21 is a report on a study of six urban drainage basins within the city of Atlanta which were served by combined and separated sewers. As a part of the effort to determine the major pollution sources during storm events, automatic sampling devices were used. The Serco Model NW-3 Sampling Device was used, but several difficulties are indicated. On page 4 several interesting conclusions are noted: "Samples collected by automatic sampling devices tended to freeze in the sampling tubes during cold weather. Furthermore, the location of these vacuum operated devices at safe heights above peak flow levels limited the volume of samples that could be collected." "The automatic triggering device utilized during this study was not reliable. Dampness deteriorates electrical contacts and solenoids causing failure of apparently well insulated parts. The consequent necessity for manual triggering of the automatic samplers reduces their usefulness and indicates the need for an improved triggering device." "No significant differences exist between water quality analyses of simultaneous samples obtained by grab and automatic sampling techniques."

STORM WATER PROBLEMS AND CONTROL IN SANITARY SEWERS

Reference 22 is a report of an engineering investigation which was conducted on stormwater infiltration into sanitary sewers and associated problems in the East Bay Municipal Utility District with assistance from the cities of Oakland and Berkeley, California. Grab samples were collected with a rope and a bucket. Wet weather samples were collected with an Edison Lever Action Diaphragm Pump with a 3.8 cm (1.5 in.) suction line. Two types of portable samplers were used for dry weather flow; the Hinde Effluent Sampler which has a positive displacement pump with a 6m (20 ft.) lift and an N-Con Surveyor automatic composite sampler. The only real difficulty encountered in using the automatic samplers was that the suction tubing was so small that stringy and large size material tended to plug the lines. This problem was circumvented by placing a 20-mesh galvanized wire fabric stilling well around the ends of the suction tubes. Also, it was not possible to obtain samples automatically at one location because its 7.3m (24 ft.) depth exceeding the lift capacity of the samplers. It is noted on page 61 that the results of the analyses which were conducted on the samples gathered with the automatic sampling equipment were somewhat erratic.

UNDERWATER STORAGE OF COMBINED SEWER OVERFLOWS

Reference 23 is a report of a demonstration study of off-shore underwater temporary storage of storm overflow from a combined sewer. It is interesting to note that one of the recommendations given on page 3 is that, "collection of grab samples of all flows should be used liberally to confirm results from automatic samplers." The sampling program included grab samples for the dry weather flow, individually timed samples and composite samples of the storm overflow from the combined sewer drainage area, composite samples of effluent from the storage tanks, and grab samples of bay water at the outfall. At the time of design no sampler was commercially available to do the required job and at the same time secure a representative composite sample. Therefore a sampler was designed and constructed especially for this program. No operational data regarding this sampler are given but apparently no great difficulties were encountered.

MAXIMIZING STORAGE IN COMBINED SEWER SYSTEMS

Reference 24 is a report on maximizing storage in combined sewer systems in the municipality of Metropolitan Seattle. Programmed automatic-refrigerated samplers were designed and built as a part of the demonstration grant to simplify the sample collection tasks. These were manufactured by Sirco and were their Sewer-Test Vary-Sampler models. The report notes that, "the connotation of the term 'automatic' is somewhat deceiving; considerable manual effort is involved in collecting samples, replacing bottles and testing and repairing the various electrical components". Originally the samplers were supervised, maintained and serviced by different personnel. On the newly designed samplers, there was a 6-month period during which the samplers were broken in and various parts changed or modified. A single technician was assigned supervisory, service and maintenance responsibility for each of the automatic samplers and, since then, performance has been satisfactory.

A number of sampler problems were encountered including the electrical system which was quite complicated, the wiring which was difficult to maintain, instances of inadequate fuses, and failures of timers, microswitches, relays and reed switches. It is also noted that despite an automatic purging feature, the 0.95 cm (3/8 in.) diameter sampling tubes often became clogged with rags and other debris and required constant checking. During periods of extremely high flows, the sampler tubes were often flushed over emergency overflow weirs and left hanging high and dry when the flow subsided.

After the reporter's extensive history with the use of these samplers, two of the conclusions were especially noteworthy; "Samplers and recorders to be effective require regular surveillance and maintenance. The smallest failures can reduce valuable data to a level that is unuseable for certain statiscal analyses." "The best sampling equipment is generally the least complex, is portable, does not require lines, constrictions, or bends, and is not likely to become damaged when submerged (a large order)."

OTHER EPA PROJECTS

Among EPA projects surveyed for which final reports are not available is a project (EPA No. 11023 FAT) for the construction, operation and evaluation of a stormwater detention and chlorination station to treat combined sewer overflows on the Charles River in Boston, Massachusetts. Operation of the station commenced in early summer of 1970. Two Pro-Tech, Inc., Discrete Flow Samplers, Model DEL-240, are installed for obtaining discrete samples of inflow to the plant. These can be adjusted to sample at various time intervals from 1 minute to 24 hours. In a recent telephone conversation with the engineer in charge of the facility, it was learned that numerous troubles were experienced with the samplers during early operation. After various adjustments and modifications by the manufacture, the samples operated satisfactorily. The specific nature of the troubles experienced was not discussed.

In a project (EPA No. 11023 FAS) for the chlorination of a large volume of stormwater draining to Lake Pontchartrain in Louisiana, seven samplers were designed and constructed specifically for the project. Difficulty was experienced with solenoid operation of a brass valve. Apparently, satisfactory operation was attained after redesigning the valve in PVC. Initially, a telephone tone was used to start and stop the samplers. This method of actuation did not prove to be satisfactory and was discontinued. Information concerning these samplers was obtained by telephone conversation with the project engineer.

In a project (EPA No. 14-12-24) for the demonstration of a method of treating municipal sewage with a deviced termed a "rotating biological contactor", Serco automatic samplers were used for sampling in the treatment plant. Apparently, under the controlled plant conditions, performance of the sewer samplers was satisfactory. A "rotating belt sampler", custom built for the project, was used to sample wet weather flows to the plant. Samples were obtained "by means of a mechanical sampler installed in a drop manhole in the street. A series of sampling cups was driven along a belt to collect 250 ml samples about every 15 minutes during the combined flow. The sampler was actuated by the flow measuring device and was stopped by a limit switch when the first sample reached the drive system near the top of the manhole. Records collected for the project show that the device operated on 18 days during periods of fairly small flow, usually under 283 lps (75 gps).

In a grant project (EPA No. 11023 DXC) for the characterization and treatment of combined sewer overflows in San Francisco, California, a unique partially hand sampling device was used. A 30.5 cm (12 in.) pipe core, set in pipe guides, is dropped to the bottom of the channel with its cover open. Thus a partially integrated sample is forced into the pipe. The cover is then closed and the sample is surfaced by means of compressed air.

In a grant project (EPA No. 11020 FAX) to demonstrate system control of combined sewer overflows in a large urban area, an automatic sampler manufactured by Rock and Taylor of Birmingham, England, was used. Megator Corporation, Pittsburgh, Pennsylvania, is distributor of the sampler. It is of suction type with a maximum lift of 5.5m (18 ft) operating on a 12-volt battery or 120 VAC. Performance of this sampler was continually troubled by blockage due to papers, rags, disposable diapers, etc. Such troubles are described in project reports during most months of operation. After a period of freezing during the winter, use of the automatic sampler was discontinued, and hand sampling was substituted.

In a grant project (EPA No. Y-005141) the Rochester Pure Waters District has the overall responsibility for a comprehensive, on-going combined sewer overflow abatement program in Rochester, New York. District is directing its efforts towards an abatement program for the combined sewer overflows within its system, under which, management and control of the total system can be identified, characterized, modeled, designed, and demonstrated. The program is intended to tie together all aspects of collection, transmission, and treatment of combined sewage under a central control and management system. Within the total program is a subprogram for overflow monitoring and characterization. Measurements are being made at thirteen overflows and four interceptors.

The samplers installed at each overflow location were manufactured by Sigmamotor and are similar to their Model WM-5-24. Modifications in the sampler package were necessary to meet the head conditions at each location. For those overflow conduits that are more than 6m (20 ft) underground, the sampler pump is installed in a JIC waterproof box within 3m (10 ft) of the minimum overflow level. The pump pushes the sample to an above-ground location where the sample bottles are stored in a refrigerator. A relay which accepts the 4-20 ma signal from the flowmeter probe at each outfall is used to start the sampler automatically when the signal increases to approximately 4.2 ma. This is intended to coordinate the starting of the sampler with the first measurable amount of overflow. Samples are collected at 15 minute intervals unless the pumping distance is such that suction and purge times of greater than 15 minutes are necessary.

RECAPITULATION

In fairness to present day equipment, it must be pointed out that some of the above cited complaints stem from equipment designs of up to six years ago, and many commercial manufacturers, properly benefitting from field experience, have modified or otherwise improved their products' performance. The would-be purchaser of commercial automatic samplers today, however, should keep in mind the design deficiencies that led to the foregoing complaints when selecting a particular unit for his application.

Although not in the storm and combined sewer area, the field experience of the EPA Region VII Surveillance and Analysis Division recently reported (8) must be mentioned. Their experience, involving over 90,000 hours use of some 50 commercial automatic liquid samplers of 15 makes and models, has indicated that the mean sampler failure rate is approximately 16 percent with a range of 4 percent to 40 percent among types. They have found that the ability of an experienced team to gather a complete 24-hour composite sample is approximately 80 percent. When one factors in the possibility of mistakes in installation, variations in personnel expertise, excessive changes in lift, surcharging, and winter operation, it is small wonder that projects on which more than 50 or 60 percent of the desired data were successfully gathered using automatic samplers were, until recently, in the minority.

In their report (8) the writers summarize a long and extensive history of field experience with portable automatic liquid samplers, give operational problems encountered on a make and model basis, offer valuable tips on the installation and operation of sampling equipment, and present comparison data of different commercial units used on a side-by-side basis. They noted variations in data traceable to differences in equipment performance ranging (at best) from ±9 to 24 percent. In some instances differences in total suspended solids levels were over 300 percent. Such findings re-emphasize the need for careful equipment selection if flows high in suspended solids are to be sampled.

In recently completed controlled laboratory testing supported by the EPA (32), four different types of automatic samplers manufactured by four different companies were tested on a side-by-side basis with known flow parameters (particle density, size, and concentration and flow velocity and depth). As a typical example, in a flow mixture of water and a synthetic organic suspended solid (specific gravity = 1.06, grain size 10 mesh $\geq$ d $\geq$ 12 mesh) at a 300 ppm concentration and a velocity of 0.6 m/s (2 fps), analysis of samples taken by the commercial samplers indicated that sample representativeness varied from 25 percent low to over 400 percent high. Similar results were obtained at a concentration of 600 ppm, and the results are especially significant because these conditions should allow for "easy" sampling. With finer (120 mesh $\geq$ d $\geq$ 140 mesh), heavier (specific gravity = 2.65) suspended solids, the performance of commercial samplers was even poorer - the concentration generally being grossly understated.

The commercial sampler testing discussed above, although just scratching the surface, clearly points out the need for more controlled laboratory testing and for the development of performance specifications for automatic wastewater samplers as well as standard testing and acceptance procedures. Only then will we be able to speak authoritatively about the ability of an automatic sampler to characterize a wastewater stream in a pollutant mass discharge sense.

SECTION IX

STATE-OF-THE-ART ASSESSMENT

As can be noted from a review of the preceding sections, despite the plethora of automatic liquid sampling equipment that is available today, none is eminently suited for a storm and/or combined sewer application. An assessment of the current state-of-the-art from the technological viewpoint is in order to indicate where and how improvements can be made and to give design guides for the development of new automatic samplers. The material is arranged in subsections which deal with each of the basic sampler functions, and the emphasis is on technical considerations to assure satisfactory execution of each function. The functions are interrelated, however, and the designer must use a systems approach in his synthesis and analysis activities.

SAMPLER INTAKE ASSESSMENT

The sample intake of many commercially available automatic liquid samplers is often only the end of a plastic suction tube, and the user is left to his own ingenuity and devices if he desires to do anything other than simply dangle the tube in the stream to be sampled. In the following paragraphs we wish to examine the functions of a sampler intake that is intended to be used in a storm or combined sewer application and the design considerations that arise therefrom.

Pollutant Variability

A general discussion of the character of storm and combined sewage is given in section III where the variability of pollutant concentration is also treated. We wish to consider the latter factor here in somewhat more detail. Let us consider first some empirical data from (25). In the study, a special pressurized circulating loop was assembled containing a 25.4 cm (10 in.) square test section some 4.6m (15 ft) long. Careful measurements of the velocity contours were made and near uniformity was observed. From figure 23, which shows such velocity contours for a nominal 1.5 m/s (5 fps) velocity flow, it can be seen that the velocity 1.3 cm (0.5 in.) from the wall exceeds 1.4 m/s (4.5 fps) everywhere except near the corners. Since the variability of a pollutant will be a function of velocity variations (among other factors), it is of interest to note the horizontal and vertical variations of sediment distribution observed experimentally in this test section with its very small velocity variation.

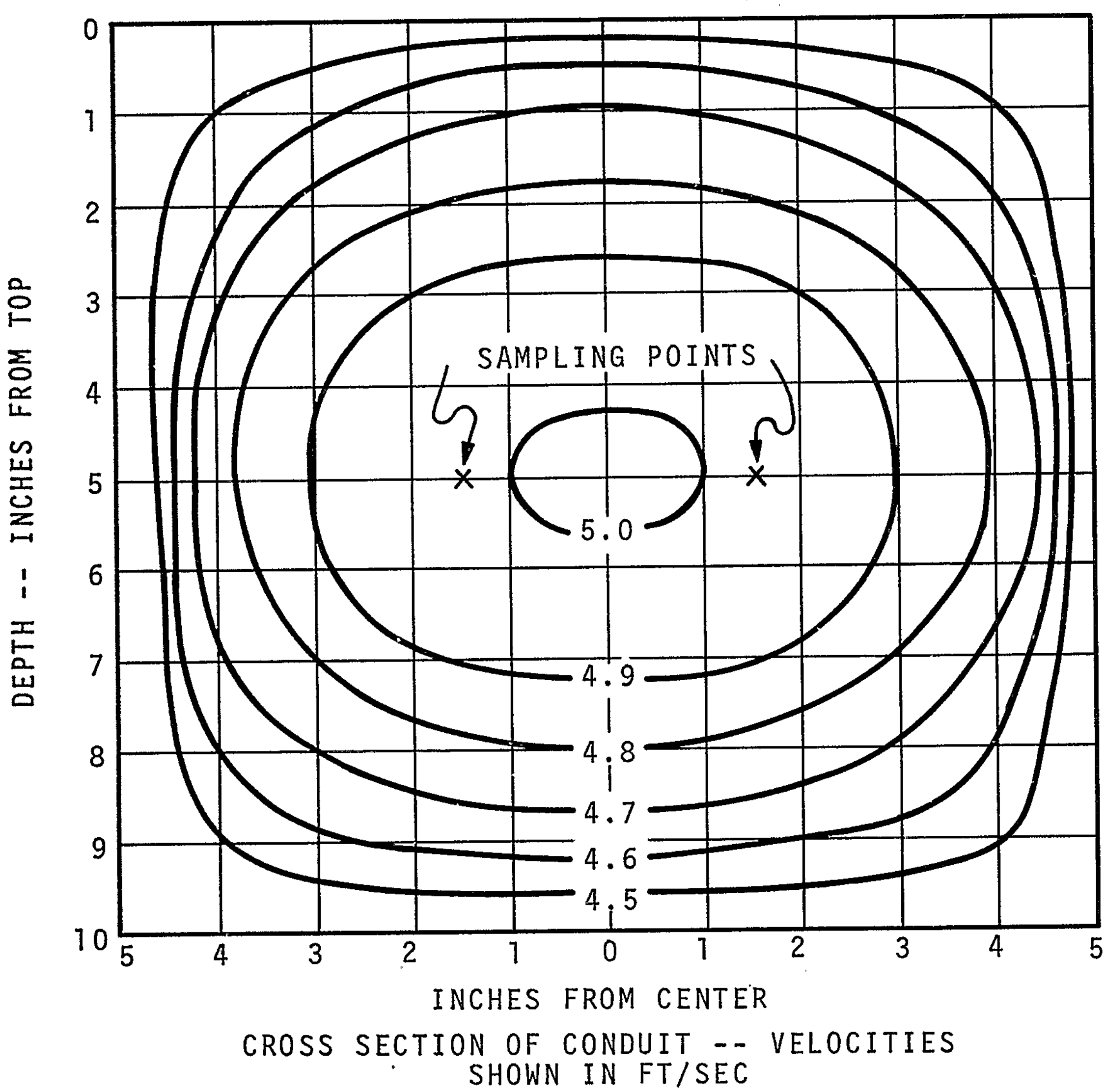


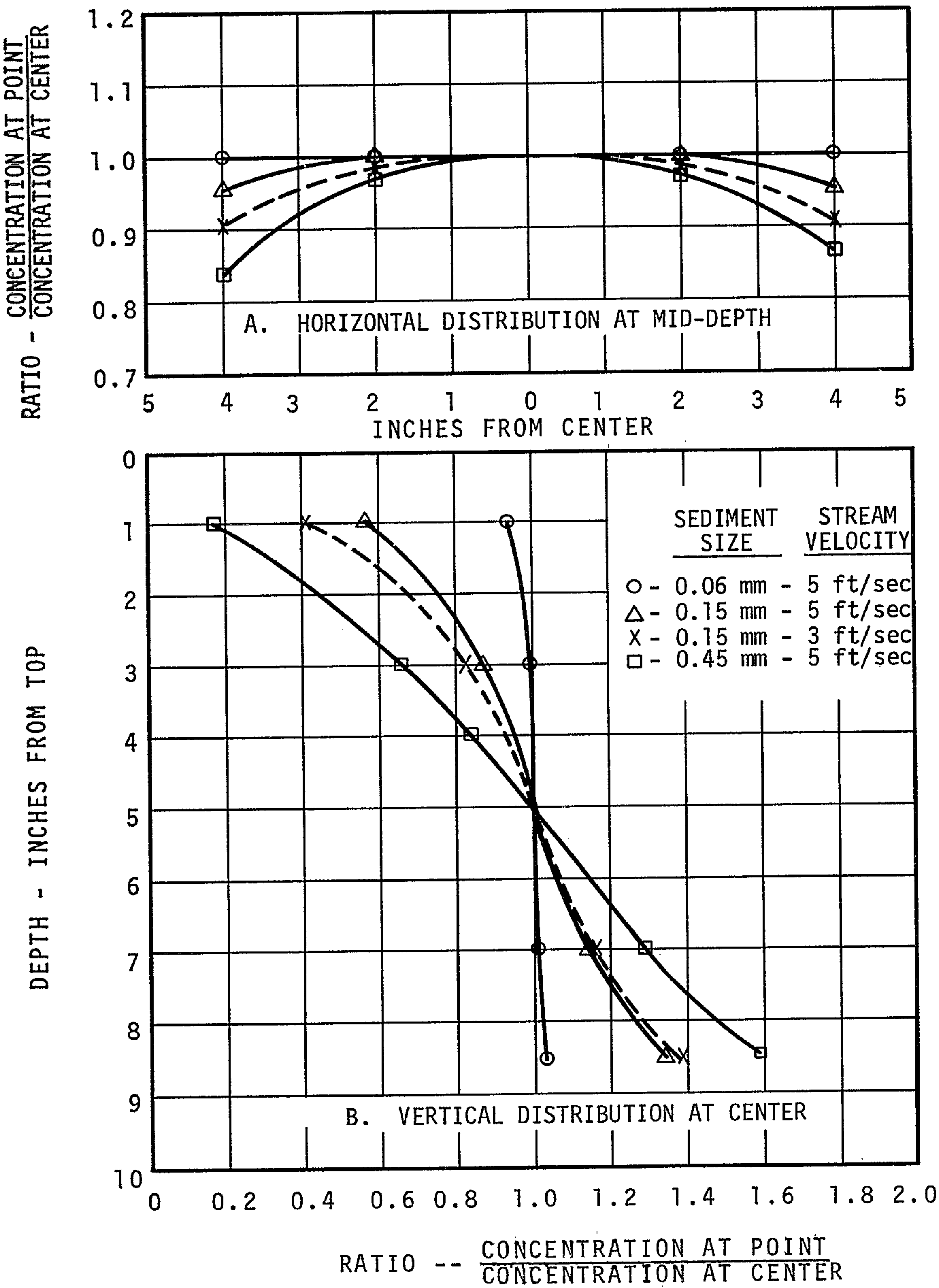
Figure 23. Velocity Contours at Sampling Station*

* Taken from reference 24.

Four readily available commercial sands, differing principally in size, were used in the study. They are referred to by mean particle size (50 percent finer by weight) as 0.45 mm, 0.15 mm, 0.06 mm and 0.01 mm. Observed sediment distribution for the three coarsest sands are indicated in figure 24. For all practical purposes the 0.01 mm sand was uniformly distributed. It should be noted here that the vertical variation is probably enhanced due to the design of the test loop, which would tend to enhance concentrations of heavier particles to the outside (the bottom of the test section in this case) due to the action of centrifugal forces. Observations made in (7) indicate this effect rather effectively. In their test set-up a 2.4m (8 ft.) wide flume was narrowed to a 46 cm (18 in.) test section by placing an insert in the flume bed along the wall opposite to that from which samples were to be extracted. Although the reduction in width occurred some 11m (36 ft.) upstream of the sampler inlet, for the 0.45 mm sand used in the investigation, concentrations at 2.5 cm (1 in.) from the wall were found to be two to four times greater than at 7.6 cm (3 in.) from the wall. Similar but less pronounced horizontal concentration gradients were observed for the finer sands as well.

The observation was made in (7) that, in addition to variations in sediment concentration within the cross-section at a given time, the sediment concentration at any point in the cross-section was highly variable with respect to time, especially for the coarser sediments (0.45 mm). This observation was also made in (24) where data are presented on concentration variation with respect to time as a function of sampling interval. The concentration of successive 20-second samples was found to vary over a range of 37 percent of the mean, and the concentration of successive 60-second samples varied over a range of 10.5 percent. Such variations arise from the natural turbulence of the flow as would be encountered in an actual sewer and from the non-uniform nature of re-circulated flows in test loops which is peculiar to such laboratory simulations.

So far we have focused our attention on relatively heavy (specific gravity approximately 2.65) solids and their distribution in a flow. For the lighter organic solids with specific gravities near unity, the particle distribution will be more nearly uniform in a turbulent flow. It would appear that one can expect a reasonable degree of uniformity in the distribution of particles which fall in the Stokes' Law range of settling velocities, i.e., for values of the external Reynolds' number less than unity. If one describes



* Taken from reference 24.

Figure 24. Sediment Distribution at Sampling Station*

a particle in terms of its hydraulic size W, defined as the velocity of uniform fall in a fluid at rest, Stokes' Law can be written as

$$W = gd^2 (s.g.-1)/18\nu \qquad (1)$$

where d is mean particle diameter, s.g. is the specific gravity of the particle material, ν is the kinematic viscosity of the fluid, and g is the acceleration of gravity. The external Reynolds' number (so called because the linear dimension upon which it is based is a particle dimension rather than a flow dimension) can be expressed as

$$Re = Wd/\nu \qquad (2)$$

Combining equations (1) and (2) we can express the range of validity of Stokes' Law as

$$Re = gd^3 (s.g.-1)/18\nu^2 < 1 \qquad (3)$$

If one considers water at 15.6°C (60°F) as the fluid (ν=1.217 x10^{-5} ft^2/sec), a plot of equation (3) over the range of interest is given in figure 25. Here it can be noted that, within the range of Stokes' Law, the maximum particle diameter for sand with a specific gravity of 2.65 is less than 0.1 mm while for organic particles with a specific gravity of 1.05 it is about 0.3 mm.

Since the kinematic viscosity of water is temperature dependent, the Stokes' Law particle diameter limit will also be a function of temperature. A typical plot of this variation is given in figure 26 for sand with a specific gravity of 2.65 and Re=1. Here it can be noted that a decrease in water temperature from the upper eighties to the mid-forties results in a 50 percent increase in the maximum particle diameter.

Sampler Intake Functions

The operational function of a sampler intake is to reliably allow gathering a representative sample from the flow stream in question. Its reliability is measured in terms of freedom from plugging or clogging to the degree that sampler operation is affected and invulnerability to physical damage due to large objects in the flow. It is also desirable, from the viewpoint of sewer operation, that the sampler intake offer a minimum obstruction to the flow in order to help prevent blockage of the entire sewer pipe by lodged debris, etc.

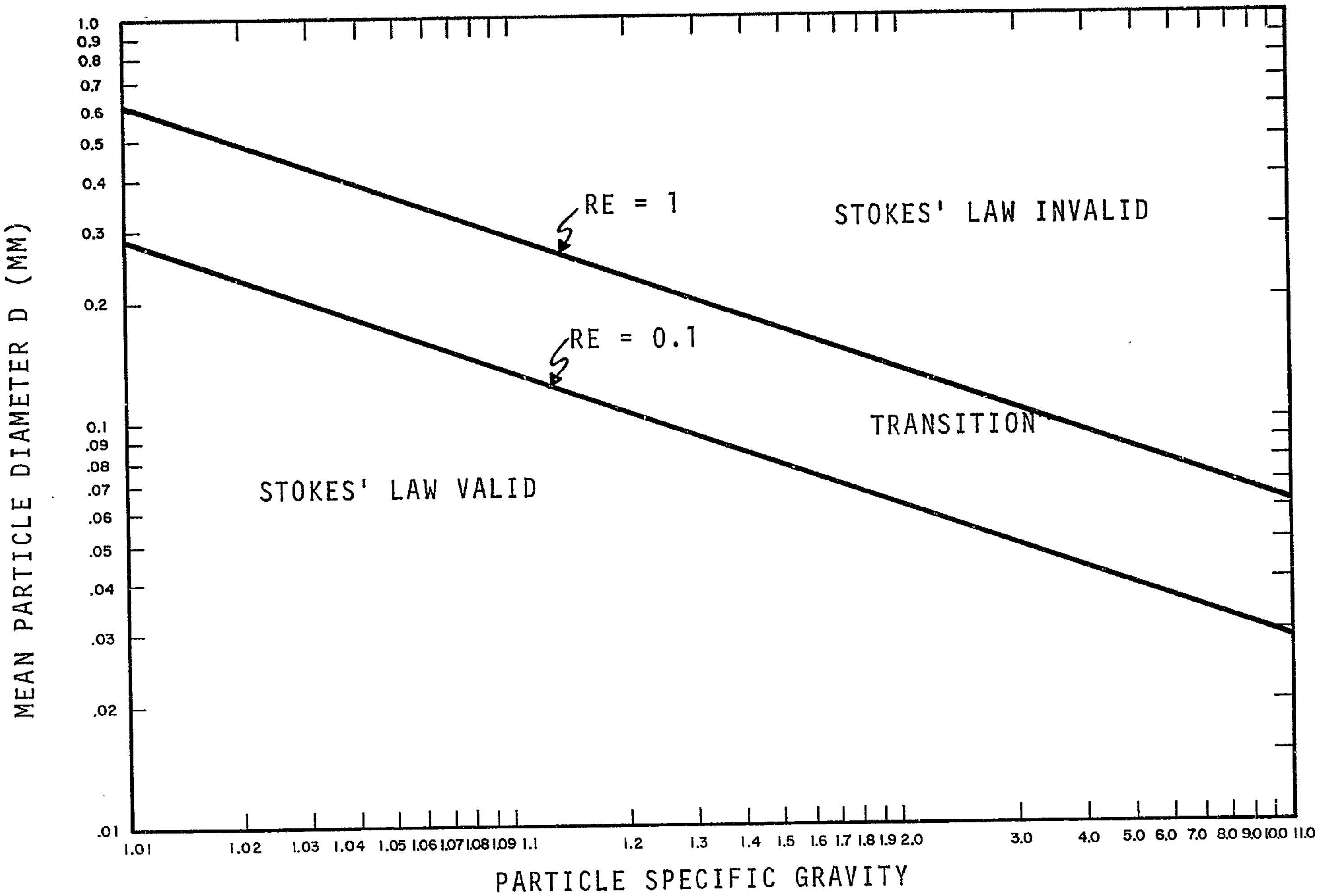


Figure 25. Region of Validity of Stokes' Law

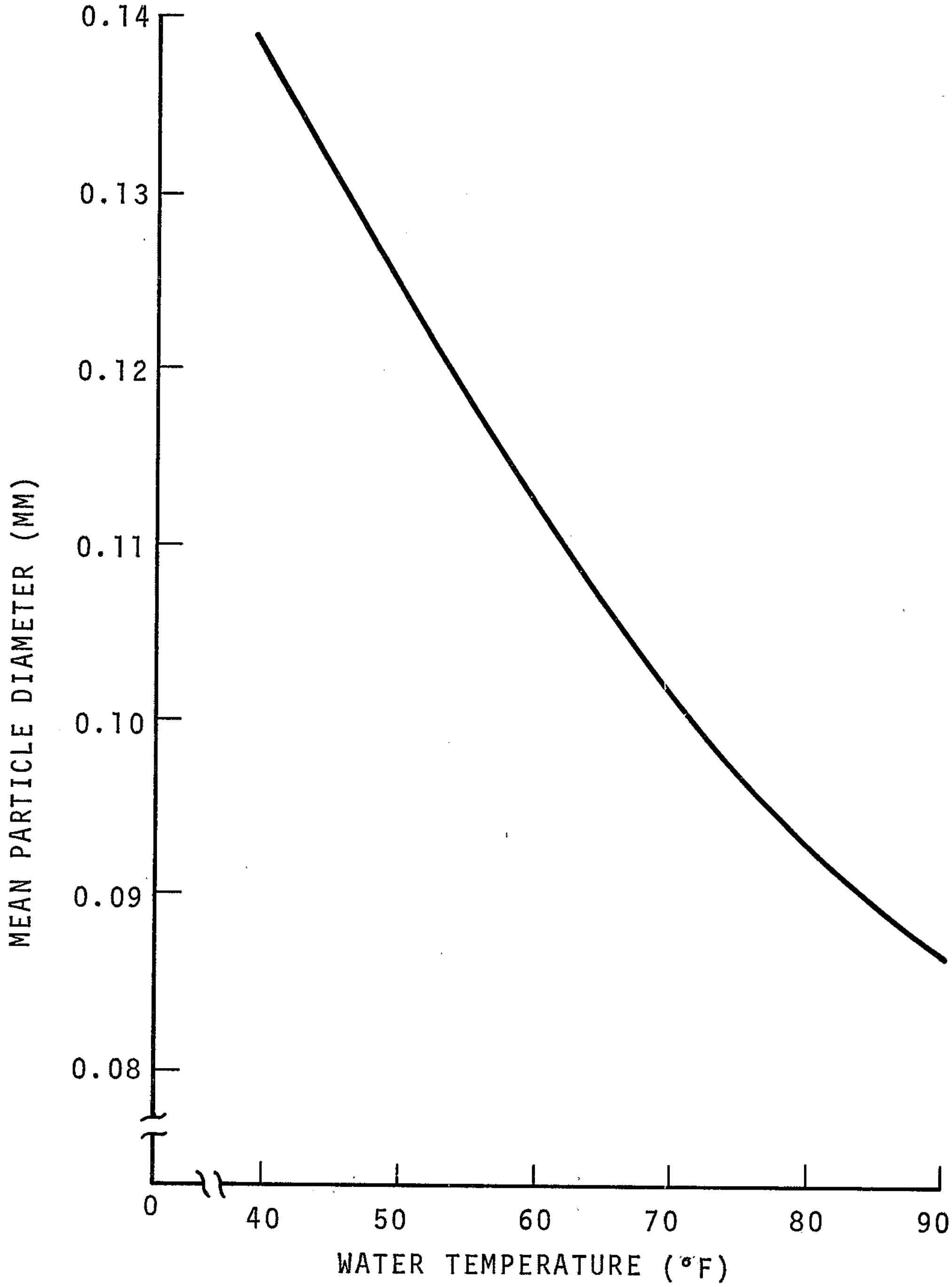
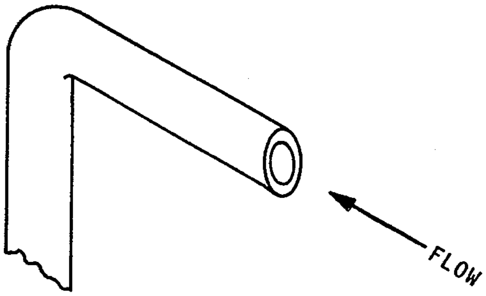


Figure 26. Effect of Temperature on Maximum Particle Size (Re=1)

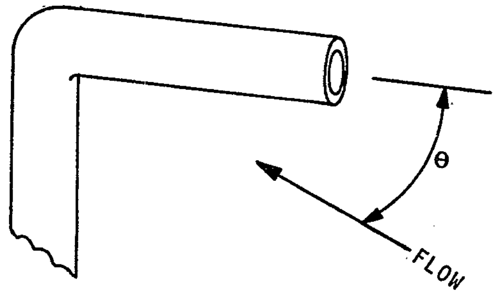
Let us first consider the ability of the intake to gather a representative sample of dense suspended solids in the sediment range, say up to 0.5 mm with specific gravity of 2.65. The results of a rather thorough examination of relatively small diameter intake probes, 0.63 and 0.32 cm (1/4 and 1/8 in.) I.D., are given in (25). The argument is developed that, for a nozzle pointing directly upstream into the flow (figure 27a), the most representative sample of a fluid/suspended-solids mixture will be obtained when the sampling velocity is equal to the flow velocity at the sampling point. Using this as the reference criteria, investigations were conducted to determine the effects of a) deviations from the normal sampling rate, b) deviations from the straight-into-flow position of the probe, c) deviations in size and shape of the probe, and d) disturbance of sample by nozzle appurtenances. The effect of the sampling velocity on the representativeness of the sample is indicated in figure 28 which presents the results for 0.45 mm and 0.06 mm sand. For the latter size, which falls within the Stokes' Law range, less than ±4 percent error in concentration was observed over sampling velocities ranging from 0.4 to 4 times the stream velocity. For the 0.45 mm particles, the error at a relative sampling rate of 0.4 was +45 percent, and at a relative sampling rate of 4 the error was -25 percent.

For probe orientations up to 20° to either side of head-on (figure 27b), no appreciable errors in concentration were observed. Similarly, introduction of 0.381 and 0.952 cm (0.150- and 0.375-in.) probes showed comparatively little effect on the representativeness of the sample. The probe inlet geometry, i.e., beveled inside, beveled outside, or rounded edge, also showed little effect on the representativeness of the sample, when compared to the standard probe. Finally, in instances where a sampler body or other appurtenance exists, the probe should be extended a short distance upstream if a representative sample is to be collected. In summary, it was found that for any sampler intake facing into the stream, the relative sampling rate is the primary factor to be controlled.

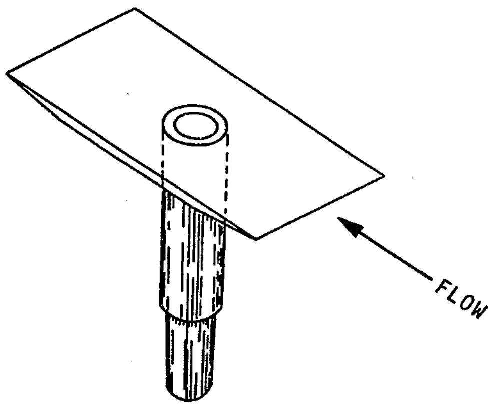
Tests were also run with the sampling intake probes in the vertical position (figure 27c) to determine the effect such an orientation had upon the representativeness of the sample. With such intakes, the sample entering them must undergo a 90° change of direction, and consequently there is a tendency for segregation and loss of sediment to take place. Tests were run with the standard probe, a 0.63 cm (1/4 in.) diameter orifice in the center of a 2.5 x 5 cm (1 x 2 in.) plate oriented so that its longest dimension was in the direction of flow, and with an orifice in a crowned (mushroom shaped)



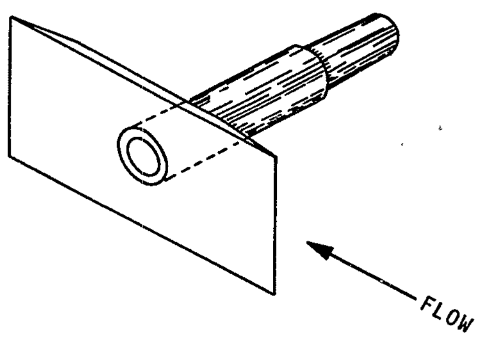
27a. Normal Orientation Directly Into Flow



27b. Orientation at an Angle to Head-on



27c. Vertical Orientation (0°) - Orifice in Flat Plate



27d. Horizontal Orientation (90°) - Orifice in Flat Plate

Figure 27. Sampler Intake Orientations Tested

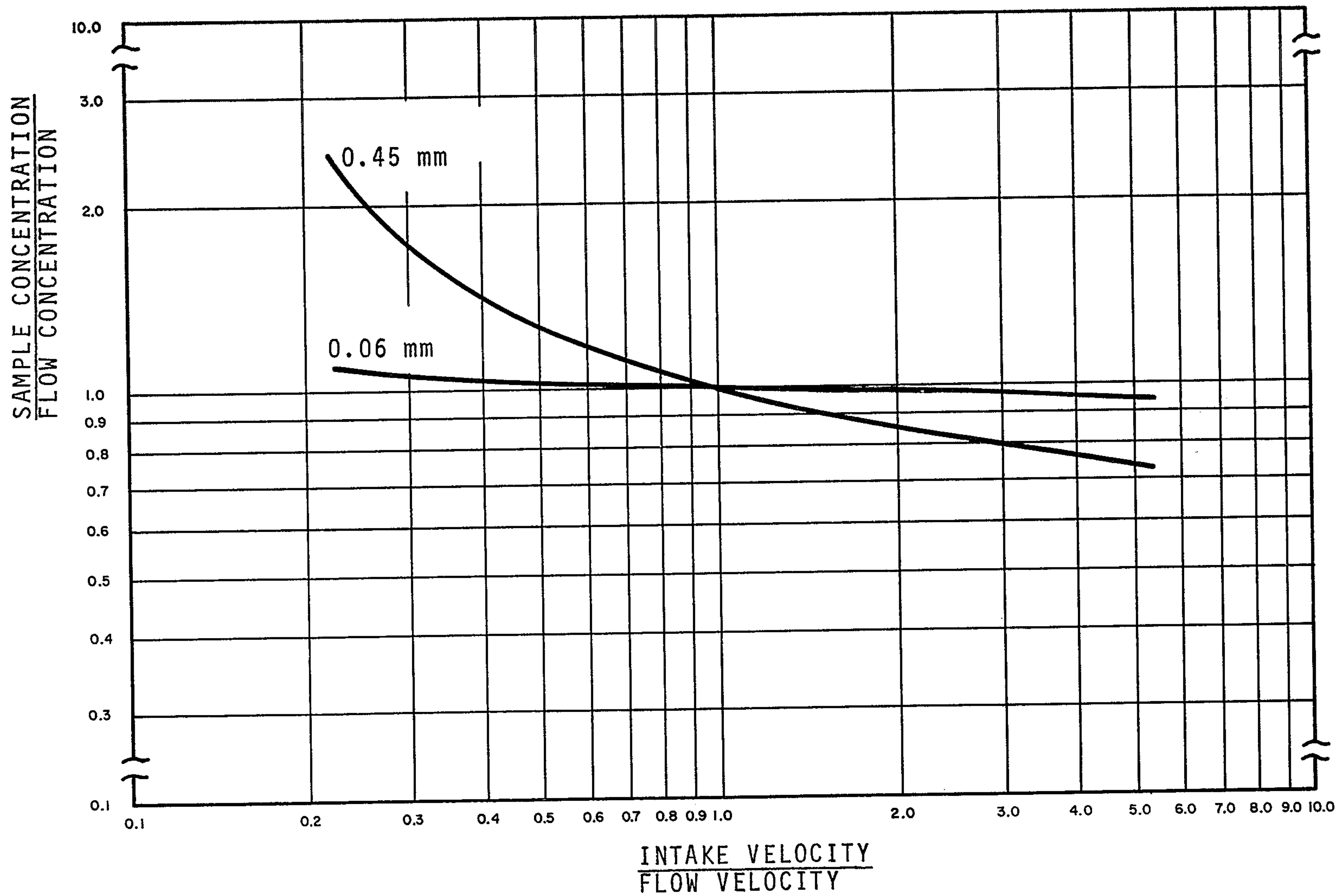


Figure 28. Effect of Sampling Velocity on Representativeness of Suspended Solids*

* Data from reference 24.

flat plate 3.2 x 5 cm (1.25 x 2 in.). The results all showed negative errors in concentration, increasing with particle size and increasing with intake velocities less than the stream rate but nearly constant for intake velocities higher than the stream rate.

Since the smallest errors were found for the orifices in the flat and mushroom shaped plates (whose performances were nearly identical for intake velocities greater than one-half the stream velocity), it was decided to investigate the effect of lateral orientation, i.e., to rotate the plate 90° so that it might represent an orifice in the side of a conduit rather than in the bottom (figure 27d). The results for 0.15 mm sand are presented in figure 29. It can be noted that while the side orientation caused greater errors (as was to be expected), these errors approached the nearly constant error of the 0° orientation (figure 27c) as the relative sampling rate was increased above unity.

The work reported in (7) was a laboratory investigation of pumping sampler intakes. Nine basic intake configurations, all representing an orifice of some type in the side wall of the flume, were examined. They included 1.3, 1.9, 2.5, and 3.8 cm (0.5, 0.75, 1.0, and 1.5 in.) diameter holes with square edges, 1.9 cm (0.75 in.) diameter holes with 0.32 and 0.63 cm (0.125 and 0.25 in.) radii, 1.3 x 2.5 cm (0.5 x 1 in.) ovals, one oriented vertically and the other horizontally, and a 1.9 cm (0.75 in.) diameter hole with a 5 cm (2 in.) wide shelf just under it. Sand sizes of 0.10 mm and 0.45 mm were used in the study.

Reference samples were taken with a probe located near the wall and pointing into the direction of the flow. The reference sample intake velocity was equal to the stream velocity. The primary measurement was sampling efficiency, the ratio of the sediment concentration in the test sample to that of the reference sample computed for a point 1.3 cm (1/2 in.) from the wall. The reference sample was taken just before and just after the test sample was gathered. Although the data exhibited considerable scatter, several conclusions were drawn. With regard to the intake velocity, greater than 0.9 m/s (3 fps) is generally desirable and, for sands coarser than 0.2 mm, an intake velocity equal to or greater than the stream velocity is desirable. With regard to intake configuration, for intake velocities greater than about 0.9 m/s (3 fps), the sampling efficiencies showed little effect of size of intake (range of 1.3 to 3.8 cm diameter), of rounding the intake edges, or of shape and orientation of the axis of the oval intake. Sampling efficiency was found to decrease with increasing particle size above 0.10 mm for all intakes tested. Finally,

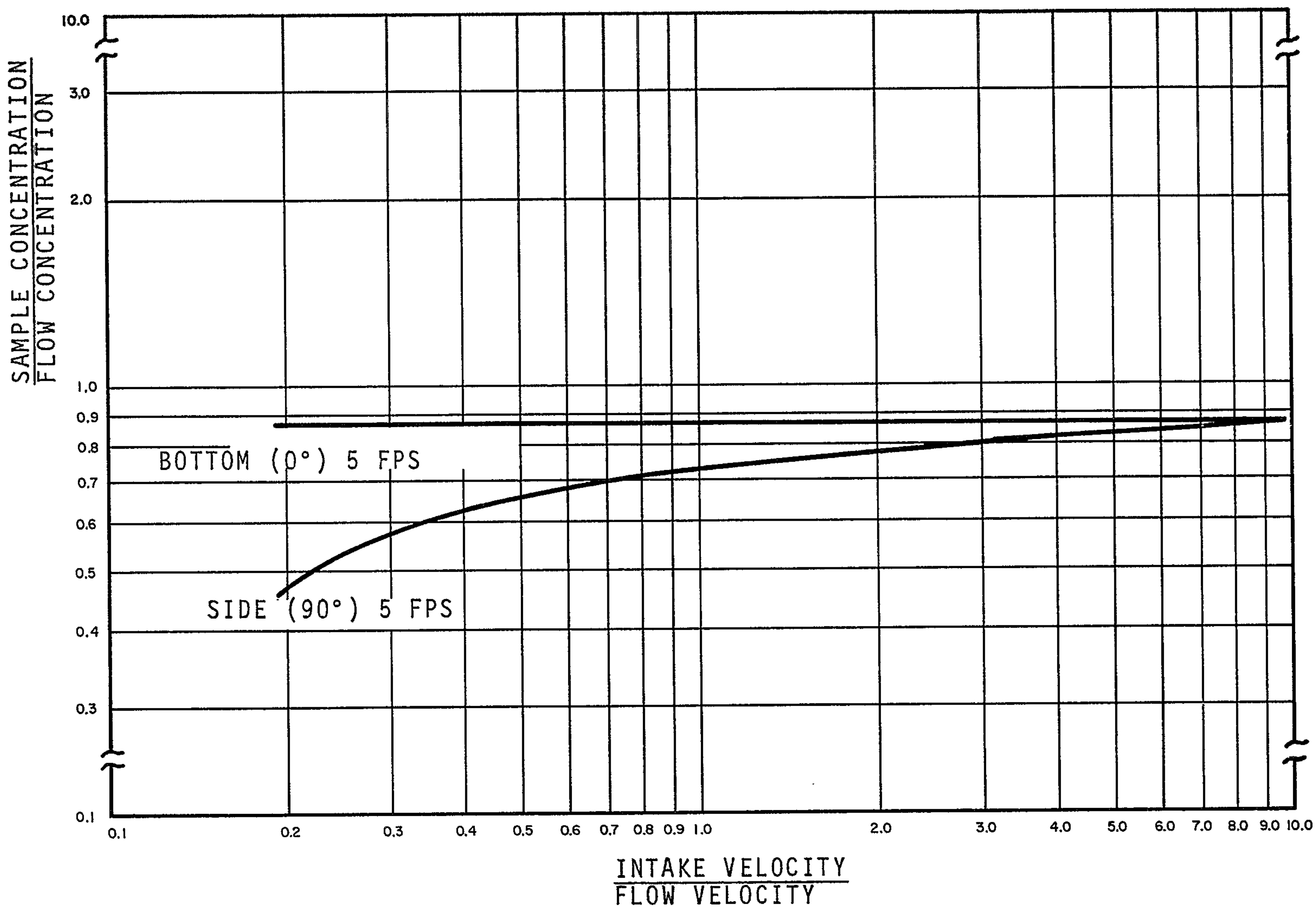


Figure 29. Effect of Lateral Orientation of Sample Intake*

* Data taken from reference 25.

although the shelf intake showed somewhat higher sampling efficiency for coarse particles and high stream rates, its performance was very erratic over the entire range of test parameters.

Similar observations were made in field tests with river water samples at St. Paul and Dunning, Nebraska, reported in (26). In addition to the "standard" intake which was a flush mounted 2.5 cm (1 in.) pipe coupling, alternate intakes included 2.5 x 5 cm (1 x 2 in.) and 2.5 x 23 cm (1 x 9 in.) nipples; 2.5 x 23 cm (1 x 9 in.) nipple with a 0.32 cm (1/8 in.) thick steel plate 36 cm (14 in.) high and 43 cm (17 in.) wide at its end; and a 2.5 cm (1 in.) street elbow with a 2.5 x 5 cm (1 x 2 in.) nipple oriented down, into the flow and up. It was concluded that the standard intake was as good as any in terms of sampling efficiency and was therefore preferable since it offered no obstruction to the flow and was therefore less vulnerable to damage by debris. The sediment being sampled was rather fine; in high flows 88 percent was finer than 0.062 mm and 100 percent was finer than 0.50 mm.

To summarize the foregoing as it relates to the sampler intake function of gathering a representative sample we note the following:

1) It becomes difficult to obtain a one-to-one representation, especially for inlets at 90° to the flow, for large, heavy suspended solids.

2) For particles that fall within the Stokes' Law range, consistent, representative samples can be obtained.

3) The geometry of the sampler intake has little effect on the representativeness of the sample.

4) The sample intake velocity should equal or exceed the velocity of the stream being sampled.

Sampler Intake Design

The foregoing suggest certain directions that the design of a sampler intake for storm and combined sewer flows should take. At the outset, it appears unwise to attempt to sample suspended solids that fall much outside the Stokes' Law range. A realistic maximum size for sand with specific gravity of 2.65 would appear to be around 0.1 mm to 0.2 mm.

High sample intake velocities will be required, perhaps in excess of 3 m/s (10 fps), if the sample is to be representative. Although the flow may be nearly homogeneous, except for very coarse solids and large floatables, more than one sample intake is desirable for reliability of operation as well as insurance against some unforeseen gradient in the pollutant. In view of the changing water levels in the conduit with changing flows, the changing velocity gradients within the flows, and the possibility of changing pollutant gradients not only with respect to these but also with type of pollutant; not even a dynamically adaptive sampler intake can be designed to gather a sample that is completely representative in every respect at the same time.

In order to better illustrate this point, let us consider a round pipe of radius R containing a flow at depth d and an arbitrary vertical concentration gradient of some pollutant.

Locate the origin of a cartesian coordinate system at the invert with the y axis positive upwards. We now assume that the pollutant concentration gradient can be expressed as a polynomial in y, i.e.,

$$p = \sum_n a_n y^n \tag{4}$$

The expression for the amount of pollutant in an arbitrary cross-sectional zone (say between depths y_1 and y_2) is

$$P = \iint \sum_n a_n y^n dxdy = 2 \int_{y_1}^{y_2} \sum_n a_n y^n \sqrt{2yR-y^2}\, dy \tag{5}$$

If one sets $P=\sum_n P_n$ the first few terms are;

$$P_o = a_o\left\{\left[(y_2-R)\sqrt{2Ry_2-y_2^{\,2}} - (y_1-R)\sqrt{2Ry_1-y_1^{\,2}}\right] + R^2\left[\sin^{-1}(y_2/R-1) - \sin^{-1}(y_1/R-1)\right]\right\} \tag{6}$$

$$P_1 = 2a_1\left\{-\frac{1}{3}\left(2Ry_2-y_2^{\,2}\right)^{3/2} + \frac{1}{3}\left(2Ry_1-y_1^{\,2}\right)^{3/2} + \frac{RP_o}{2a_o}\right\} \tag{7}$$

$$P_2 = 2a_2\left\{y_2 - \frac{5}{12}R\left(2Ry_2 - y_2^{\,2}\right)^{3/2} - y_1 + \frac{5}{12}R\left(2Ry_1 - y_1^{\,2}\right)^{3/2} + \frac{5R^2P_o}{8a_o}\right\} \quad (8)$$

etc.

Using such a formulation one can obtain the values of y which divide the flow cross-section up into some number of zones each of which contains an equal amount of pollutant; let us designate them as $y_1, y_2, \ldots, y_m$. If one extracts a sample from the center of each zone, one can argue that its representativeness will be quite good, especially for large values of m. Unless the samples extracted from each zone are kept discrete, which would result in an inordinately large number of samples, the quantity of sample gathered from each inlet must be varied in accordance with the velocity gradient if the composite sample is to be representative in a mass transport sense. For a different concentration gradient p^1, one will obtain new values $y_1^{\,1}, y_2^{\,1}, \ldots, y_m^{\,1}$ and hence different port locations and different quantities of sample required even for the same flow depth.

In view of the over-riding design mandate that simplicity maximizes probability of success, it becomes immediately apparent that the equipment sophistication implied by the foregoing would doom the design to operational failure if such a course were to be attempted. In the absence of some consideration arising from the particular installation site, a regular distribution of sampling intakes across the flow, each operating at the same velocity, would appear to suffice. Since the intakes should be as non-invasive as possible in order to minimize the obstruction to the flow and hence the possibility of sewer line blockage, it seems desirable to locate them around the periphery of the conduit.

GATHERING METHOD ASSESSMENT

As was noted earlier, three basic sample gathering methods or categories were identified; mechanical, suction lift, and forced flow. Several different commercial samplers using each method are available today. The sample lift requirements of the particular site often play a determining role in the gathering method to be employed. Some mechanical units were specifically designed for lifts to 61m (200 ft.). The penalty that one must trade-off in selecting a mechanical gathering unit is principally the necessity for some obstruction to the flow, at least while the sample is being taken. The tendency for exposed mechanisms to foul, together with the added vulnerability of many moving parts, means that successful operation will require regular, periodic inspection, cleaning, and maintenance.

Forced flow from a submersible pump also necessarily results in an obstruction to the flow. Pump malfunction and clogging, especially in the smaller sizes often used in samplers, remains a distinct possibility and, because of their location in the flow stream itself, maintenance is more difficult to perform than on above-ground or easily removable units. Pneumatic ejection is employed by several manufacturers, the gas source being either a compressor or bottled refrigerant. The latter units must necessarily be of small scale to avoid an enormous appetite for the refrigerant. The advantages of explosion-proof construction and high lift capability must be weighed against low sample intake velocities and relatively small sample capacities.

Suction lift units must be designed to operate in the environment near the flow to be sampled or else their use is limited to a little over 9.1m (30 ft.) due to atmospheric pressure. The necessity to have a pump that is free from clogging has led some designers to use peristaltic tubing pumps. Most of these operate at such low flow rates, however, that the representativeness of suspended solids is questionable. Newer high-capacity peristaltic pumps are now available and should find application in larger automatic samplers. The ability of some of these pumps to operate equally well in either direction affords the capability to blow down lines and help remove blockages. Also, they offer no obstruction to the flow since the transport tubing need not be interrupted by the pump, and strings, rags, cigarette filters and the like are passed with ease. New, small capacity, progressive-capacity screw-type pumps may also find some service in samplers. With all suction lift devices a physical phenomenon must be borne in mind and accounted for if sample representativeness is to be maintained. When the pressure on a liquid (such as sewage) which contains dissolved gases is reduced, the gases will tend to pass out of solution. In so doing they will rise to the surface and entrain suspended solids in route. (In fact, this mechanism is used to treat water; even small units for aquariums are commercially available.) The result of this is that the surface layer of the liquid may be enhanced in suspended solids, and if this layer is a part of a small sample aliquot, the sample may not be at all representative. In the absence of other mitigating factors, the first flow of any suction lift sampler should therefore be returned to waste.

All in all, the suction lift gathering method appears to offer more advantages and flexibility than either of the others. The limitation on sample lift can be overcome by designing the pumping portion of the unit so that it can be separated from the rest of the sampler and thus positioned not more than 9.1m (30 ft.) above the flow to be sampled. For the majority of sites, however, even this will not be necessary.

SAMPLE TRANSPORT ASSESSMENT

The majority of the commercially available automatic samplers have fairly small line sizes in the sampling train. Such tubes, especially at 0.3 cm (1/8 in.) inside diameter and smaller, are very vulnerable to plugging, clogging due to the build-up of fats, etc. For application in a storm or combined sewer, a better minimum line size would be 0.95 to 1.3 cm (3/8 to 1/2 in.) inside diameter.

It is imperative that adequate sample flow rate be maintained throughout the sampling train in order to effectively transport the suspended solids. In horizontal runs the velocity must exceed the scour velocity, while in vertical runs the settling or fall velocity must be exceeded several times to assure adequate transport of solids in the flow.

The complexities inherent in the study of a two-phase mixture such as soil particles and water are such that rigorous analytical solutions have not yet been obtained except in certain limiting cases such as the work of Stokes cited earlier. The use of hydraulic size, which is the average rate of fall that a particle would finally attain if falling alone in quiescent distilled water of infinite extent, as a descriptor for a particle involves its volume, shape and density. It is presently considered to be the most significant measurement of particle size. However, there are no analytical relationships to allow its computation; recourse must be made to experiment. The geometric size of a particle can be based upon its projected lengths on a set of right cartesian coordinates oriented so that a is its major axis, b is its intermediate axis, and c is its minor axis. With patience and a microscope the lengths a, b, and c of a particle can be determined. Since the number of particle shapes is infinite, a system for classification is required. One put forth in (27) is the shape factor defined as:

$$SF = c/\sqrt{ab} \tag{9}$$

which approximately defines the shape in terms of three of a multitude of dimensions of an irregular particle. Of course there may be rounded, angular, smooth and rough particles all with the same shape factor.

An excellent discussion of the fundamentals of particle size analysis is given in (28). Table 5, which is taken from data presented therein, illustrates the effect of shape factor on hydraulic size for sand particles with specific gravity of 2.65 in water at 20°C. It can be noted that while a sphere with a nominal diameter of 0.2 mm will fall only about one-third faster than a similar sized particle with a shape factor of 0.3; a sphere with a nominal diameter of 4.0 mm falls over 2-1/2 times faster than a particle with SF=0.3. For curves showing temperature effects, correction tables, etc., the reader is referred to (28).

In the absence of better data, the hydraulic size of a particle can be computed from the following (29);

$$W^{3/2} = gd^{3/2}\,(s.g.-1)/11.2\sqrt{\nu} \quad \text{when } 1<Re<30,\ 0.1<d<0.6 \text{ mm} \tag{10}$$

$$W^{1.8} = gd^{1.2}\,(s.g.-1)/4.4\nu^{0.2} \quad \text{when } 30<Re<400,\ 0.6<d<2.0 \text{ mm} \tag{11}$$

$$W = 0.875\sqrt{gd(s.g.-1)} \quad \text{when } Re>400,\ d>2 \text{ mm} \tag{12}$$

Equation (10) is Prandtl's formula for a smooth channel, while equation (12) is the so-called square law.

The transport of solid particles by a fluid stream is an exceedingly complex phenomena and no complete theory which takes into account all of the parameters has yet been formulated. Empirical formulae exist, however, some of which have a fairly wide range of applicability. An expression for the lowest velocity at which solid particles heavier than water still do not settle out onto the bottom

TABLE 5. EFFECT OF SHAPE FACTOR ON HYDRAULIC SIZE (IN CM/SEC)*

Nominal Diameter (mm)	Shape Factors				
	0.3	0.5	0.7	0.9	Spheres
0.20	1.78	1.94	2.11	2.26	2.43
0.50	4.90	5.63	6.31	7.02	7.68
1.00	8.49	10.10	12.10	14.00	15.60
2.00	12.50	15.50	19.30	23.90	28.60
4.00	17.80	22.40	28.00	35.60	46.90

* Taken from reference 28.

of the pipe or channel has been developed by Knoroz (30) on the basis of numerous experiments carried out under his direction at the All-Union Scientific Research Institute for Hydraulic Engineering. It expresses the velocity in meters per second as

$$V = 3\left[\sqrt{gd}\ \lg \frac{R}{4d} + W\ p^{1/4} \left(\frac{R}{d}\right)^{0.4}\right] \tag{13}$$

where average values of d and W for the solids mixture are to be used; R is the hydraulic radius; and p is the consistency by weight of the mixture, i.e., in percent the expression for p is:

$$p = \frac{\gamma_m - \gamma}{\gamma_p - \gamma_m} \frac{\gamma_p}{\gamma} \tag{14}$$

where γ is the specific weight of the fluid, γ_p is the specific weight of the particles, and γ_m is the specific weight of the mixture. For a review of this and other Russian work on the flow of a two-phase mixture, see (29).

A somewhat simpler expression for the adequate self-cleaning velocity of sewers derived by Camp from experimental findings of Shields as given in (31) is:

$$V = \sqrt{6.4gd\ (s.g.-1)/f} = \frac{1.486}{n} R^{1/6} \sqrt{0.8d(s.g.-1)} \tag{15}$$

where f is the friction factor, n is Manning's roughness coefficient, and all other terms are as previously identified. Using equation (15), for example, it is seen that a velocity of 0.6 m/s (2 fps) is required to adequately transport a 0.09 mm particle with a specific gravity of 2.65 and a friction factor of 0.025. By comparison, the fall velocity of such a particle is around 0.06 m/s (0.2 fps).

In summary, the sampling train must be sized so that the smallest opening is large enough to give assurance that plugging or clogging is unlikely in view of the material being sampled. However it is not sufficient to simply make all lines large, which also reduces friction losses, without paying careful attention to the velocity of flow. For a storm or combined sewer application, minimum line sizes of 0.95 to 1.3 cm (3/8 to 1/2 in.) inside diameter and minimum velocities of 0.6 to 0.9 m/s (2 to 3 fps) would appear warranted.

SAMPLE CAPACITY AND PROTECTION ASSESSMENT

For storm and combined sewer applications, discrete sampling is generally desired. This allows characterization of the sewage throughout the time history of the storm event. If the samples are sufficiently large, manual compositing can be performed based on flow records or some other suitable weighting scheme. Although the quantity of sample required will be a function of the subsequent analyses that are to be performed, in general at least a liter, and preferably two, will be desired. An additional benefit arises because such relatively large samples are less vulnerable to errors arising from cross-contamination.

A brief look at the different types of composite samples is in order. Any scheme for collecting a composite sample is, in effect, a method for mechanically integrating to obtain average characteristics. Let us consider a given flow rate q(t) and pollutant concentration level k(t) where:

$$q \overset{d}{=} L^3T^{-1} \text{ and } k \overset{d}{=} ML^{-3} \tag{16}$$

The quantity of flow and pollutant are then:

$$Q = \int qdt \text{ and } P = \int qkdt \tag{17}$$

where:

$$Q \overset{d}{=} L^3 \text{ and } P \overset{d}{=} M \tag{18}$$

Let us consider first the simple composite, where a constant volume of fluid is added at evenly spaced time intervals. We will denote such a sample by T_cV_c, meaning time interval between successive aliquots constant and volume of aliquot constant. Let the time duration of the event in question be divided up into n elements and a subscript i be used to denote instantaneous values ($0<i\leq n$). Then the overall concentration of the simple composite sample will be:

$$K = \frac{P}{Q} = \frac{1}{n}\sum_{i=1}^{n} k_i \tag{19}$$

If one wishes a more representative sample, some type of proportioning must be used. This is equivalent to saying that equation (19) is a very poor scheme for numerical integration, and a higher order method is desirable. There are two fundamental approaches to obtaining better numerical integration given a fixed number of steps. One is to increase the order of the integration scheme to be used; as in going from the trapezoidal rule to Simpson's rule, for instance. The other is to vary the step size in such a way as to lengthen the steps when slopes are changing very slowly and shorten them when slopes change rapidly. Typical of the first approach are the constant time interval, variable volume ($T_c V_v$) proportional composites. There are two straightforward ways of accomplishing this. One is to let the aliquot volume be proportional to the instantaneous flow rate, i.e.:

$$v_i = Aq_i \tag{20}$$

and the other is to make the aliquot volume proportional to the quantity of flow that has passed since extraction of the last aliquot, i.e.:

$$v_i = B(Q_i - Q_{i-1}) = B\Delta Q_i \tag{21}$$

The respective concentrations of samples are

$$K_A = \frac{\sum_{i=1}^{n} q_i k_i}{\sum_{i=1}^{n} q_i} \text{ and } K_B = \frac{\sum_{i=1}^{n} \Delta Q_i k_i}{\sum_{i=1}^{n} \Delta Q_i} \tag{22}$$

Typical of the second approach is the variable time interval, constant volume ($T_v V_c$) proportional composite. Here a fixed volume aliquot is taken each time an arbitrary quantity of flow has passed (Q/n), i.e. the time is varied to give a constant ΔQ. The concentration will be:

$$K = \frac{1}{n}\sum_{i=1}^{n} k_i \tag{23}$$

It must be remembered that here the time steps are differing so that comparison of equations (23) and (19) has no meaning.

It is instructive to compare these four composite sample schemes with each other. For the purposes of this exercise let us arbitrarily set $n=10$ and normalize time so that $0 \le t \le 1$. We will examine four flow functions; $q=c$, $q=t$, $q=1-t$, and $q=\sin\pi t$. We will also examine five concentration functions; $k=1-t$, $k=1-t/2$, $k=\cos\pi t/2$, $k=e^{-t}$, and $k=\sin\pi t$.

These selections are completely arbitrary (except for simplicity in exact integration), and the curious reader may wish to examine more typical expressions. For a storm event, the combination $q=\sin\pi t$ and $k=e^{-t}$ allows for low volume, highly polluted flow initially, with pollutant concentration falling throughout the event. However the resemblence is qualitative only, and more refined expressions could be used. For each flow/concentration combination, the exact average concentration of the flow was computed (as though the entire flow stream were diverted into a large tank for the duration of the event and then its concentration measured). The ratio of the composite sample concentration to the actual concentration so computed is presented in matrix form in table 6. The four lines in each cell represent the four types of composite samples discussed as indicated in the legend. The best overall composite for the cases examined is the T_cV_v with the volume proportional to the instantaneous flow rate q. The T_cV_v, where the volume is proportional to the flow since the last sample, and the T_vV_c gave very similar results with a slight edge to the former. However, the differences are not large for any case. This brief look at compositing merely scratches the surface, but a more definitive treatment is outside the scope of the present effort. Suffice it to say here that both flow records and a knowledge of the temporal fluctuation of pollutants, as can be obtained from discrete samples, are required in order to choose a "best" compositing scheme for a given installation.

The sample container itself should either be easy to clean or disposable. The cost of cleaning and sterilizing makes disposable containers attractive, especially if bacteriological analyses are to be performed. Although some of today's better plastics are much lighter than glass and can be autoclaved, they are not so easy to clean or inspect for cleanliness. Also the plastics will tend to scratch more easily than glass and, consequently, cleaning a well-used container can become quite a chore. The food packaging industry, especially dairy products, offers a wide assortment of potential disposable sample containers in the larger sizes. Both the 1.91 (1/2 gal) paper and plastic milk cartons can be considered viable candidates, and their cost in quantity is in the pennys-each range.

The requirements for sample preservation were enumerated in section IV and will not be repeated here. It should be mentioned, however, that if the samples are allowed to become too cold, they may no longer be representative.

TABLE 6. RATIO OF COMPOSITE SAMPLE CONCENTRATION TO ACTUAL CONCENTRATION

q FLOW \ CONC k	$1-t$	$1-\frac{t}{2}$	$\cos\frac{\pi t}{2}$	e^{-t}	$\sin\pi t$
c	0.90 0.90 0.90 0.90	0.97 0.97 0.97 0.97	0.92 0.92 0.92 0.92	0.95 0.95 0.95 0.95	0.99 0.99 0.99 0.99
t	1.35 0.90 0.86 0.87	1.09 0.97 0.96 0.96	1.26 0.90 0.87 0.89	1.14 0.97 0.95 0.95	0.99 0.90 0.89 0.97
$1-t$	0.68 0.95 0.92 0.92	0.87 0.98 0.97 0.97	0.72 0.98 0.95 0.93	0.82 0.96 0.95 0.95	0.99 1.12 1.09 0.97
$\sin\pi t$	0.90 1.01 0.90 0.90	0.97 1.00 0.97 0.97	0.88 1.00 0.92 0.92	0.97 1.00 0.95 0.95	0.80 1.01 0.98 0.97

Line 1. $T_c V_c$ - Simple composite

Line 2. $T_c V_v$ - Volume proportional to flow rate (q)

Line 3. $T_c V_v$ - Volume proportional to flow (Q) since last sample

Line 4. $T_v V_c$ - Time varied to give constant ΔQ

For example destruction of the organisms necessary for the development of BOD may occur or freezing may cause serious changes in the concentration of suspended solids. Light can also affect samples and either a dark storage area or opaque containers would seem desirable. Unless disposable containers are used, however, it will be difficult to inspect an opaque container for cleanliness. Again the paper milk carton is attractive since not only is it relatively opaque, but its top opens completely allowing visual inspection of its contents.

CONTROLS AND POWER ASSESSMENT

The control aspects of some commercial automatic samplers have come under particular criticism as typified by comments in section VIII. It is no simple matter, however, to provide great flexibility in operation of a unit while at the same time avoiding all complexities in its control system. The problem is not only one of component selection but packaging as well. For instance, even though the possibility of immersion may be extremely remote in a particular installation, the corrosive highly-humid atmosphere which will, in all liklihood, be present makes sealing of control elements and electronics desirable in most instances.

The automatic sampler for storm and combined sewer application will, in all liklihood, be used in an intermittent mode; i.e. it will be idle for some period of time and activated to capture a particular meteorological event. If field experience to date is any indication, the greatest need for an improved control element is for an automatic starter. While the sensor is not a part of the sampler proper, its proper function is essential to successful sampler utilization. Although remote rain gages, etc. can be used for sensing elements, one of the most attractive techniques would be to use the liquid height (or its rate of increase) to start a sampling cycle. This will avoid the difficulties associated with different run-off times due to local conditions such as dryness of ground, etc.

One of the attributes essential to the control system of an automatic sampler to be used in a storm and/or combined sewer application is that it be able to withstand power outages and continue its program. Such power interruptions appear to be increasingly common as demand for electricity continues to grow. Although desirable in some instances, the provision of a random interrogate signal to be coupled with a sequence sample mode generates programming problems, especially when coupled with power interrupt possibilities.

Reliability of the control system can dominate the total system reliability. At the same time, this element will, in all liklihood, be the most difficult to repair and calibrate. Furthermore, environmental effects will be the most pronounced in the control system. The power switching function of the control system may be required to deal with multiple switching of inductive loads and must achieve the switching of these loads without the typical damage associated with transfer of energy interruptions.

The above tasks can probably be best executed, in the light of the current electronics state-of-the-art, by a solid state controller element. In addition to higher inherent reliability, such an approach will allow switching of high level loads in a manner that eliminates RFI emissions and destructive results. In addition, the unit should be of modular construction for ease of modification, performance monitoring, fault location, and replacement/repair. Such an approach also lends itself to encapsulation which will minimize environmental effects. Solid state switching eliminates the possibility of burned or welded contacts either of which will cause complete sampler breakdown.

Solid state controllers can be easily designed with sufficient flexibility to accept start commands from a variety of types of remote sensors, telephone circuits, etc.

Low operational current requirements would allow a solid state controller to continue to operate from a battery source during a local power outage. This capability would avoid logic interrupts and attendent loss of data and allow the sampler operation to be restored immediately upon the return of power service.

The foregoing discussion as it relates to problems associated with interruptions in electrical service is of course directed to samplers that rely upon outside power for some aspect of their operation. The need for high sample intake and transport velocities, larger sample lines and capacities, together with the possible requirement for mechanical refrigeration make it unlikely that such a sampler can be totally battery operated today. Although recent break-throughs have resulted in 1 kw dry cell batteries, their cost is prohibitive for this sort of an application. Other approaches to self-contained power such as custom designed wet cell packs, diesel generators, etc., while within the current state-of-the-art, introduce other problems and complexities that must be carefully weighed before serious consideration can be given to their incorporation in an automatic sampler design.

SECTION X

REFERENCES

1. Inter-Agency Committee on Water Resources Report No. 1, "Field Practice and Equipment Used in Sampling Suspended Sediment" (1940).

2. American Public Works Association - Research Foundation, "Water Pollution Aspects of Urban Runoff," Federal Water Pollution Control Administration, WPCR Series WP-20-15.

3. Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill, New York (1959).

4. Methods Development and Quality Assurance Research Laboratory, Methods for Chemical Analysis of Water and Waste, Environmental Protection Agency Technology Transfer Publication (1974).

5. Field, Richard and Struzeski, E. J., Jr., "Management and Control of Combined Sewer Overflows," Journal Water Pollution Control Federation, Vol. 44, No. 7 (1972).

6. American Society of Civil Engineers Task Committee on Sedimentation Research Needs Related to Water Quality, "Influences of Sedimentation on Water Quality: An Inventory of Research Needs, " Vol. 97, No. HY8 (1971).

7. Inter-Agency Water Resources Council Report No. T, "Laboratory Investigation of Pumping Sampler Intakes" (1966).

8. Harris, D. J. and Keffer, W. J., "Wastewater Sampling Methodologies and Flow Measurement Techniques" Environmental Protection Agency Report EPA 907/9-74-005 (1974).

9. "Strainer/Filter Treatment of Combined Sewer Overflows;" Fram Corporation; EPA Water Pollution Control Research Series Report No. WP-20-16:7/69.

10. "Stream Pollution Abatement from Combined Sewer Overflows;" Burgess and Niple, Ltd.; EPA Water Pollution Control Research Series Report No. DAST-32:11/69.

11. "Control of Pollution by Underwater Storage;" Underwater Storage, Inc.; EPA Water Pollution Control Research Series Report No. DAST-29:12/69.

12. "Engineering Investigation of Sewer Overflow Problems;" Hays, Seay, Mattern, and Mattern; EPA Water Pollution Control Research Series Report No. 11024 DMA 05/70.

13. "Microstraining and Disinfection of Combined Sewer Overflows;" Cochrane Division of the Crane Company; EPA Water Pollution Control Research Series Report No. 11023 EVO 06/70.

14. "Microstraining and Disinfection of Combined Sewer Overflows - Phase II; "Environmental Systems Division of the Crane Company; EPA Environmental Protection Technology Series Report No. EPA-R2-73-124, January, 1973.

15. "Storm Water Pollution from Urban Land Activity;" AVCO Corporation; EPA Water Pollution Control Research Series Report No. 11034 FKL 07/70.

16. "Retention Basin Control of Combined Sewer Overflows;" Springfield Sanitary District; EPA Water Pollution Control Research Series Report No. 11023 --- 08/70.

17. "Chemical Treatment of Combined Sewer Overflows;" The Dow Chemical Company; EPA Water Pollution Control Research Series Report No. 11023 FDB 09/70.

18. "Combined Sewer Temporary Underwater Storage Facility;" Melpar Company; EPA Water Pollution Control Research Series Report No. 11022 DPP 10/70.

19. "Urban Runoff Characteristics;" University of Cincinnati; EPA Water Pollution Control Research Series Report No. DQU 10/70.

20. "In-Sewer Fixed Screening of Combined Sewer Overflows;" Envirogenics Company, A Division of Aerojet General; EPA Water Pollution Control Research Series Report No. 11024 FKJ 10/70.

21. "Storm and Combined Sewer Pollution Sources and Abatement;" Black, Crow, and Eidsness, Inc.; EPA Water Pollution Control Research Series Report No. 11024 ELB 01/71.

22. "Storm Water Problems and Control in Sanitary Sewers;" Metcalf and Eddy, Inc.; EPA Water Pollution Control Research Series Report No. 11024 EQG 03/71.

23. "Underwater Storage of Combined Sewer Overflows;" Karl R. Rohrer Associates, Inc.; EPA Water Pollution Control Research Series Report No. 11022 ECV 09/71.

24. "Maximizing Storage in Combined Sewer Systems;" Municipality of Metropolitan Seattle; EPA Water Pollution Control Research Series Report No. 11022 ELK 12/71.

25. Inter-Agency Committee on Water Resources Report No. 5, "Laboratory Investigation of Suspended Sediment Samplers" (1941).

26. Inter-Agency Water Resources Council Report No. Q, "Investigation of a Pumping Sampler With Alternate Suspended Sediment Handling Systems" (1962).

27. Schulz, E. F., Wilde, R. H. and Albertson, M. L., "Influence of Shape on the Fall Velocity of Sedimentation Particles," Missouri River Division Sedimentation Series Report No. 5, U.S. Army Corps of Engineers, Omaha, Nebraska (1954).

28. Inter-Agency Committee on Water Resources Report No. 12, "Some Fundamentals of Particle Size Analysis" (1957).

29. Mkhitaryan, A. M., Gidravlika i Osnovy Gazodinamiki, Gosudarstvennoe Izdatel'stvo Tekhnicheskoi Literatury UkrSSR, Kiev (1959).

30. Knorz, V. S., "Beznapornyi gidrotransport i ego raschet," Izvestiya Vsesoyuznogo Naucho-Issledovatel'skogo Instituta Gidravliki, Vol. 44 (1951).

31. Water Pollution Control Federation Manual of Practice No. 9, Design and Construction of Sanitary and Storm Sewers (1970).

32. Shelley, P. E., "Design and Testing of a Prototype Automatic Sewer Sampling System", EPA Environmental Protection Technology Series Report No. EPA-670/2-75-XXX (in press).

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/2-75-065

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS - 1975

5. REPORT DATE
December 1975 (Issuing Date)

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Philip E. Shelley and George A. Kirkpatrick

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
EG&G Washington Analytical Services Center, Inc.
2150 Fields Road
Rockville, Maryland 20850

10. PROGRAM ELEMENT NO.
1BB034; ROAP 21 ASY; Task 039

11. CONTRACT/GRANT NO.
68-03-0409

12. SPONSORING AGENCY NAME AND ADDRESS
Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE
EPA-ORD

15. SUPPLEMENTARY NOTES
Supersedes Report No. EPA-R2-73-261, "An Assessment of Automatic Sewer Flow Samplers", June 1973.

16. ABSTRACT

A brief review of the characteristics of storm and combined sewer flows is given followed by a general discussion of the purposes for and requirements of a sampling program. The desirable characteristics of automatic sampling equipment are set forth and problem areas are outlined.

A compendium of 82 model classes covering over 200 models of commercially available and custom designed automatic samplers is given with descriptions and characterizations of each unit presented along with an evaluation of its suitability for a storm and/or combined sewer application.

A review of field experience with automatic sampling equipment is given covering problems encountered and lessons learned. A technical assessment of the state-of-the-art in automatic sampler technology is presented, and design guides for development of a new, improved automatic sampler for use in storm and combined sewers are given.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sampling, Samplers, Sewage, Water analysis, Water quality, Water pollution, Effluents, Storm sewers, Combined sewers, Overflows, Manholes, Outfall sewers, Sanitary engineering, Urban areas, Reviews		13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	350
	20. SECURITY CLASS (This page)	**22. PRICE**
	UNCLASSIFIED	

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976-657-695/5364 Region No. 5-11

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Technical Information Staff
Cincinnati, Ohio 45268

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. ENVIRONMENTAL PROTECTION AGENCY
EPA-335

Special Fourth-Class Rate
Book

If your address is incorrect, please change on the above label; tear off; and return to the above address.
If you do not desire to continue receiving this technical report series, CHECK HERE ☐; tear off label, and return it to the above address.