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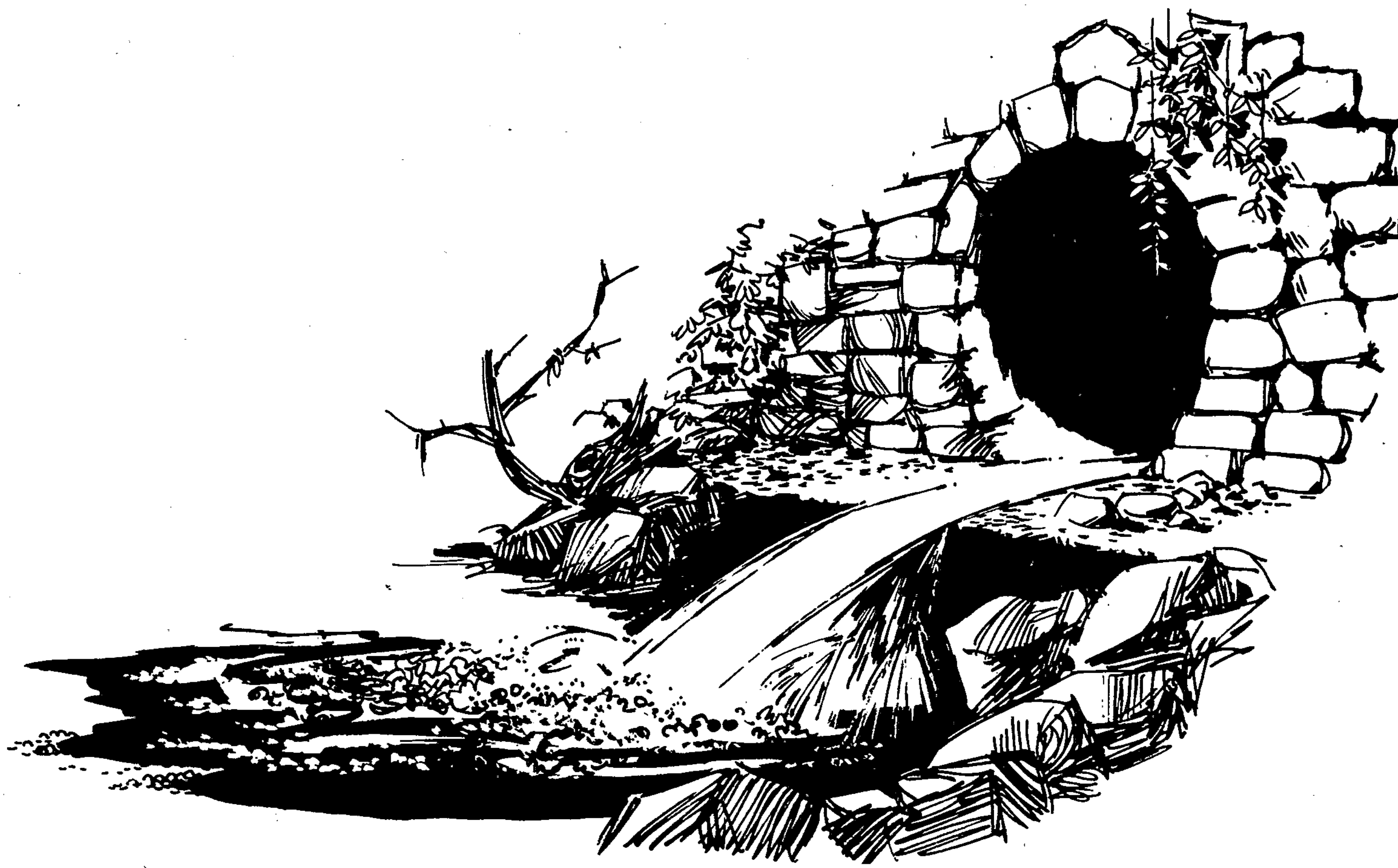
Combined Sewer Regulator Overflow Facilities



DEPARTMENT OF THE INTERIOR • FEDERAL WATER QUALITY ADMINISTRATION

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c.2

COMBINED SEWER REGULATOR OVERFLOW FACILITIES

REPORT

by the

American Public Works Association

for the

FEDERAL WATER QUALITY ADMINISTRATION

DEPARTMENT OF THE INTERIOR

and

TWENTY-FIVE LOCAL GOVERNMENTAL JURISDICTIONS

Program No. 11022 DMU c.2

Contract 14-12-456

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FWQA Review Notice

This report has been reviewed by the Federal Water Quality Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Quality Administration.

ABSTRACT

Current design, operation and maintenance practices used by local jurisdictions in the United States and Canada were determined by personal interviews and compiled in this report. Particular attention was given to the performance of various types of regulators, the use of tide gates, new designs, European practices and the systems concept of combined sewer regulation. Thirty-seven drawings and photographs of regulators are included. Seventeen recommendations are made, the adoption of which would upgrade regulator facilities and tend to reduce receiving water pollution from combined sewer overflows.

This report and accompanying manual were submitted in fulfillment of Contract 14-12-456 between the Federal Water Quality Administration, twenty-five local jurisdictions and the American Public Works Research Foundation.

APWA RESEARCH FOUNDATION
Project 68-1a

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FOREWORD

The report which follows gives the result of an extensive study conducted by the APWA Research Foundation concerning the design, operation, maintenance, and application of combined sewer overflow regulators. Publication is in two parts, this report and the accompanying manual of practice.

The American Public Works Association because of its close association with operating officials and its extensive work in the field of combined sewers and of pollution of urban storm waters has responded to the needs of local public agencies for a source of information concerning combined sewer overflow regulators. We wish to express our appreciation to the 25 local agencies and the Federal Water Quality Administration for jointly financing this project.

The Association is quite aware that the solution of our combined sewer overflow problem is not the only step in the control of pollution of our receiving waters. We are very much aware, however, that as other sources of pollution are removed through existing programs, that combined sewer overflows and related sources of pollution will remain, unless local agencies have done adequate planning to treat or prevent such pollution. The overflow regulator is one of the keys to minimizing pollution. It is not the only means and this is recognized. However, it is apparent that treatment or control facilities cannot function effectively without adequate and effective regulation.

The findings and recommendations of this report point to the need for the development of devices which will allow control of both the quantity and quality of the overflows. As regulators are rebuilt to effect control and incorporated into overall systems, there will be many opportunities for upgrading regulators. We hope that this report and manual of practice will be helpful to those who must design and operate combined sewer systems.

Samuel S. Baxter, Chairman
APWA Research Foundation

SECTION 1

FINDINGS AND RECOMMENDATIONS OF THE STUDY

An in-depth investigation of combined sewer regulator practices—in terms of design, application of types of devices, performance, and operation and maintenance experiences has been carried out by the American Public Works Association in the United States and Canada and in selected foreign countries. The study was sponsored by 25 local agencies and the Federal Water Quality Administration, Department of the Interior.

The studies brought to light information upon which to base recommendations on the more effective use and management of existing regulator facilities for the purpose of minimizing overflow quantities and maximizing the quality of wastes discharged to receiving waters.

The findings and recommendations concern the regulator facilities and not the entire combined sewer system. A report entitled "Problems of Combined Sewer Facilities and Overflows—1967," prepared by the American Public Works Association, highlighted many of the overall problems of combined sewer systems. Among the 14 findings were included such items as insufficient sewer capacity, local flooding, inadequate manpower as well as a finding that regulator facilities should be improved and better maintained. Deficiencies in the sewer system may be such that improvement of the regulator facility alone will not significantly reduce pollution. However, few systems will function effectively with minimum pollution impact, if the regulator facilities have not been properly chosen and adequately maintained.

The findings and major recommendations of the study include, but are not limited to, the following:

1. A proliferation of overflow points has led to the frequent use of insensitive regulator devices. This has been necessary in many cases, because of small flows handled by each station. It has been economically infeasible to apply expensive and sophisticated facilities in small regulator structures which handle flows of 2 cfs or less. These multiple installations are subject to infrequent maintenance service; are equipped with insensitive static devices; and experience frequent malfunctions and resultant unnecessary wet-weather overflows and undetected dry-weather discharges. Consolidation of these small regulator-overflow locations into fewer larger stations would make it feasible to provide more effective control facilities and perhaps eliminate a significant percentage of the present deterioration of water and land resources.

Efforts should be made by local jurisdictions to consolidate minor overflow points into fewer locations, in which the installation and maintenance of sophisticated regulator devices and controls will be economically and physically justified.

2. Common practice in North America has been to emphasize the quantity-control function of regulators. Little consideration has been given to the importance of controlling the quality of overflow wastes simultaneously with quantity regulation. The new definition of regulator functions propounded in this project emphasizes the control of both the *quantity* and *quality* of overflow wastes from combined sewer systems.

Regulators and their appurtenant facilities should be recognized as devices which have the dual responsibility of controlling both quantity and quality of overflows to receiving waters, in the interest of more effective pollution control.

Further research should be sponsored by the FWQA to determine the ability of new devices to induce separation and interception of concentrated pollutional solids and liquors, and the decantation of dilute storm water—sewage admixtures to receiving waters; to determine practical applications of such devices and systems; to demonstrate their potentiality by means of mathematical modelling; and to determine their cost-benefit relationships.

3. Combined sewer regulation has been based on the principle of each-regulator-for-itself. There has been little effort to tie each regulator into a complete system. Management of the entire sewer system as a total network could result in the reduction of discharges of storm flows to receiving waters.

"Total systems" management of sewer system regulator-overflow facilities should be instituted wherever this procedure can be shown to be feasible and economical. This will involve the use of dynamic-type regulator devices and the application of instrumentation and automatic-automation control methods which will be expedited by a reduction in the number of overflow points.

4. In current practice, overflows occur at points of surcharge in collector-interceptor sewers. Other parts of the same sewer system may be under-loaded because of variations in precipitation and runoff in

various parts of a community and its drainage area. The full use of the transportation and retention capacity of such a total system is not utilized by this practice. Overflows which could be prevented continue to occur.

Dynamic-type regulators should be used wherever possible and feasible for "traffic control" of combined sewer flows. This could shunt surcharges of portions of such a system into sections of sewers which are not simultaneously so affected. This approach could be enhanced by the monitoring of precipitation and sewer flows through an adequate network of stations, in communication with a central control point from whence flow routing decisions can emanate.

5. The choice and application of types of regulators in many cases has been dictated by the desire to minimize the first cost of installation and the effort of maintenance work. This has led to the use of static or insensitive devices. Dynamic-type regulators may be more costly to build and maintain, however they may reduce pollution by reacting to sewer system hydraulic needs.

The type of regulator used should be determined on the basis of its performance and potential reduction in overflow pollutional effects.

6. Many dynamic-type regulators have been removed, or have been made inoperative, to overcome the frequency and cost of maintenance and repair work. These modifications have reduced the true regulating function of these installations.

Maintenance schedules and budgetary appropriations should be planned on the basis of the specific needs of static, dynamic and instrumented units in service. Each type of regulator should be given the attention it requires to achieve maximum performance.

7. Inaccessible regulator stations and chambers which do not provide adequate space for maintenance and repair operations tend to discourage the frequency and effectiveness of inspections and attention.

Regulator facilities should be situated in accessible locations, provided with safe and dependable access facilities, be free of other safety hazards, have adequate space for necessary maintenance work and, when possible, be accessible from locations other than the street or highway right-of-way.

8. The proper functioning of overflow control devices depends, in great measure, on the capabilities of sewer system crews and the equipment and tools with which they are supplied. On-the-job training is necessary to keep maintenance personnel aware of the importance of their work and its relation to the water pollution control effort.

Maintenance crews should be adequately staffed and crews should be provided with all necessary service equipment and tools for their work and for their protection. In-service training should be provided and preventive maintenance schedules should be established. Records of maintenance work must be accurate and complete in order to assess properly the effectiveness of regulator operations and to allocate budget costs for each specific maintenance and operation procedure.

9. Regulator devices and appurtenant equipment and control facilities are exposed to extremely deleterious atmospheric and fluid conditions in combined sewer installations. Corrosion and wear can shorten the economic life of such equipment and facilities and adversely affect their efficiency of operation.

Specifications must require the use of the most serviceable corrosion-resistant and moisture and explosion-proof materials in the fabrication and installation of regulator devices and control facilities. The number of movable parts and appurtenances should be reduced as much as possible, commensurate with efforts to provide greater sophistication of regulator facilities.

10. Tide gates, or backwater gates, are often located at locations which are remotely situated from regulator chambers. These locations tend to be inaccessible and inconvenient for maintenance crews while attending regulator devices. Malfunctions and failures may result, permitting the entry of tide waters or high river stages into regulator chambers.

Where possible, tide gates should be located in adequate chambers. In cases where system control of regulator-overflow networks is provided by automatic-automated means, the proximity of tide gates with regulator chambers will facilitate the tie-in of backwater control with overflow control.

11. State and provincial water pollution control agencies have maintained very limited control over the design, installation and performance of regulator-overflow devices. The quality of the receiving waters into which combined sewers overflow is generally the responsibility of the state.

State and provincial water pollution control agencies should increase their regulatory control of this source of pollution and provide standard requirements and the engineering personnel necessary for enforcing the control of overflows from combined sewer systems. Further, such agencies must recognize

the fact that existing combined sewer systems must be upgraded if pollution levels are to be reduced.

12. This research study, for the first time, established a technical liaison between manufacturers in the regulator field, and governmental officials and designers who utilize these manufacturing services. This relationship can open up new avenues of regulator research and development, and induce better application of existing facilities.

This type of producer-consumer relations should be continued as a workable means of advancing the state of the art of combined sewer management and control. The FWQA should consider appointing an advisory committee consisting of public officials, consulting engineers, and manufacturing representatives to aid in developing workable guidelines and criteria in this field.

13. A Manual of Practice has been developed on the design, operation and maintenance of combined sewer overflow regulator and tide gate facilities, as a part of this study.

Federal, state, and local agencies, and consulting engineers should be encouraged to adopt the Manual of Practice as a technical guide for the improved application, design, operation and maintenance of regulator and tide gate facilities.

14. Clogging is the most prevalent cause of regulator malfunctions. This type of difficulty is particularly experienced in horizontal orifices or drop inlets, where protective gratings tend to clog so rapidly that they may require almost constant attention to prevent excessive wet-weather and even dry-weather overflows of volumes which "jump over" plugged entries to interceptor lines.

Efforts should be made to design regulators to minimize clogging and consequent pollutional overflows. Where clogging is inevitable, maintenance schedules should be adapted to correct this condition as expeditiously as possible.

15. Few local jurisdictions have established programs to determine the frequency and extent of overflow events. Such information, however, is necessary in the design of improved facilities. Detection of dry-weather overflows is also possible with monitoring.

As a design tool, pollution control measure, and the initial step in developing a controlled system of regulators, a monitoring system to determine the occurrence, time and volume of overflows is desirable.

16. The supplementary survey carried out in European countries disclosed the use of regulator stations and devices which tend to reduce the concentration of wastes discharged to receiving waters. These included a demonstration installation of a vortex device which has the ability to separate waterborne pollutants from the conveyed fluid flows and, thereby, to enable the diversion of heavier or more concentrated liquors to interceptor systems and treatment work and to spill relatively more dilute waste waters into receiving watercourses. Laboratory studies have indicated that similar separable solids-liquid interface phenomena may be achieved by inducing secondary motions or helical hydraulic patterns by means of structural configurations along the line of flow in the sewer conduits themselves. In European countries, devices such as screens, baffles or scumboards are used to improve the quality of the overflows.

Adaptation of such devices to American practice could serve to reduce the pollutional character of overflow wastes and improve the appearance of receiving waters and waterways. Their applicability to the regulation and control of overflow quality in the United States and Canada should be determined by appropriate research procedures.

SECTION 2

DEFINITION OF THE OVERFLOW PROBLEM AS A SOURCE OF POLLUTION

Combined sewer systems, by deliberate design and construction, are intended to overflow periodically. Overflows relieve severe and often dangerous overloading of local collection lines, interceptors, and sewage pumping and treatment works. The discharge of such overflows into nearby receiving waters creates pollution in receiving waters. Such pollution is of growing concern to water pollution control authorities.

The importance of this source of pollution was brought to light in 1967 in a report on a study of "Problems of Combined Sewer Facilities and Overflows," hereafter referred to as the 1967 investigation, conducted by the American Public Works Association and co-sponsored by the Federal Water Quality Administration, Department of the Interior. The current investigation has taken the form of "second generation," in-depth research into the design, application, performance and maintenance of regulator devices which are intended to control combined sewer overflows. Its practical goal has been to indicate changes in practices which will improve regulator performance and, thereby, minimize or even eliminate such overflows and their pollutional effects. Federal, state and local officials and engineering authorities are exploring the physical and economic feasibility of various solutions for the combined sewer overflow problem. Among such solutions is the improvement and upgrading of regulator facilities and practices. Such action should minimize the frequency and duration of overflow incidents which occur during both wet and dry weather.

If this solution can be achieved, hard-pressed communities could reduce pollution from combined sewer systems more rapidly and more economically than would otherwise be possible by procedures such as sewer separation or overflow treatment and holding facilities. The application of new and more sophisticated regulator hardware and methods, such as the "systems concept" of combined sewer management described later in this report, holds out hope that more effective overflow control is feasible, both with regard to the volume of waste waters spilled and to the pollutional concentration of these discharges.

Extent of the Regulator Problem:
Findings of the 1967 Investigation

Achievement of the goal of improving regulator facilities and practices will not be simple or inexpensive. The 1967 national survey and inventory disclosed the vast scope of the overflow problem: 1,329 governmental jurisdictions utilize combined sewers and approximately 36 million persons are served by such facilities.

The major findings of the 1967 inventory and investigation emphasized the extent of the overflow-regulator problem and disclosed the need for, and means of, providing actions.

1. A total of 10,025 regulators at combined sewer overflow structures and other locations were used by the 641 jurisdictions surveyed, to serve 34 million people. The most commonly used types were perpendicular weirs, side weirs, and other "static" devices non-responsive to flow conditions. The least commonly used were "dynamic" types, that are responsive to flow conditions, such as hydraulic cylinders, float-operated gates, and tipping gates.
2. A total of 14,212 overflow points were reported; all were not equipped with regulator devices.
3. Dry weather overflows from combined sewers were reported by 96 jurisdictions. The cause of such overflows was described by one-half of those reporting as troublesome regulators, and the other half reported insufficient sewer capacities.
4. Many regulator devices were reported to be inadequate, unreliable or insensitive to flow variations; they were inadequately inspected and maintained; and they produced unnecessary and extended overflows. Better regulator devices coupled with more effective maintenance practices, offered a means of reducing the overflow problem.
5. Better guidelines for the choice of facilities to meet specific flow control conditions and improved devices for such applications, would pay dividends in the form of reduced overflow pollution.
6. Improved maintenance and management practices would result in better operation of existing regulator installations.
7. The numerous instances of dry weather overflows, occurring because of troublesome regulators and insufficient sewer capacity, constituted a continuing source of pollution. Since such overflows were seldom monitored, it

was assumed that many more occurred than were actually reported.

8. In one representative community, overflow of a combined sewer system into a watershed was estimated to have lowered the potential value of abutting land more than $5 million, representing an annual revenue loss of $70,000 in city taxes.

These findings and conclusions led to the following significant recommendations:

"It is recommended that programs to monitor combined sewer overflow events be initiated, and that remedial steps be taken to prevent or reduce this source of pollution as soon as practical."

"It is recommended that a thorough study be instituted on regulator facilities, aimed at developing better application engineering, improved devices and more effective maintenance practices."

The latter recommendation emphasized the need for this in-depth study of regulator practices, relating to design, application, construction, control, operation and maintenance; and for the development of guidelines for improved designs and procedures. This recommendation was implemented by the contractual agreement between the Federal Water Quality Administration and the APWA Research Foundation. This report documents the investigations carried out pursuant to the terms of this contractual agreement.

This current project offers a two-faceted concept of regulation and the function of a regulator. This may be referred to as the "Two Q's" concept—that is, control of *the quantity* and *the quality* of overflow waste waters.

Effective Regulator—Overflow Facilities as a Means of Pollution Control

As has been stated, a combined sewer system is basically designed and built to permit a portion of wet-weather flow to overflow. Thus, the regulator-overflow facility acts as a safety valve to protect the interceptor and the treatment works from overload and surcharge. It is equally evident that any spills not actually required to protect the interceptor and treatment facility, or to eliminate any hazard of overloading or flooding of combined sewer systems, and unnecessary and unjustified loadings of pollution to receiving waters. Any means which will reduce the *quantity* of spill will automatically reduce the pollutional effect of combined sewer overflows.

While the volume of flows can be imposed and controlled in and within sewer systems, to varying degrees by present regulator and control devices, there are few, if any, installations which attempt or accomplish *quality* improvement of the overflow waste waters. If there were some means for reducing the concentration of pollutional constituents of the sanitary sewage-storm water admixture at the regulator-overflow structure, the result could be a marked improvement in the characteristics of the overflow, and a reduction in pollutional loading on receiving waters. Means for *quality* control are discussed later in this report.

Both the 1967 investigation and the current study demonstrate that four factors relating to the type and operation of regulators contribute to excessive and unnecessary pollution of receiving waters:

1. Regulators which permit overflow during dry-weather flow periods, or during periods of minimal runoff resulting from minor precipitation events, before the volume of sanitary and storm flows reaches a predetermined designed wet-weather:dry-weather carrying ratio;
2. Regulators which continue to overflow for durations considerably longer than required to protect the interceptor system or treatment facility;
3. Regulator-overflow structures which fail to remove contaminating constituents in the flow, such as coarse trash and organic solids and grit, and to direct these wastes to the interceptor instead of to overflow points; and
4. Tide gates or backwater control devices which fail to protect interceptors from the inflow of receiving waters into the sewer system, and this eventually produces surcharges which result in unnecessary spillage of combined flow into these receiving waters.

These conditions result from improper application of types of regulators or tide gates at specific overflow points, malfunctioning of the existing facilities, and lack of coordinated preventive and periodic maintenance of the regulating devices.

The importance of improving regulator performance is proved by the projected estimated cost of pollution control from combined sewer sources. The fact that corrective measures are so fiscally costly and physically inconvenient makes their application as practical solutions unattainable and unrealistic under present conditions. The 1967 investigation estimated a cost of $48 billion for the separation of public sewer systems and necessary plumbing and drainage separation procedures in private structures; and $15 billion for such alternate pollution control facilities as retention and treatment works for handling overflow wastes.

The 1967 investigation concluded that improved regulator practices would pay dividends in the form of reduced pollution contributions at points of overflow at lower costs than the extensive procedures outlined above. However, this is only a first step in controlling pollution from combined sewers.

How Improved Regulator Practices Can Reduce Pollution

What, then, are the available practical solutions for this problem, in terms of improvement of regulator practices? The current investigation has demonstrated that these benefits might be achieved by:

1. Better application of regulators, by way of appropriate choice of types and locations of such installations;
2. Extensive use of regulators which are sensitive to variations in hydraulic patterns, to replace existing ineffective installations;
3. Better operation and maintenance practices which will result in improved performance of existing facilities and would, in the future, insure the realization of the full potential of new developments and devices in the regulator field;
4. Utilization of the "total system concept" approach to the integration of individual regulators into a complete management of the total regulator problem and of the complete combined sewer collection, interception and treatment system, rather than considering each individual regulator as an unrelated device;
5. The use of instrumentation for the purpose of implementing this "total systems" approach, by taking full advantage of the available storage capacity of the total combined sewer system upstream of the regulating devices or by means of "traffic routing" of wet-weather flow volumes within the system;
6. Development and application of new regulator devices and techniques, not yet used in current combined sewer practices, for controlling both the quantity and quality of overflow spills; and
7. Provision of trained and better-equipped personnel to administer and maintain regulating systems, backed up by adequate budgetary appropriations for these purposes.

It must not be assumed from this evaluation of the corrective measures available for reducing the pollution impact stemming from better control of sewer overflows that these corrective measures are applicable to all systems. These are merely suggested guidelines. A complete engineering study and evaluation of the problems and solutions applicable to each particular combined sewer system is the only way to assure improved regulator practices at the lowest possible cost.

SECTION 3

SCOPE OF THE STUDY PROJECT: PLAN OF ACTION

The problems of regulator design, applicability, construction, operation and maintenance were ascertained and evaluated by the following research approaches:

1. A survey of representative existing regulator installations, referred to as the National Survey, for the purpose of ascertaining their capabilities to perform the function of regulators as described in Section 2 of this report;
2. An evaluation of current practices for the purpose of showing designers, municipal officials and state water pollution control agencies how to provide better management and utilization of existing facilities, and to replace ineffective or malfunctioning regulator devices with more efficient equipment;
3. The establishment of criteria for improved regulator facilities, followed by explorations with manufacturers which could lead to the development and production of such improved equipment and systems, and to the evolution of overflow management methods and techniques not now being employed in the regulator field; and
4. Application of instrumentation for total systems control of complete sewer networks and all regulators, wherever this type of combined sewer system management can result in more effective utilization of the storage capacities of sewer systems by "traffic routing" procedures and for reduced pollution impacts caused by overflows.

The research project provided for further investigations by a three-member Consulting Engineering Panel, leading to:

"Basic design criteria for regulator facilities; the exploration of design theories and applicability of regulators; the determination of the need for new methods of regulation, and the principles on which they would function; all to be incorporated in a Manual of Practice."

In order to create a fruitful climate in which an evaluation of existing regulator facilities could be achieved, and the development of new techniques and equipment could be stimulated, discussions were instituted with a Manufacturers' Advisory Panel on available regulator devices and appurtenant equipment; applicability of such facilities; choice of materials to withstand deleterious conditions in sewers and regulator chambers; new products and processes applicable to regulator installations; improved maintenance procedures; and other phases of regulator practices. The functioning and findings of this manufacturers' group are discussed in Section 9 of this report.

Survey of Eighteen Representative Combined Sewer Systems

Evaluation of the applicability, performance, and effectiveness of maintenance of presently installed regulators was accomplished by detailed on-site investigations of eighteen combined sewer systems in the United States and Canada. These field surveys were conducted by trained and experienced sanitary and municipal engineers engaged in private practice, public service and universities. This staff of investigators was chosen to utilize the knowledge and experience of persons indigenous to the particular regions being investigated. These investigators were carefully briefed in the purposes of the study.

The systems included in the survey were:

1. Akron, Ohio
2. Allegheny County Sanitary Authority, Pa. (ALCOSAN)
3. Metropolitan District Commission, Mass. (MDC)
4. Metropolitan Sanitary District of Greater Chicago, Ill. (MSD)
5. Metropolitan Sanitary District of Greater Cincinnati, Ohio
6. Cleveland, Ohio
7. Detroit Metropolitan Water Services, Mich.
8. District of Columbia
9. Milwaukee Sewerage Commission, Wis.
10. Minneapolis-St Paul Sanitary District, Minn. (MSSD)
11. Montreal, Quebec, Canada
12. New York City, N. Y.
13. Omaha, Nebr.
14. Philadelphia, Pa.
15. San Francisco, Calif.
16. St. Louis, Mo.
17. St. Paul, Minn.
18. Municipality of Metropolitan Seattle, Wash.

These jurisdictional entities were chosen on the basis of data developed in the 1967 investigation, including such factors as population; geographical location; regulator types; specific maintenance procedures; existence of special problems such as discontinuance of the use of specific types of regulators; application of instrumentation techniques and use of instrumentation methods to effect total systems control; and the existence of FWQA combined sewer demonstration projects of various types.

Tide gates, or backwater gates, were included in the survey because they were deemed to be part of the overall regulation control of flows out of, or into combined sewer interceptor systems.

The 18 surveyed systems provided a highly representative cross section of the regulator facilities in use in the United States and Canada. Investigation revealed that this choice of only 18 jurisdictions would encompass almost 25 percent of the total regulators found by interviews in the 641 jurisdictions included in the 1967 Inventory. The survey of the 18 jurisdictions covered 15 percent of the float-operated gates; 46 percent of the tipping gates; 16 percent of the leaping weirs; 19 percent of the side-spill weirs; 29 percent of the fixed orifices; 87 percent of the manually operated gates; 26 percent of the horizontal orifices or drop inlets; and 16 percent of the other regulator types inventoried in 1967.

Table 1, Number of Regulators Actually Surveyed in Each Jurisdiction and Relationship to Jurisdictions Interviewed in 1967, indicates the number of regulators, by type, surveyed in each of the jurisdictions and compares these totals to those determined in the 1967 investigation.

Each of the 18 investigations ascertained the types of regulators in service; the number of regulators out of service or inoperative; dates the regulators were installed; their locations along the interceptor system, at the collector-interceptor junction, at pumping stations, at treatment facilities, at junctions with other jurisdiction's systems, or at other points.

The local interviews covered details of construction of regulator devices and reasons for the choice of specific regulators. An effort was made to obtain data on the capital costs of integral parts or elements of regulator stations; details on design criteria relating to wet-weather to dry-weather flow ratios (WWF:DWF) for discharge in interceptor systems; precipitation records and intensity data; and overflow connection layouts.

Operation and maintenance practices were investigated in terms of types of malfunctions; reasons for malfunctions; frequency and duration of overflows; variations in performance; frequency of maintenance, by regulator type; repairs and adjustments required, by regulator type; the makeup and numbers of maintenance crews; and the maintenance tools and equipment used for this work, by regulator type.

The investigation provided the relatively limited amount of information available on the utilization of automatic devices, automation facilities and instrumentation practices in collection systems, in whole or in part.

Data concerning special control methods, including automatic-automation devices and instrumentation facilities, were obtained wherever available in the surveyed communities.

The correlation between FWQA demonstration projects and existing regulator practices was investigated in those systems where such federally sponsored studies were underway.

In-depth surveys were carried out in 12 of the 18 jurisdictions. The remaining six were investigated for the purpose of disclosing specific points of interest including: Total systems control of entire combined sewer systems, such as those being developed in Seattle and Minneapolis–St. Paul; use of special structures housing tide gates and regulators in San Francisco; use of inflatable dams for flow regulation purposes in a FWQA demonstration program in Minneapolis–St. Paul; and the conditions which led to the abandonment of certain types of regulators in the Boston metropolitan area served by the Metropolitan District Commission.

Result of Survey of Practices of State Water Pollution Control Agencies

Over and above the field surveys of reprrsentative jurisdictional entities, an effort was made to investigate and evaluate present and future policies and practices of state water pollution control agencies in regulating the design, construction, operation and maintenance of overflow facilities. Agencies in the 50 states and the 10 Canadian provinces were surveyed. The survey asked for information on the following questions:

1. What are the existing practices regarding combined sewer overflow regulator facilities?
2. What types of regulatory devices are used?
3. Have design criteria been established for regulator installations?
4. Are regular reports made by state engineers concerning the operation, field conditions, and maintenance practices of regulator devices in community sewer systems?

All but one state responded to the questionnaire; the results may be summarized as follows:

1. In states where few combined sewer systems exist, i.e., where the ratio of combined sewer systems to separate systems is less than 25 percent, little interest in combined sewers was

TABLE 1
NUMBER OF REGULATORS ACTUALLY SURVEYED IN EACH JURISDICTION AND RELATIONSHIP TO JURISDICTIONS INTERVIEWED IN 1967

Location of Jurisdictional Sewer System Agency	Type of Regulator: Fixed Orifice (Vert.)	Drop Inlets	Leaping Weirs	Side-Spill Weirs	Man. Oper. Gate	Siphons	Float Oper. Gates	Tipping Gates	Cylindrical Gates	Cylinder Oper. Gates	Motor Oper. Gates	Total
Akron		38										38
Boston				11								11
Chicago	4(1)				283(1)						45(1)	332(1)
Cincinnati	5	141		68			48					262
Cleveland	221		103	234			16					574
Detroit	3				3		44			1		51
Milwaukee	61		6					85				152
Montreal (3)							4		7			11
New York	104		2	14	62		4			126		312
Omaha		25				26				28		79
Philadelphia			73		5		81			15		174
Pittsburgh	116				7			147				270
St. Paul (4)	25	18	5	18								66
San Francisco	40											40
Seattle										6	8	14
Washington	7	58		14			13					92
Total Units Surveyed (2)	586	280	189	359	360	26	210	232	7	176	53	2479
Total in 641 Jurisdictions in '67 Survey	2033	1069	1185	1884	416	—	1356	505	—	Shown as Others 1577		10,025
Percent of Units Surveyed Total in '67	28.8%	26.2%	15.9%	19.1%	86.5%	—	15.5%	46.0%	—	—		24.8%

(1) Number shown refers to structures, each structure contained 1—4 gates.
(2) Only units actually surveyed are shown, jurisdiction may have had additional units or other types.
(3) Montreal not included in 1967 survey.
(4) Minneapolis-St. Paul Sanitary District is presently carrying out a demonstration project with the FWQA (see Section 9). Fifteen, remotely controlled inflatable fabric dams regulating combined sewer flows to a seciton of the interceptor system.

indicated. No state regulations or legislation were mentioned and few records were kept. The standard comment from state authorities was that where combined sewer systems exist in the state they are being systematically separated as quickly and as economically as possible. Twenty-eight states were included in this group. Only one indicated an interest in the problem.

2. In states where the ratio of combined sewer systems to separate sewer systems is between 25 and 50 percent, the response to the questionnaire by state water pollution control authorities was evenly divided. One-half of the group recognized that combined sewer overflows were a problem. They indicated that they lacked legislation, manpower, and necessary design criteria to meet the need for state control. Their comments indicated interest in the results produced by the APWA-FWQA regulator study; this interest indicated that the problem was of sufficient magnitude to warrant some type of action. The other half of these agencies demonstrated only a limited concern over the importance of overflows in terms of water pollution problems in their states.

3. In states where more than 50 percent of the sewer systems are combined, all but one of the agencies indicated concern over the problem. Five states were in this category.

States that expressed the most specific interest in the problem were Georgia, Indiana, Massachusetts, Maine, New Jersey, New York, Ohio, Pennsylvania and Wisconsin. Each recognized the pollution caused by combined sewer overflows and said it would welcome guidelines for the application of regulatory devices. Their answers indicated that states have little or no legislation upon which to base overflow control and regulator practices. They lack information concerning regulator facilities in service; proper applications and standard practices; and operating and maintenance needs. Most states reported that they have insufficient personnel to approve or inspect regulator installations and, consequently, there is little follow-up of operating conditions and practices by agency personnel.

The State of New York reported that its policy is: to eliminate overflows where possible and feasible; and to reduce overflows to a practical minimum.

Technical Bulletin No. 20 of the New York Department of Health outlines that department's attitude concerning combined sewer overflows, as follows:

(A) Evaluate overflows by surveillance-measuring the quantity, the frequency, and the quality of the overflow.
(B) Measure the effectiveness of existing control devices at overflow locations. These include regulatory devices and tide gates.
(C) Monitor overflow locations, providing instrumented information at central locations where possible.

Special attention is called to the fact that the present State policy is to approve new sanitary sewer projects only. Old combined sewers may be replaced or repaired, but they should be separated at such times—if possible—in conformity with master plans for sewage and drainage services. The bulletin lists the following methods and procedures to minimize combined sewer overflows:

(A) Utilize maximum storage capacity in combined sewers without backflooding.
(B) Disinfect along the interceptor immediately prior to overflow points to reduce bacterial loading.
(C) Eliminate separate storm water connections to interceptors and collector sewers.
(D) Separate storm water from sanitary sewage as quickly and as economically as possible.
(E) Locate and eliminate illegal cross-connections of local storm sewers.
(F) Utilize the maximum storage capacity in the interceptor in order to reduce shock loading on the treatment facilities.

New York State was not alone in stressing the fact that new combined sewer systems are no longer permitted. A number of states referred to this policy in explaining the absence of supervision of regulator design, construction and performance, and the absence of any plans to modify this procedure in the foreseeable future. The following states reported that they do not allow combined sewers: Arkansas, Florida, Georgia, Hawaii, Kentucky, Mississippi, Missouri, Nevada, Nebraska, New Mexico, North Dakota, Oklahoma, Rhode Island, Texas, Utah, Virginia, and Wyoming. The following states indicated that they seldom permit or are reducing the number of combined sewer systems: Alaska, Alabama, Arizona, Colorado, Louisiana, Montana, North Carolina, New Jersey, South Carolina, Tennessee, and Washington.

Combined sewer systems are prohibited in many states and existing systems are being phased out. Since overflows are not recognized as a problem, however, little control is provided by the state agencies and contact with the immediate authority utilizing regulator devices is minimal. In states where combined sewers form a large percent of the total sewer installations, the importance of control of overflows by means of regulators is generally acknowledged.

Special Survey on Operation and Maintenance Practices

Because of the effect of the performance of regulator devices, in terms of operation and maintenance experiences, on pollution control conditions, and the influence of the choice of various types of regulator devices for specific control functions on operation and maintenance practices, it was deemed advisable to augment the 18 jurisdictional surveys by carrying out an investigation in a number of additional communities. The communities where operation and maintenance data were solicited were chosen on the basis of data obtained during the 1967 investigation.

The items investigated included: types and frequency of regulator malfunctions; operation experiences, including abandonment, modification, dangerous or inaccessible installations, excessive corrosion, and other conditions; devices used for the protection of regulator equipment; types and numbers of maintenance experiences, including maintenance crews and equipment; and cost of maintenance service. Responses were received from 15 jurisdictions. The results of the survey are shown in Table 2, Supplementary Survey—Operation and Maintenance Evaluation. The data show that static regulators are being inspected an average of 43 times per year by three-man crews. This compares to dynamic regulators which are inspected an average of 49 times per year by three-man crews.

The most common malfunction experienced is clogging, as reported by 60 percent of the respondents. Operational problems relating to corrosion of mechanical components were reported by 40 percent of the respondents. Some of the regulators have been abandoned or require changes. The survey demonstrated that the principal reasons for abandoning or modifying regulator units were the lack of well-organized, preventive maintenance programs, shortage of funds to carry out these programs, and the age of the regulators which caused problems, many of which were installed more than 30 years ago.

None of the 15 jurisdictions reporting in the supplementary survey had any experience with instrumentation, automation or automatic devices.

Special Survey of Overflow Quality Control Practices

The project stressed the importance of improving the quality of the combined sewage discharged to overflow, as outlined in the "Two Q" concept in Section 2 of this report. In order to learn more about national practice of overflow quality control, a mail questionnaire was sent to 115 jurisdictions using combined sewer systems, chosen on the basis of data obtained in the 1967 investigation. These systems reported the use of some form of screens to improve overflow quality.

The information requested included: type of regulators and locations where overflows resulted; the types of devices used to protect regulators or to improve the quality of overflows, including screens, comminutors, baffles or skimmers, modified weir crest configurations, special orifices or other devices; the benefits of quality control, as shown by monitoring data on overflow liquids before and after the installation of quality improvement devices.

Twenty-five percent of the jurisdictions responded to the mail survey. Of these, only Muncie, Indiana used screens, and none used baffles or skimmers or other quality improvement devices. In 30 percent of the jurisdictions equipped with side-spill weir regulators, modifications of some type have been made to weir crests.

This special survey attempted to obtain information not only on improvements within regulator overflow stations, but also on improvement of overflow liquids by means of in-system or off-system retention tanks, storm water holding tanks, and disinfection installations. Terre Haute, Indiana, and Ontonagon, Michigan, of the eight jurisdictions which reported on quality control of overflows, used in-system storm water holding tanks; none used off-system holding tanks.

Greenfield, Indiana, reported the use of settling tanks and overflow chlorination; it was the only jurisdiction reporting this form of overflow quality control.

The results of this supplementary survey indicated very limited use of waste water improvement procedures in combined sewer regulator chambers or in overflow treatment or retention facilities installed between overflow chambers and receiving waters.

Special Survey on Overflow Monitoring

Limited information concerning monitoring of the quality and quantity of overflow wastes was

TABLE 2 (a)
SUPPLEMENTARY SURVEY
OPERATING AND MAINTENANCE EVALUATION
A – ORIFICES

	No.	Times Inspected Annually	Crews No.	Crews Men/Cr.	Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	Inspection Maintenance V	L	O	Major Equipment T	S	R	Type of Malfunction C	E	S	WB	M	PF	Operational Problems A	RC	D	I	Co	Others	Rating
Baltimore, Maryland	–	12-24	2	2	5	–	Y	–	–	–	–	–	–	–	–	–	–	–	N	N	–		–	–	1
Dunkirk, N. Y.	–	12	1	3	5	–	Y	–	–	–	–	–	Y	–	–	–	–	–	–	–	–	–	–	–	1
Portland, Oregon	–	52	2	2	50	–	Y	–	–	Y	Y	–	Y	–	–	–	–	–	–	–	–	–	–	Y	2
Providence R. I.	–	52	1	4	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Average		34	1.5	2.8																					1.5

Legend
V—Visual Inspection
L—Lubricate
O-Operate
T—Truck
S—Safety Equipment
R—Radio

Rating
Satisfactory 3
Satisfactory within limitations 2
Limited 1
Unsatisfactory 0

C—Clogging, Blocking, Jamming, etc.
E—Electrical
S—Sticking
WB—Weir Breakout
M—Mechanical
PF—Power failure

A—Abandoned
RC—Requires changes
D—Dangerous, difficult installation
I—Inaccessible
CO—Corrosion
Y—Yes
N—No
—No Data

TABLE 2 (b)
SUPPLEMENTARY SURVEY
OPERATION AND MAINTENANCE EVALUATION
B – WEIRS

	Times Inspected Annually		Crews		Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	Inspection Maintenance			Major Equipment			Type of Malfunction						Operational Problems					Others	Rating
	No.	Annually	No.	Men/Cr			V	L	O	T	S	R	C	E	S	WB	M	PF	A	RC	D	I	Co		
Bay City, Michigan	–	52	1	4	100	62	Y	Y	–	–	Y	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Dunkirk, New York	–	12	1	3	5	–	Y	–	–	–	–	–	Y	–	–	–	–	–	–	–	–	–	–	–	1
Honesdale, Pa.	–	104	1	2	20	26	Y	–	–	Y	–	–	–	–	–	–	–	–	N	N	–	–	–	–	2
Huntington, Pa.	6	6	1	2	5	26	Y	–	–	–	–	–	Y	–	–	–	–	–	–	–	–	Y	–	–	0
Lancaster, Ohio	–	52	1	4-5	30	–	Y	–	–	–	–	–	Y	–	–	–	–	–	–	–	–	–	–	–	1
Providence, R. I.	–	52	1	4	80	–	–	–	–	–	–	–	–	–	–	–	–	–	N	Y	Y	N	N	–	2
Syracuse, New York	66		2	5	40	126	Y	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Unknown (a)	–	4	1	3	1	–	Y	–	–	–	–	–	Y	–	–	–	–	–	–	–	–	–	–	–	3
Average	40	1.1	3.5		60																				1.4

Legend

V–Visual Inspection
L–Lubricate
O–Operate
T–Truck
S–Safety Equipment
R–Radio

Rating
Satisfactory 3
Satisfactory within limitations 2
Limited 1
Unsatisfactory 0

C–Clogging, Blocking, Jamming, etc.
E–Electrical
S–Sticking
WB–Weir Breakout
M–Mechanical
PF–Power failure

A–Abandoned
RC–Requires changes
D–Dangerous, difficult installation
I–Inaccessible
CO–Corrosion
Y–Yes
N–No
–No Data

TABLE 2 (c)
SUPPLEMENTARY SURVEY
OPERATION AND MAINTENANCE EVALUATION
C – MANUALLY OPERATED GATES

	No.	Times Inspected Anually	Crews No.	Crews Men/Cr.	Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	Inspection Maintenance V	L	O	Major Equipment T	S	R	Type of Malfunction C	E	S	WB	M	PF	Operational Problems A	RC	D	I	Co	Others	Rating
Honesdale, Pa.	16	104	1	2	20	26	Y	—	—	Y	—	—	—	—	—	—	—	—	N	—	—	—	—	—	2
Sparks, Nev.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	N	—	—	—	—	—
Unknown (a)	3	—	1	3	1	—	Y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Average																									2.0

TABLE 2 (d)
D – FLOAT-OPERATED GATES

	No.	Times Inspected Anually	Crews No.	Crews Men/Cr.	Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	V	L	O	T	S	R	C	E	S	WB	M	PF	A	RC	D	I	Co	Others	Rating
Dunkirk, N. Y.	—	12	1	3	5	—	Y	—	—	—	—	—	Y	—	—	—	—	—	N	N	N	Y	Y	Y	1
Huntington, Pa.	2	26	1	2	5	26	Y	—	—	—	—	—	Y	—	—	—	—	—	—	—	Y	—	—	—	1
Kokomo, Ind.	—	156	2	2	100	—	Y	Y	—	—	—	—	Y	—	—	—	Y	—	—	—	—	Y	Y	—	2
Richmond, Va.	—	12	1	3	25	—	—	—	—	—	Y	—	Y	—	—	—	—	—	—	—	—	—	—	—	1
Syracuse, N. Y.	Abandoned due to difficult operating conditions																		Y	Y	Y	—	—	—	0
Unknown (b)	12	—	1	1-2	—	26	Y	Y	—	—	—	—	Y	—					Y	—	—	—	—	—	0
Average		52	1.2	2.3																					0.8

Legend
V—Visual Inspection
L—Lubricate
O—Operate
T—Truck
S—Safety Equipment
R—Radio

Rating
Satisfactory 3
Satisfactory within limitations 2
Limited 1
Unsatisfactory 0

C—Clogging, Blocking, Jamming, etc.
E—Electrical
S—Sticking
WB—Weir Breakout
M—Mechanical
PF—Power failure

A—Abandoned
RC—Requires changes
D—Dangerous, difficult installation
I—Inaccessible
CO—Corrosion
Y—Yes
N—No
—No Data

TABLE 2 (e)
SUPPLEMENTARY SURVEY
OPERATION AND MAINTENANCE EVALUATION
E – TIPPING GATES

	No.	Times Inspected Annually	Crews No.	Crews Men/Cr.	Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	Inspection Maintenance V	L	O	Major Equipment T	S	R	Type of Malfunction C	E	S	WB	M	PF	Operational Problems A	RC	D	I	Co	Others	Rating
Bay City, Michigan	–	52	1	2	70	62	Y	Y	–	–	–	–	Y	–	Y	–	–	–	–	Y	–	Y	–	–	2
Muncie, Ind.	–	26	1	2	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Y	–	2
Providence, R. I.	–	52	1	4	80	–	–	–	–	–	–	–	–	–	–	–	–	–	N	Y	Y	N	N	–	2
Average		43	1	2.7																					2.0

TABLE 2 (f)
F – CYLINDER GATES

	No.	Times Inspected Annually	Crews No.	Crews Men/Cr.	Percent of Time Crew Spent on Regulators	Man-Hours Per Unit Annually	V	L	O	T	S	R	C	E	S	WB	M	PF	A	RC	D	I	Co	Others	Rating
Portland, Oregon	–	52	2	2	50	–	Y	–	–	Y	Y	–	Y	–	–	–	–	–	–	–	–	–	Y	Y	2

Legend

V–Visual Inspection
L–Lubricate
O–Operate
T–Truck
S–Safety Equipment
R–Radio

Rating

Satisfactory 3
Satisfactory within limitations 2
Limited 1
Unsatisfactory 0

C–Clogging, Blocking, Jamming, etc.
E–Electrical
S–Sticking
WB–Weir Breakout
M–Mechanical
PF–Power failure

A–Abandoned
RC–Requires changes
D–Dangerous, difficult installation
I–Inaccessible
CO–Corrosion
Y–Yes
N–No
–No Data

obtained as a result of surveys carried out in the 1967 investigation. Similarly, a lack of basic monitoring information was evident in the field surveys conducted in the 18 communities in the current project. In order to focus more definite attention on the importance of monitoring data upon which to base decisions on the pollutional effects of overflows and justification of expenditures for overflow control, inquiries were addressed to 54 jurisdictions which, in the 1967 investigation, reported some method of monitoring overflows. The letter of inquiry to these jurisdictions requested a brief synopsis of any monitoring studies, together with pertinent findings on the quantity and quality of overflows, their frequency, and the pollutional effect on receiving waters. Data pertaining to statistical evaluation of the monitoring were solicited. Of the 15 communities which replied, only San Francisco, Philadelphia, Detroit, and Wilmington, Delaware, actually had carried out some form of overflow monitoring. Of these, two measured the quantity of overflow. The monitoring of overflows for quality determination in the remaining two jurisdictions was carried out on a momentary or "catch sampling" basis. There were no reports of overflows having been monitored consistently over long periods.

Special Survey on the Impact of First-Fluush Phenomena on Regulator Practices

The common opinion among many persons associated with the field of waste water collection and disposal has been that, with the advent of a storm, peak flows in combined sewers tend to dislodge solids deposited in the conduits during dry-weather flow periods. In accordance with this concept, solids tend to move along the sewer barrel as a concentrated "slug" and to produce a sudden heavily polluted discharge of waste water through regulator-overflow installations and into receiving waters. On the basis of the occurrence of first-flush phenomena, some designers have attempted to retain this brief peak flow in the system and prevent its discharge to receiving waters, on the assumption that subsequent overflows would be diluted with relatively cleaner storm water which would reduce the pollutional impact on receiving waters.

To obtain information concerning the actual existence of these phenomena in practice, letters of inquiry were addressed to the 19 members of the project's Advisory Committee. The communities which these members represent were financial participants in the project and, as such, have experienced overflow-regulator operational problems. The general findings of this supplementary survey can be summarized as follows.

1. Is there a first-flush condition in combined sewers which produces a peak of high-strength condition in overflows when storm flows occur? Table 3 evaluates opinions concerning the existence of the first-flush phenomenon. Fifty-eight percent of those reporting believed that a first-flush condition exists within the entire combined sewer system; 79 percent expressed the belief that the phenomenon exists in their local collector sewers.

2. Are solids deposited in your combined sewers during dry-weather flows, which are then flushed from the lines during storms, thus producing overflows of greater pollutional strength in receiving waters? Table 4 shows no clear concensus on this question.

TABLE 3
OPINION SURVEY ON EXISTENCE OF FIRST-FLUSH PHENOMENON

	Yes	No	In Part	Don't Know
(A) In Total Combined Sewer Systems				
No. of Jurisdictions Reporting	8	2	3	1
Percent of Jurisdictions Reporting	58	14	21	7
(B) In Local Collector Sewers				
No. of Jurisdictions Reporting	11	2		1
Percent of Jurisdictions Reporting	79	14		7

TABLE 4
ARE SOLIDS DEPOSITED DURING DRY-WEATHER FLOW, WHICH ARE FLUSHED OUT DURING STORMS, PRODUCING OVERFLOWS OF GREATER POLLUTIONAL STRENGTH?

	Yes	No	In Part	Don't Know
No. of Jurisdictions Reporting	5	4	1	4
Percent of Jurisdictions Reporting	37	28	7	28

3. Do all solids flushed along sewers under such flow conditions scour out of combined sewers during the early stages of storms, or are they moved slowly along the barrel of sewers and leached out over a long period of storm flow?

Table 5 indicates that 58 percent of the jurisdictions surveyed believe that solids are flushed out of the combined sewer system during the entire period of the storm.

TABLE 5
ARE SOLIDS FLUSHED OUT OF COMBINED SEWER SYSTEM DURING EARLY PART OF STORM OR CONTINUOUSLY OVER LONG PERIOD OF STORM FLOWS?

	Early Part of Storm	During Entire Storm	Don't Know
No. of Jurisdictions Reporting	4	8	2
Percent of Jurisdictions Reporting	28	58	14

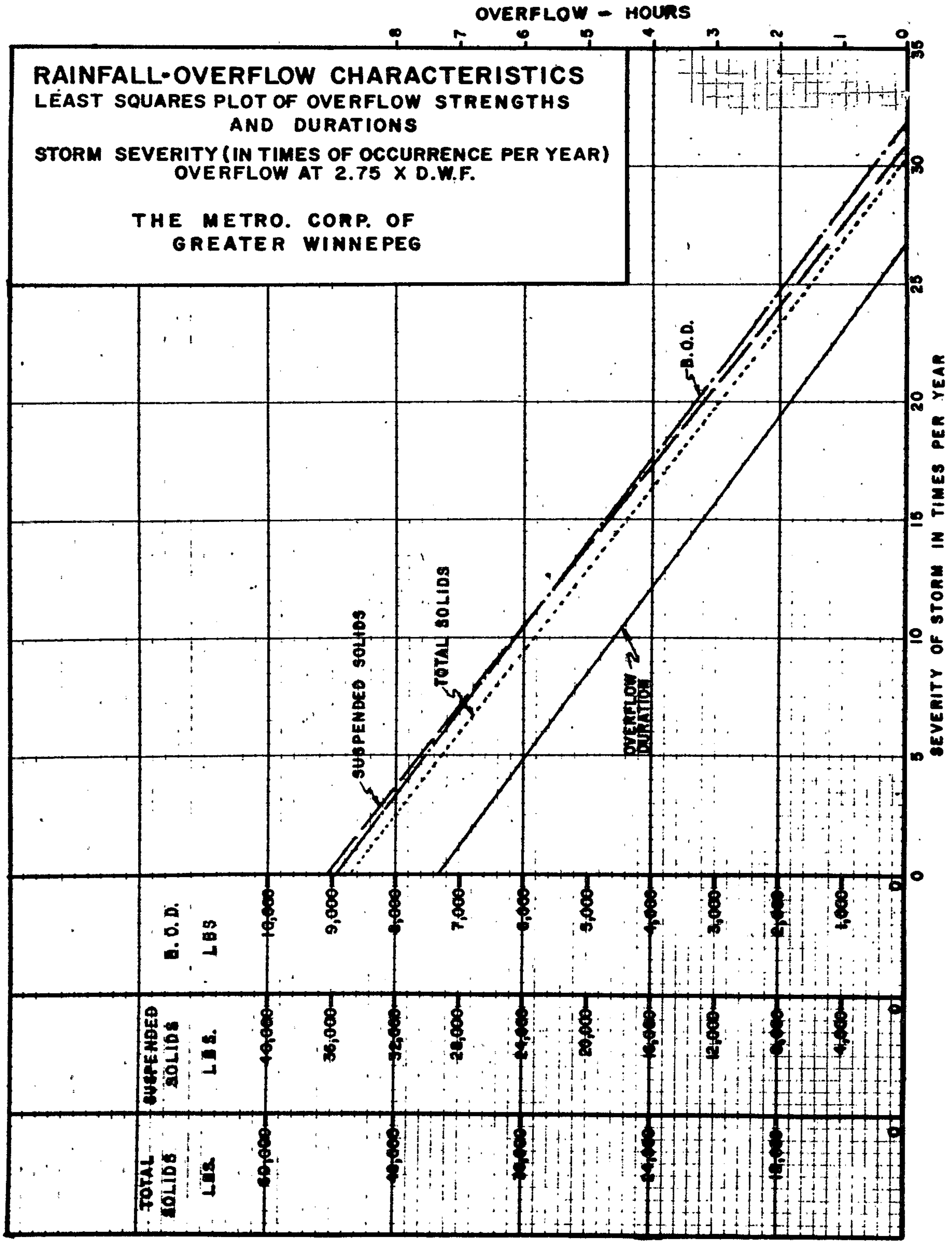
4. Does the coarse trash material in combined sewers during dry-weather flows, as well as debris contained in storm runoff flows, cause trouble at regulator chambers? Only 14 percent reported having this problem under dry-weather flow conditions, as indicated in Table 6.

This survey indicated that although personnel from several reporting jurisdictions believe the phenomenon of first-flush does exist, none produced evidence to support the theory. Opinions indicated that in small sectors of the drainage basin and their local combined sewers, there may be a higher concentration of pollutant loads coincident with the first peak of storm water flow; however, in major elements of the combined sewer system, it is more likely that the pollution load during periods of wet-weather flow varies in direct proportion to the intensity and duration of the particular storm. The concentration of pollutants, the quantity of suspended solids, solids in the sewer invert, volatile matter and floating debris in the wet-weather flow, will increase with the length of time between storms.

The Metropolitan Corporation of Greater Winnipeg has established that the pollution load in the overflow varies in direct proportion to the intensity of the particular storm. Figure 1, Rainfall-Overflow Characteristics, presents these findings graphically for one facility at an overflow of 2.75 x Dry Weather Flow (DWF). Similar results were obtained for 5 x DWF.

To improve the quality of overflow during a storm, jurisdictions surveyed recommended the following procedures: Maintenance of self-cleansing velocities in combined sewers during dry-weather flow conditions by using vertically-oriented, elliptical-sewer cross sections, or by providing dry-weather flow channels; use of side inlets instead of catch basins; initiation of thorough street sweeping programs in order to reduce the volume of street dirt and debris flushed into the combined sewer system; inauguration of a combined sewer flushing program, particularly during prolonged periods of dry weather,

FIGURE 1


RAINFALL-OVERFLOW CHARACTERISTICS
LEAST SQUARES PLOT OF OVERFLOW STRENGTHS AND DURATIONS
STORM SEVERITY (IN TIMES OF OCCURRENCE PER YEAR)
OVERFLOW AT 2.75 X D.W.F.
THE METRO. CORP. OF GREATER WINNEPEG
OVERFLOW - HOURS
SEVERITY OF STORM IN TIMES PER YEAR
B.O.D.
TOTAL SOLIDS
SUSPENDED SOLIDS
OVERFLOW DURATION
B. O. D. LBS
SUSPENDED SOLIDS LBS.
TOTAL SOLIDS LBS.

and reduction in the number of overflow locations within the jursidiction so that, within the economies of the system, retention, sedimentation, and disinfection of the overflow will be feasible.

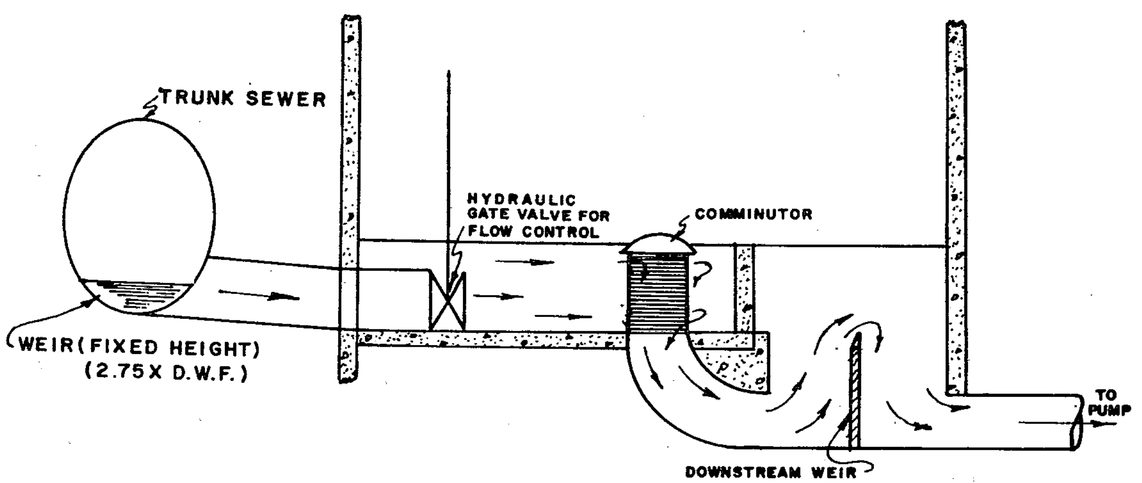
The presence of concentrated amounts of solids in the flow to the interceptor tends to cause pump malfunctions. Figure 2, Typical Interception System—the Metropolitan Corporation of Greater Winnipeg, illustrates that area's use of comminutors to reduce the size of solids in the flow to the treatment plant prior to pumping.

TABLE 6
DOES SOLID MATERIAL SETTLED OUT DURING DRY-WEATHER FLOW PERIODS AND DEBRIS FROM WET-WEATHER FLOWS CAUSE BLOCKAGES AT REGULATOR CHAMBERS?

	Yes	No	Don't Know	
(A) Under Wet-Weather Conditions				
No. Of Jurisdictions Reporting	8	4	2	
Percent of Jurisdictions Reporting	58	28	14	

	Yes	No	Don't Know	Occasionally
(B) Under Dry-Weather Conditions				
No. of Jurisdictions Reporting	2	8	2	2
Percent of Jurisdictions Reporting	14	58	14	14

FIGURE 2



TYPICAL INTERCEPTION SYSTEM
THE METRO. CORP. OF GREATER WINIPEG

SECTION 4

TYPES AND APPLICABILITY OF REGULATORS IN USE IN COMBINED SEWER SYSTEMS

Regulator devices serving systems in the United States and Canada have been developed to divert waste water flows from one flow system to another and to control the quantity diverted. The regulator is generally sized to intercept peak dry-weather flow and a portion of the wet-weather flow. Excessive wet-weather flow is bypassed to receiving waters, or to holding tanks or treatment facilities which prevent overflow of these waters or provide some degree of treatment prior to discharge.

Regulators may also operate as emergency overflow devices. A typical application is protection of pumping stations and waste water treatment plants where excessive flow is diverted to an outfall, in order to prevent overloading of mechanical facilities and treatment processes. A common application is in upstream areas of collection systems where surcharging of local combined sewers may be relieved by overflow regulators which divert wet-weather flow to nearby receiving waters or a dry watercourse.

When regulators are used to direct waste water into an interceptor system which delivers flow to a treatment plant, three distinct methods are used to control the quantity of combined flow intercepted:

1. Control of flow by its upstream depth in the collector. This method results in little control of the amount of flow to the interceptor and the treatment plant.
2. Control of quantity by depth of flow in the interceptor. This method exercises accurate control of the diverted water up to the interceptor's maximum designed capacity. This method produces more uniform conditions of flow in the interceptor and at the treatment facility; it makes maximum use of both, providing a reduction in overflow quantity but not necessarily making any attempt to improve the quality of the overflow.
3. Control of quantity by depth of flow, both in the interceptor and the collector sewer. Actuated by remote control, and in sequence with other similar diversion structures, this method can vary flow conditions in both systems. The flexibility of the total system produces a more accurately controlled flow in the interceptor and at the treatment plant, reducing flow peaks by retaining runoff volumes in collector mains. This insures maximum utilization of interceptor and treatment plant capacities. Reduction of the number of overflow points and quantity of overflow is possible. The quality of overflow may also be improved.

For the purpose of this report, regulators are described as either "static" or "dynamic." A static regulator cannot be adjusted without manual changes or structural modification. Flow rates over or through the regulator increase as the hydraulic head upstream increases. These devices operate primarily on the basis of pre-installation design criteria; they include fixed orifices, side-spill weirs, simple siphons, and leaping weirs.

A dynamic regulating device is one which functions semi-automatically or automatically to adjust the quantity of flow introduced into the interceptor and, consequently, the volume diverted to overflow. Dynamic regulators include tipping gates; cylinder-operated gates; cylindrical float-operated gates, motor-operated gates, and some types of siphons. The mechanical devices, by design, have a range of settings which permits varying volumes to be intercepted and diverted in response to flow conditions upstream, downstream, or both, in accordance with pre-established design criteria.

The principal application of regulators presently in use in North America has been to control the flows entering the interceptor system and to protect pumping and waste water treatment plant facilities. Thus, control of the pollution effect of combined sewer overflows plays only a secondary role. The quantity, duration and quality of overflow waste discharges have been neglected and, in many cases, they have been disregarded.

The ideal combined sewer regulator should perform the following functions:

1. Divert peak dry-weather flow to the interceptor system;
2. Cause street, gutter inlet and sewer-scour debris to be retained and intercepted when interceptor capacity permits;
3. Minimize frequency of combined sewer overflows;
4. Provide optimum utilization of the storage capability of collector sewer lines;
5. Permit utilization of potential storage capability of interceptor sewers in separate areas under varying storm and runoff conditions, making available the maximum capacity of the interceptor;

6. Permit overflows when necessary at selected locations, where the effects of pollution on receiving waters will be minimized, and where it may be possible to construct overflow treatment facilities; and

7. Reduce the concentration of overflow waste water in order to minimize the pollutional effect of these spills.

Most devices investigated in the study, more or less, meet the first requirement. The second requirement may, to a large degree, be accomplished by retaining the heavy debris which arrives at the regulator staiton in the form of a first-flush, an extended period of scour flow, or in some other form or time interval. This can be accomplished either by providing retention tanks or by remotely regulating the flow in the collection and interception system in order to provide more effective utilization of system storage capacity. Frequency of combined sewage overflows may be reduced by remotely controlling regulator actuation to fully utilize system storage capacity. Other means of splitting storm flows to divert concentrated liquids to the interceptor may include use of such means as scum or baffle boards, screens, vortex solid-liquid separators and helical separation devices.

There are eleven existing major types of regulator devices presently in use in North America. Their functions, applicability and performance were investigated during the national survey conducted for this research project. These factors are discussed in this section of the project report.

For ease of reference, regulator descriptions have been grouped into three major groups.

1. Static Regulators
   - (a) Fixed orifices (vertical)
   - (b) Fixed orifices (horizontal) (the drop inlet)
   - (c) Leaping weirs
   - (d) Manually operated gates
   - (e) Side-spill weirs (side-flow weirs)
   - (f) Siphons (internal self-priming)
2. Dynamic Regulators—Semi-Automatic
   - (a) Float-operated gates
   - (b) Tipping gates
   - (c) Cylindrical gates
3. Dynamic Regulators—Automatic
   - (a) Motor-operated gates
   - (b) Cylinder-operated gates

I. Static Regulators

A. Fixed Orifices

Function

The fixed orifice diversion regulator consists of a perpendicular weir constructed across a combined sewer, which dam diverts peak dry-weather flows through an opening or orifice into the interceptor. During a storm, the excess wet-weather flow discharges over the weir to overflow.

The principal advantages of fixed orifice regulators are:

1. Maintenance is usually limited to periodic inspection by unskilled labor, as malfunctions are ordinarily confined to clogging,
2. The structure and housing are small and inexpensive,
3. Standard construction materials are used,
4. Few, if any, metal components are required,
5. They operate effectively under minimum head,
6. They operate in a stable, predescribable manner when submerged, and
7. They may be adapted to shear or sluice gate control.

The orifice may be rectangular or circular. The circular units may be fitted with rings or sleeves, i.e., the flow can be adjusted to meet the interceptor conditions. Rectangular orifices, when gate-regulated, present a uniform aperture which does not clog as readily as the crescent-shaped opening produced by a gate-controlled circular orifice.

The minimum opening of orifices encountered in the national survey was 8 inches. The consensus, however, indicated that a more desirable minimum would be in the order of 12 to 15 inches. Because of the size of the opening, flow control is sacrificed in order to reduce maintenance problems. Although design diversion capacity may be based on a 2:1 wet-weather:average dry-weather ratio, it actually may be as high as 6:1 during periods of rainfall.

The fixed orifice was undoubtedly one of the first types of regulators used to divert combined sewer flows and to prevent surcharge of the interceptors and overload of downstream pumping and treatment facilities.

Today, the simple orifice is applicable principally for diverting relatively small flows where, because of pipe sizes, space is limited. They are applicable where mechanical regulating devices would be uneconomical to install and difficult to maintain, or where flow-responsive regulators would function intermittently due to low head.

In its vertical application, an orifice regulator consists of two components: a diversion chamber and an orifice chamber. When a tide gate is required to protect the interceptor from high water levels in receiving waters, this third regulating appurtenance is also housed in a chamber. The diversion chamber contains a dam or perpendicular weir, which diverts normal dry-weather flow into the orifice chamber. In flat regions and/or where combined sewer slopes are less than 1 percent, the height of this weir is generally restricted in order to minimize backwater effects in the upstream collection system during storm flows. With this height limitation, it is sometimes necessary to depress the invert of the upstream sewer in the diversion chamber, so that the peak dry-weather flow can be diverted. In hilly regions, or where head is available, this limitation need not be imposed.

Flow through the orifice may occur as in an open channel, as through an orifice with free discharge, or as through a submerged orifice, depending on the water surface elevations upstream and downstream of the orifice. During a storm the orifice will discharge quantities greater than the peak dry-weather flow, or the design discharge rate. This may surcharge the interceptor and/or the branch interceptor connecting the orifice chamber to the interceptor. If the latter is surcharged, the hydraulic grade line may rise sufficiently to submerge the orifice, thus reducing the flow to the interceptor. This is the basis of the claim that, with vertical orifices, the flow entering the interceptor under storm conditions will automatically adjust itself to the capacity of the interceptor.

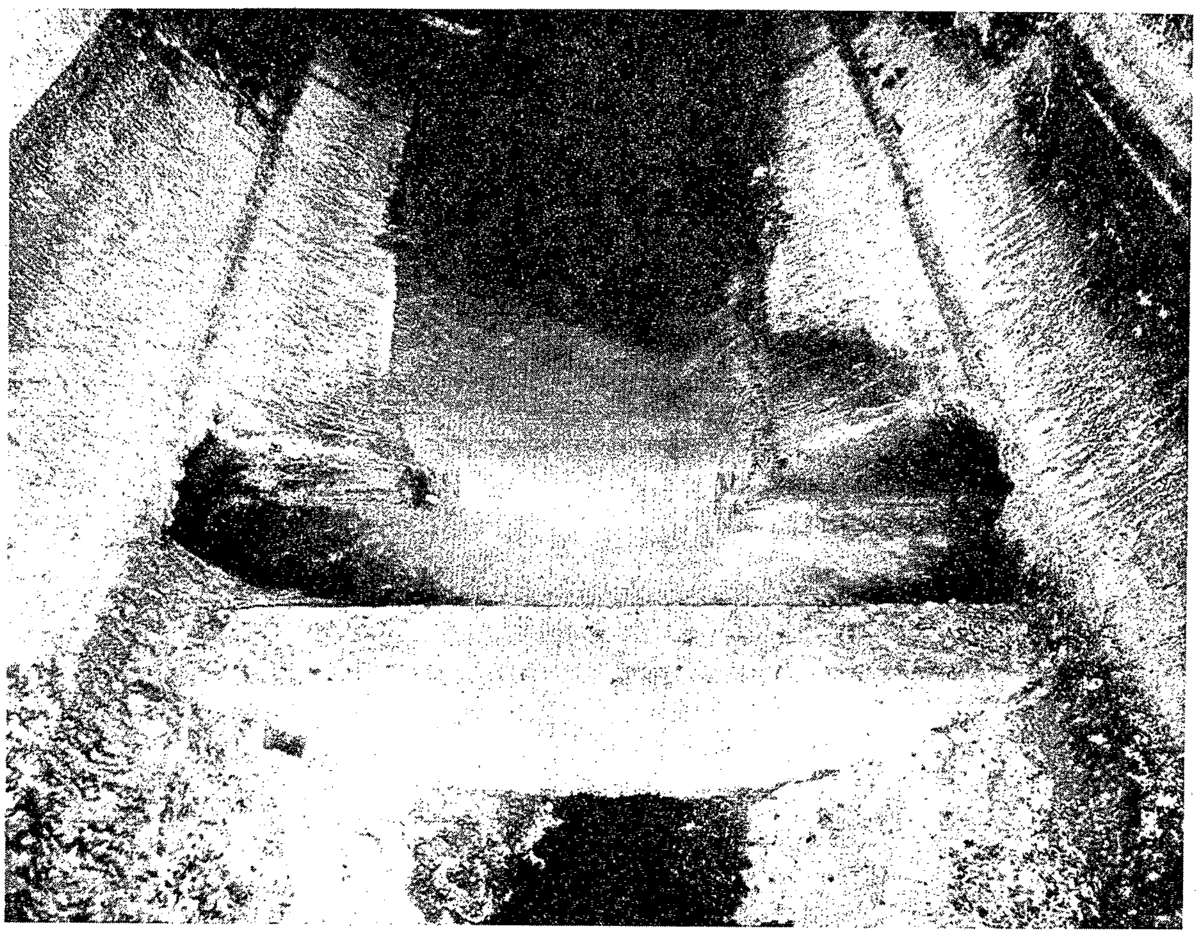
Figure 3, Orifice with Perpendicular Weir, shows a simple diversion device. In this structure the weir was poured in the sewer invert and some dry-weather flow continues to the receiving waters.

Application

The fixed orifice is used to advantage where the intercepted flow is to be further regulated downstream by a more sophisticated regulating device. The fact that excess flow may be discharged to the interceptor through the orifice during periods of rain, is not significant because of the downstream regulation.

The national survey disclosed that New York City employed fixed orifices for storm-water flows

FIGURE 3



ORIFICE WITH PERPENDICULAR WEIR

less than 4 cfs. The Allegheny County Sanitary Authority (ALCOSAN) has applied them when flows are less than 2 cfs. Such use reflects the practice of other surveyed systems.

Practices in Surveyed Jurisdictions

ALCOSAN uses a total of 116 vertical fixed orifice regulators. The intercepted flow is diverted to a large system of intercepting sewers, which principally carry sanitary sewage and industrial flows to the Authority's treatment works. At the time of design the orifice regulators were considered to be more applicable than mechanical regulating devices when used to divert relatively small amounts of sewage, for the following reasons:

1. Construction cost is low due to small structures and elimination of mechanical equipment except for floodgates (tide gates) when required,
2. Maintenance is confined to cleaning chambers and occasional lubrication of backwater gate hinges,
3. Maintenance can be carried out by unskilled labor,
4. Considering the small flow, the orifice aperture is relatively large, resulting in fewer incidences of clogging, and
5. It functions as a relief for a surcharged interceptor.

A regulator using two vertical fixed orifices was also reported by ALCOSAN. An engineering report prepared by consulting engineers to the Authority stated that, ideally, the regulator structure should offer minimum resistance to small flows being diverted, and maximum resistance to large flows to the interceptor. Since these ideals are somewhat contradictory, a compromise structure was developed which provided:

1. A rectangular orifice mounted in the common wall between the diversion chamber and the orifice chamber: and
2. An orifice chamber having a dry-weather flow channel directed to a circular orifice and outlet pipe, with the outlet pipe having a slope which will generate self-cleansing velocities.

Nine other surveyed jurisdictions reported utilizing 470 fixed orifice regulators. In Detroit, three orifice regulator stations were installed to restrict the flow from the combined sewer to the interceptor. They permit the passage of all dry-weather flow, but restrict excessive amounts of storm flow entering the interceptor. The WWF:DWF design ratio was 1.5:1. The orifices are used on sewers carrying a minimum amount of dry-weather flow.

Officials in Cleveland reported that the 221 orifices in their interceptor-collector system are very effective. The major reasons for this opinion were low capital and maintenance cost, reliability, and absence of major backwater flooding problems.

Milwaukee Sewerage Commission personnel reported that 4-inch orifices or larger are less troublesome than mechanical devices, indicating their concern over the clogging problem.

In New York City, 104 orifice units are in operation, installed at collectors, branch interceptor junctions, interceptors, and at junctions with other systems. They are used to advantage where a number of parallel combined sewers must be intercepted. Instead of installing a complex and costly mechanical regulator on each combined sewer, fixed orifices are used and the intercepted flows from several sewers are conveyed through a branch interceptor to a downstream mechanically controlled regulator. Table 7, 1964 Cost of Regulator, Structure and Tide Gates—New York City, indicates a total cost for this type of regulator facility of from $10,300 to $22,800.

TABLE 7
1964 COST OF REGULATOR, STRUCTURE AND TIDE GATES
NEW YORK CITY

Orifice Diam.	No. of Regulator Structures	Total Cost
12"	1	$12,700
15"	1	11,200
18"	2	16,200-22,800
24"	4	10,300-22,400

Forty vertical orifices have been installed in San Francisco. These are located on collector-interceptor junctions, in locations where the collector continues to the outfall. They are used as part of a structure designed to reduce the backwater effects of tidewater. The regulator chamber is depressed and a channel with a weir diverts flow to the interceptor. A low-profiled, perpendicular weir is placed across the collector invert downstream from the regulator to prevent discharge of dry-weather flows. Past the perpendicular weir, the gradient rises to the outfall. The outfall is protected by a tide gate, which is only submerged when a 7.5-foot tide occurs. In this event, backflow of saline water into the interceptor was reported to cause sludge digestion problems in the waste water treatment facility downstream.

The device, as applied in San Francisco, does not regulate or control the overflow. Its primary purpose is to reduce tidewater backflow into the interceptor system.

B. Fixed Orifice Regulators—Horizontal (The Drop Inlet)

Function

The drop inlet is a static regulator that is analagous to the leaping weir, in that it is a horizontal orifice located at the invert of the combined sewer. It is designed to allow at least the peak dry-weather flow to be delivered via a connecting conduit to the interceptor sewer. Sometimes the drop inlet is referred to as a slot regulator.

Description

Drop inlets are usually housed in a single regulating chamber. However, in the case of small sized collector sewers, manhole access may be sufficient.

Under dry-weather conditions, the peak flow is intercepted. During periods of wet-weather flow, most of the combined wastes pass over the opening and continue to overflow. The positive interception of peak dry-weather flows and the prevention of "jumping over" the inlet without interception during periods of storm flow is induced by placing a low-profiled, perpendicular weir at the downstream lip of the orifice.

The national survey indicated that in almost all cases, the inlet to the connecting conduit was protected from clogging by a grating. These gratings have the added purpose of protecting maintenance crews from the hazard of falling into the downdraft opening.

Applicability

The drop inlet is used when diverting low flows in the order of 2 cfs or less. The interceptor system should be protected by further automatic downstream regulation to prevent surcharging of the interceptor.

The advantages of the drop inlet are:

1. Low initial cost;
2. Simple construction with no mechanical parts; and
3. Simple maintenance by unskilled labor.

When considering the installation and use of the drop inlets, the following problems should be considered:

1. Continuous maintenance of the grates is required. Some surveyed communities reported such maintenance as a 7-day-per-week, 24-hour-per-day problem.
2. Blockage of grates is inevitable during periods of wet-weather flow. In the case of large sewers and large flows, the high volume of combined wastes prevents clearance of the blockage by maintenance personnel during storm flows, with the result that for at least the duration of the storm all suspended and floating solids are permitted to discharge to the receiving stream.
3. Unless a large maintenance staff is available to remove the debris from the orifice grating immediately after the storm, dry-weather flow, i.e., raw sanitary sewage, will pass over the inlet and overflow into the receiving stream.

Practices in Surveyed Jurisdictions

Drop inlets are in use in five surveyed systems. The design criteria established for the interception, pumping and sewage treatment system for Akron provide diversion facilities handling two times the estimated water consumption in the tributary area, plus an allowance for infiltration and for increased future waste water flows. The inlet is satisfactory when diverting peak sanitary flows which approximate one-fifth of the pipe capacity. However, when operating under wet-weather flow conditions, from 2.75 to 5 times dry-weather flow will be intercepted unless the inlet connection pipe from the orifice to the interceptor is restricted so as to throttle this excess flow. Such a design modification is presently being considered.

Studies to determine the performance of inlet gratings indicate that for 36-inch and 48-inch diameter combined sewers, gratings may be suitably selected without inhibiting the delivery of flow to the interceptor. Inlet gratings were standardized in two basic sizes and frames of different sizes are used with combinations of these standard gratings.

The cost of these regulators ranged from $1,500 to $2,000 each.

Because the drop inlets with gratings are subject to a large amount of maintenance to keep them clear of refuse, a monitoring system has been established in Akron. Sensors monitor flow conditions in the interceptor and the collector. These serve to alert maintenance personnel when gratings are blocked.

In Omaha, 25 units of this type are in use. They were chosen many years ago when limited sewer size and flexibility of control were factors. At that time, treatment of waste water was not required and the prime consideration was relief of surcharge in combined sewer mains due to lack of capacity. Present plans call for the elimination of at least half of these units.

In Cincinnati MSD, 141 grated drop inlets are utilized to avoid overloading of the interceptor sewer. A telemetering system is used to monitor overflows and advise personnel where and when overflows occur, and to record how often overflows take place. The monitoring system alerts maintenance personnel when clogging at the inlet grate occurs.

C. Leaping Weirs

Function

Leaping weirs are located at the invert of the combined sewer and are designed to allow at least the peak dry-weather flow to drop through it via a connecting pipe to the interceptor sewer. Under wet-weather flow conditions the increased velocity and depth cause most of the flow to leap over the opening and continue to the outfall.

An adjustable orifice plate may be an integral part of the design. Installed over the opening, this plate can be adjusted as part of the field operation, so that the quantities of sewage to be intercepted or diverted to overflow may be varied to satisfy downstream interceptor conditions.

Description

Two types of leaping weirs were found in use during the national survey:

1. The continuous invert leaping weir, as the name implies, is a horizontal orifice placed at the invert of the combined sewer with no special modifications to the conduit configuration; and
2. The stepped invert leaping weir has a raised upstream lip, the downstream lip being the invert of the combined sewer. This raised lip may be a part of the regulator chamber design and constructed of concrete for a new installation; alternatively, in the case of existing combined sewers, a plate may be installed.

During dry-weather flow conditions, the orifice of the leaping weir intercepts all sanitary sewage. During wet-weather flow, much of this excess flow is presumed to leap over the weir to discharge at the overflow. In practice, however, these devices are subject to "jumping over," with the result that almost all of the combined sewage will overflow. In an attempt to insure that dry-weather flow volumes will be intercepted at all times, some leaping weirs have been designed so that the orifice is tipped up at the downstream lip, usually by means of a low profile perpendicular weir. This has the effect of arresting and intercepting a portion of the flow. By using the dam, heavier solids in the stream flow are intercepted for conveyance to the treatment facility.

Applicability

The leaping weir is usually applied when intercepting small flows. As in the case of the vertical orifice, design capacities have been limited in practice to a maximum of 4 cfs. On the average, the national survey indicated that interception of a maximum of 2 cfs was most acceptable. They therefore are used frequently in local drainage basins where flows are low and mechanical equipment for regulating purposes might not be economically justified. Being a compact unit, the leaping weir is well suited for the space limitations generally associated with small capacity sewer main installations. In this application, a special regulator chamber may not be required and manhole access may suffice.

The advantages of this device are as follows:

1. Low capital cost;
2. Useful for interception of small flows in local drainage areas; and
3. Simplicity of the device, permitting routine maintenance by unskilled labor.

Disadvantages included:

1. Control of the amount of flow to be intercepted is difficult to regulate;
2. Under wet-weather flow conditions, all or most of the combined sewage may pass over the opening, and no flow will be intercepted; and
3. Without a regular preventive-maintenance type of operation, blocking or bridging of the orifice will result in the overflow of sanitary sewage and storm flows.

Practices in Surveyed Jurisdictions:

A total of 189 leaping weir units are being used in the surveyed jurisdictions. Philadelphia utilizes 73 leaping weirs. The branch conduit from the weir to the interceptor is terra-cotta. Under present traffic wheel loadings this material has in many instances failed, blocking off the regulator chamber from the interceptor. It was also reported that blockage was more of a problem in industrial areas.

Itemized below is the cost of a leaping weir regulator installation in Philadelphia, including special structures, built in 1963. The regulator was designed for an ultimate flow of 1.35 cfs.

1. Excavation – General	$1,500
– Interceptor	8,000
– Drop Manhole	2,100
2. Intercepting chamber	1,708
3. Drop manhole	1,580
4. Tide gate chamber	3,360
5. Tide gate	1,900
Total:	$20,148

In Cleveland, 103 units are used to divert excess flows from the collectors and interceptors. The interception ratio is being modified for a 4:1 WWF:DWF ratio. Investigations are now being conducted for improvement of the system by centrally controlling and monitoring the operation of regulators. The purpose is to make additional use of in-system storage, thereby reducing overflows. This will render larger leaping weirs obsolete. Cost of these units, when built in 1964, was $1,500 to $3,200.

Six leaping weirs are used on the collector sewers at the interceptor junction in the Milwaukee

Sewerage Commission system.

D. Manually Operated Gates

Function

The purpose of a manually operated gate is to permit flow through a vertical orifice, the opening of which may be varied by manual adjustment. As in the case of the fixed orifice, this regulator consists of a perpendicular weir constructed across the channel of a combined sewer, which directs peak dry-weather flow to the interceptor through an orifice. The size of the orifice and, consequently, the amount of combined sewage intercepted, is a function of the position of the gate. During a storm, additional wet-weather flow discharges over the weir to overflow. Figure 4, Typical Manually Operated Gate Regulator—Philadelphia, illustrates a typical installation. Figure 5 is a photograph of a typical orifice with a manually operated shear gate.

Description

The manually operated gate regulator consists of two chambers. The first, for diversion purposes, consists of a perpendicular weir positioned across the combined sewer channel, which diverts normal dry-weather flow into the second or orifice chamber. The height of the dam is restricted in order to minimize backwater effects in the upstream collection system during storm flows.

The orifice chamber consists of a channel with a gate seated on the outlet orifice, which is preferably located on the common wall between the orifice and diversion chambers. A branch sewer conveys the flow from the orifice chamber to the interceptor. The manual unit may be a shear or sluice gate. Slide gates are used in open flumes and are not tight enough for this purpose. Openings in shear gates are adjusted by raising and lowering the gate by means of a lifting handle generally two feet long and held open by attaching the handle to a hook on the wall. Sluice gates may be self-contained gates with the operating mechanism attached to the top of the frame, or may have a bench stand mounted on a wall bracket or a floor stand mounted on the floor above the gate. In either case the gate is operated by manually turning a wheel or crank which may or may not be connected to reduction gears.

Applicability

The major advantages of the manually operated gate regulator are:

1. It provides greater control than an orifice;
2. It is simple to adjust to meet desired operating conditions;
3. Capital and maintenance costs are low; and
4. It may be possible to adapt it for motorized and remote control.

Manually operated gates are subject to clogging, particularly if circular orifices and gates are used, as debris has a tendency to jam in the two sides of the crescent-shaped opening formed when the gate is partially closed.

The setting of the gate should be calculated on a conservative design flow, as excessive amounts of water may be diverted to the interceptor under storm conditions, due to upstream surcharging and the subsequent pressure head which is developed. In applications in New York City, as much as six times the dry-weather flow has been diverted for a system designed to intercept a WWF:DWF ratio of 2:1.

Some surveyed jurisdictions reported the use of manually operated gates to throttle wet-weather flows and protect pumping stations and waste water treatment facilities from surcharging. In this application, the regulating station was between the interceptor and the plant facility.

Manually operated gates have been used in several jurisdictions as a temporary substitute for more sophisticated equipment. One inherent advantage of this type of regulator, whether temporary or permanent, is that it is adaptable to automatic operation and remote control.

Practices in Surveyed Jurisdictions:

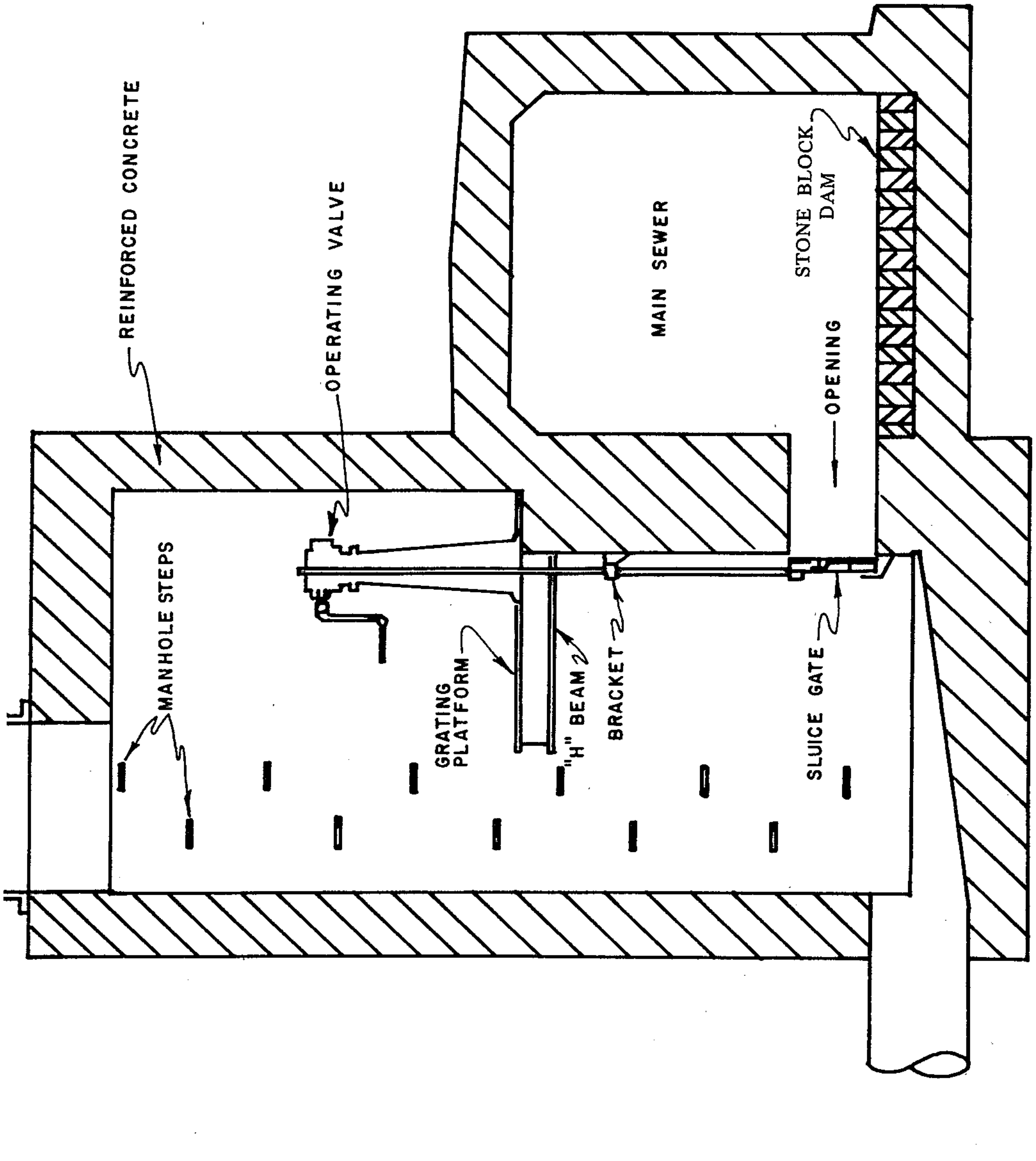
In Chicago MSD, a total of 328 such regulating stations are in use. The design criteria for the system provide for twice the dry-weather flow to be intercepted, with manually operated gates being fixed to accept 1.5 times peak dry-weather flow, and the remaining wet-weather flow being discharged to outfall. Shear gates are used at 260 regulating stations. One hundred and twenty-five units are replacements for float-operated gates, which were found to be unsatisfactory because of excessive clogging, corrosion of shafts and jamming of float mechanisms.

For installations requiring more than three square feet of orifice opening, sluice gates are used in the Chicago system and 23 regulating structures of this type are presently in service. They were selected because of ease of operation in larger sizes.

The cost of the regulator installation in Chicago, including special structures and equipment, ranged from $6,000 to $200,000, depending on the size and complexity of the regulator structures and their location.

In New York City, 62 manually operated gate regulators are in use. Their choice was based on simplicity and economy, and the fact that more accurate control of flows less than 4 cfs. was not required. The gate is usually set with a minimum opening of 4 inches and is operated on a regular basis

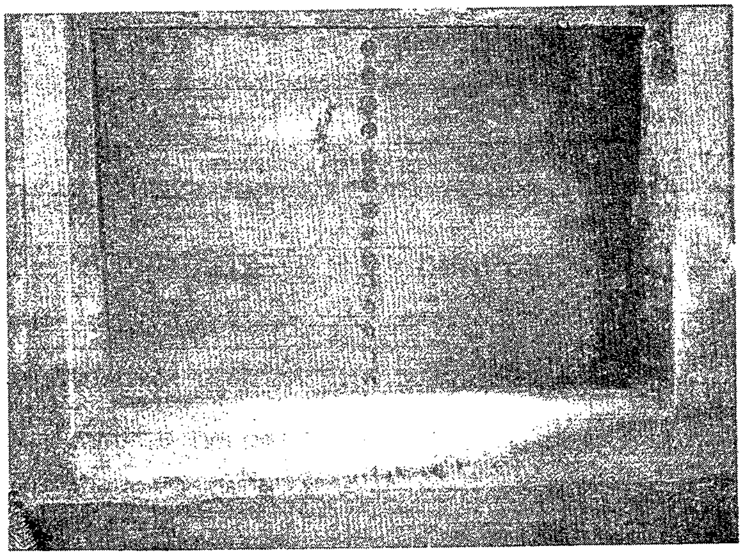
FIGURE 4



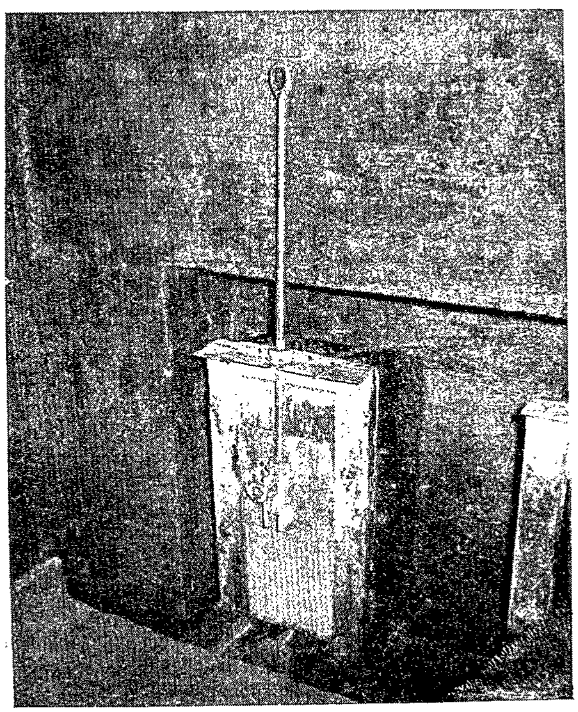
TYPICAL MANUALLY OPERATED
GATE REGULATOR
PHILADELPHIA

FIGURE 5

ORIFICE WITH MANUALLY OPERATED SHEAR GATE
NEW YORK CITY



Typical dam and backwater gate.
Orifices are to right of gate.



Typical orifice with shear gate.

to prevent freezing or jamming. The minimum size of gate is 8 x 8 inches, or 12 inches diameter, for flows less than .4 cfs. Because a certain minimum opening must be maintained, the diverted flow during storms may exceed the desired interceptor WWF:DWF ratio.

In the future, New York City intends to use cast iron shear gates, instead of the present sluice gates, with provisions for setting the gates at various openings.

In Philadelphia, five manually operated gates are utilized at a particular group of collector-interceptor junctions as a temporary expedient, pending motorization and an overall systems program in that area.

E. Side-Spill Weirs

Function

The side-spill weir is a static regulator which consists of a standard weir constructed parallel to, or at a slight angle to the flowline or axis of the combined sewer. As flow in the combined sewer increases, the weir is crested and overflows to the side, to be discharged into the receiving stream. Peak dry-weather flow and some portion of the wet-weather flow continues past the weir, to be further regulated downstream. Figure 6, Side-Overflow Weir for Small Overflow, illustrates an example of this device for small flows.

Description

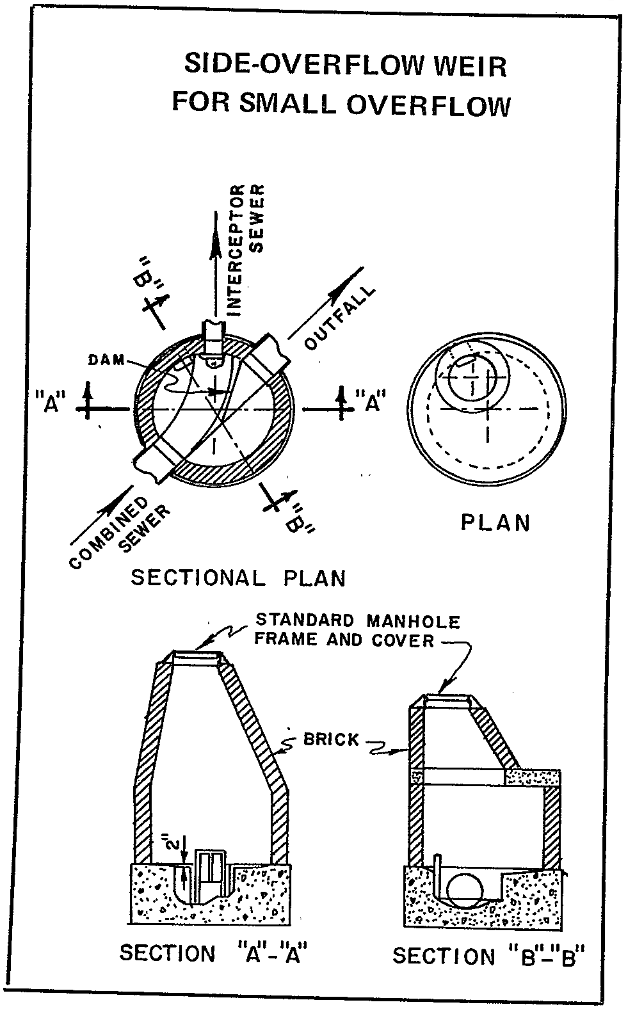
Side-spill regulators are used principally to divert relatively small flows where, because of pipe sizes, space is limited and mechanical regulating devices would be uneconomical and difficult to maintain. Two types of side-spill weirs are in use: low side-spill weirs; and high side-spill weirs.

Low side-spill weirs consist virtually of side weirs formed along the length of a combined sewer by cutting away the sides of the conduit. They are located below the horizontal diameter of the pipe. They are economical, easy to operate, easy to maintain, and they function with negligible head loss in the main channel. However, they do present several basic problems. Their hydraulic behavior is difficult to analyze and large errors in calculating flows overflowing the weir or continuing downstream are probable. Any downstream problem or slight increase in combined sewer flow rate results in a premature overflow, discharging sanitary sewage to the receiving stream. This poor control of discharge over the weir is undesirable for three reasons:

1. The overflow spills too much of the highly polluting first-flush, if this occurs, and spills too frequently in small storms;
2. In larger storms, too much flow is passed on to treatment; and
3. Floating solids easily pass over the weir to outfall during periods of slight increase in combined sewer flow.

The weir crest in high side-spill weir applications is above the horizontal diameter of the pipe and preferably near the sewer crest elevation. The amount of flow continuing down the combined sewer past the overflow is not as variable as with the low side-spill weir. The degree of control of the volume which overflows is dependent on the length of weir used. Rule-of-thumb design indicates that, on the average, the successfully operating high side-spill weir length equals 20 times the diameter of the inlet sewer. In England, because of unsatisfactory experience with conventional side-spill weirs, this type of regulator is in frequent use. Unlike the conventional weir, the flow continuing downstream is controlled either by

FIGURE 6



an orifice or a "throttle pipe." A single regulating chamber is required. Access should be provided through the roof of the chamber to a platform at both ends of the weir.

Application

The side-spill weir is used in upstream parts of the sewer system to prevent surcharge of combined sewers. As an area becomes developed, these existing combined sewers may become overloaded so that relief storm sewers are constructed, carrying storm water directly to overflow. Many years ago, this device was used on large collectors and interceptors where they functioned as surcharge relief units. The principal advantage of the side-spill weir regulator is its low capital cost and the fact that it rarely needs maintenance, and that maintenance which is required may be carried out by unskilled labor.

Practices in Surveyed Jurisdictions

The New York City, Cincinnati and Cleveland systems are using side-spill weirs on small local combined sewers to serve as relief overflows. The policy in New York City is to further control diversion downstream by means of an automatic or semi-automatic regulator station.

The Metropolitan District Commission (MDC), Boston, indicated that 111 side-spill weirs were installed during the period 1893 to 1936. The elevation of the crest of the weir in the original design provided for overtopping of the weir when experiencing a rainfall rate that represents a WWF:DWF ratio of 2:1. These units were located principally at junctions with other systems. However, 10 were located on the interceptor and one at the treatment plant.

Because of tide gate operation problems, backflow into the collector and interceptor system caused damage to the downstream system. Consequently, the MDC had side-spill weirs raised and blocked off with timber in a majority of their installations. The MDC reported that, for all practical purposes, they had discontinued overflow operations, since this timber shoring had raised the crest of the weir to such a height that overflows take place only under rainfalls of hurricane proportion. Discontinuance of regulation has the effect of surcharging the interceptor and requiring control by other collector-interceptor facilities.

In Cleveland, where 234 side-spill weirs are in service, the design WWF:DWF ratio is 2:1. However, tests have indicated that interception volumes may be as high as 9:1. Cincinnati MSD plans to reduce its ratio to 4:1. Installation costs in Cleveland were reported to be between $750 and $21,000 each.

F. Siphons

Function

Siphons of the internal, self-priming type are static devices which may be used to regulate flows from the collection system to the interceptor, or they may function as overflow units, thereby controlling the amount of flow discharged to the overflow.

If the combined sewer does not have sufficient depth, a chamber may be required at the diversion point. This chamber acts as a stilling basin by constricting the downstream outlet, throttling the flow and creating sufficient head to activate the siphon.

Description

The siphon regulator is used where obstruction or elevation problems do not permit the use of a vertical fixed orifice with branch interceptor. In the case of dry-weather flows, it may be used to control the water level in a conduit leading to treatment facilities or pumping stations by discharging excess flows to receiving waters when the water level rises above a certain maximum.

To control overflows, one or more siphons are used to discharge excess wet-weather flow from the collector. In this case, a large chamber is required. The downstream outlet is constructed to carry peak dry-weather flow and some portion of the wet-weather flow. The remainder of the flow is collected in the chamber and discharged through the siphons.

The inlet to the siphons is set well above invert level and below top water level to avoid, as far as possible, the carry-over of either heavy or floating debris. Use of a scum board or vertical baffle ahead of the entrance to the siphon will reduce the amount of floating material discharged to overflow.

Maximum operating sewage level in the interception chamber at Omaha is normally established at from 160 to 185 percent of the inlet sewer diameter.

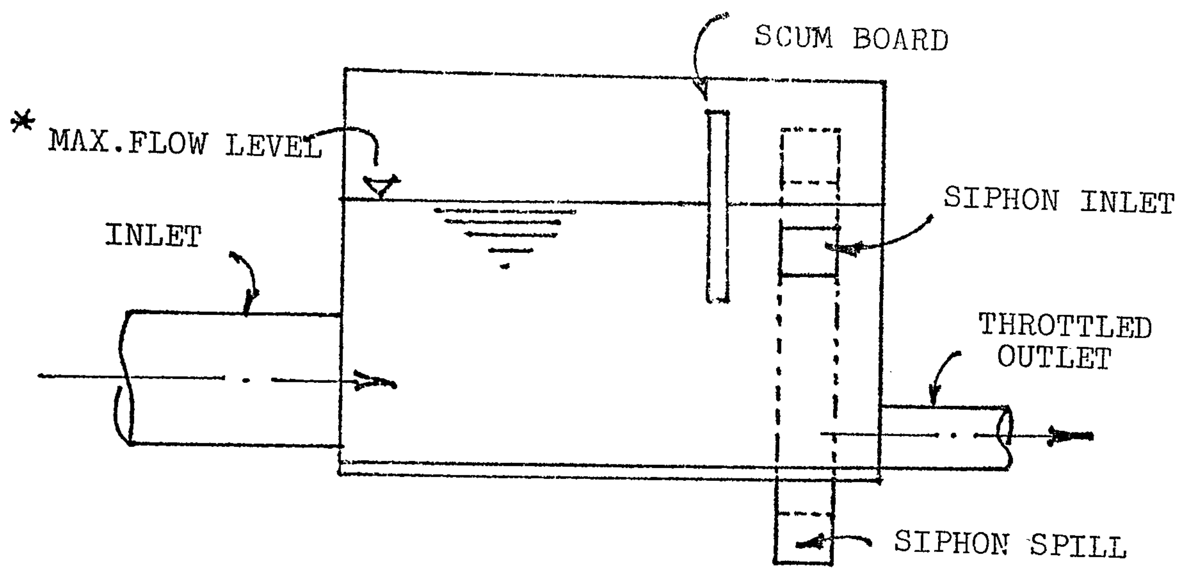
Applicability

Clogging is a prime consideration in siphon design. The positioning of the orifice in the diversion chamber is of major importance in preventing clogging. Furthermore, a minimum diameter of 12 inches is recommended. Siphon velocities are considerably higher than normal combined sewer flow rates and the operating head on a siphon is considerably greater than the allowable head above other static devices. Consequently, the diversion chamber may be quite compact, reducing capital cost.

During periods of overflow, the upstream level entering the diversion chamber does not rise above priming level. Consequently, the available storage

FIGURE 7

SIPHON OVERFLOW – OMAHA



*Maximum flow level set by design. Standard depth is 1.6-1.85 x inlet diameter.

capacity of the sewer and the diversion chamber may be used to advantage.

The principal advantages of the siphon overflow are:

1. Capital cost is low;
2. Materials used are not subject to corrosion;
3. Maintenance may be performed by unskilled labor; and
4. Quality of overflow can be better than in other regulator devices.

The principle disadvantages are created when the device clogs. If the clogging takes place in the siphon tube itself, all flows must be diverted in another manner, and the removal of the obstruction is arduous. To prevent this clogging, it may be desirable to protect the opening to the siphon with a grating similar to that used with drop inlets. This would protect the siphon and as the opening is vertical, there would not be as great a degree of plugging as the horizontal drop inlet grating. In congested areas, odor may be emitted to the atmosphere, as venting is generally required to reduce turbulence and prevent air lock for proper siphon operation.

Practices in Surveyed Jurisdictions

Omaha, Nebraska, was the only community interviewed in the national survey which used siphons. The 26 units in service were installed prior to 1940. Because of the difficulty in restoring these regulators to operation once they become clogged, the community is considering replacing siphons with another type of regulator. Figure 7, Siphon Overflow–Omaha, is a cross section of a typical siphon overflow.

Dynamic Regulators–Semi-Automatic

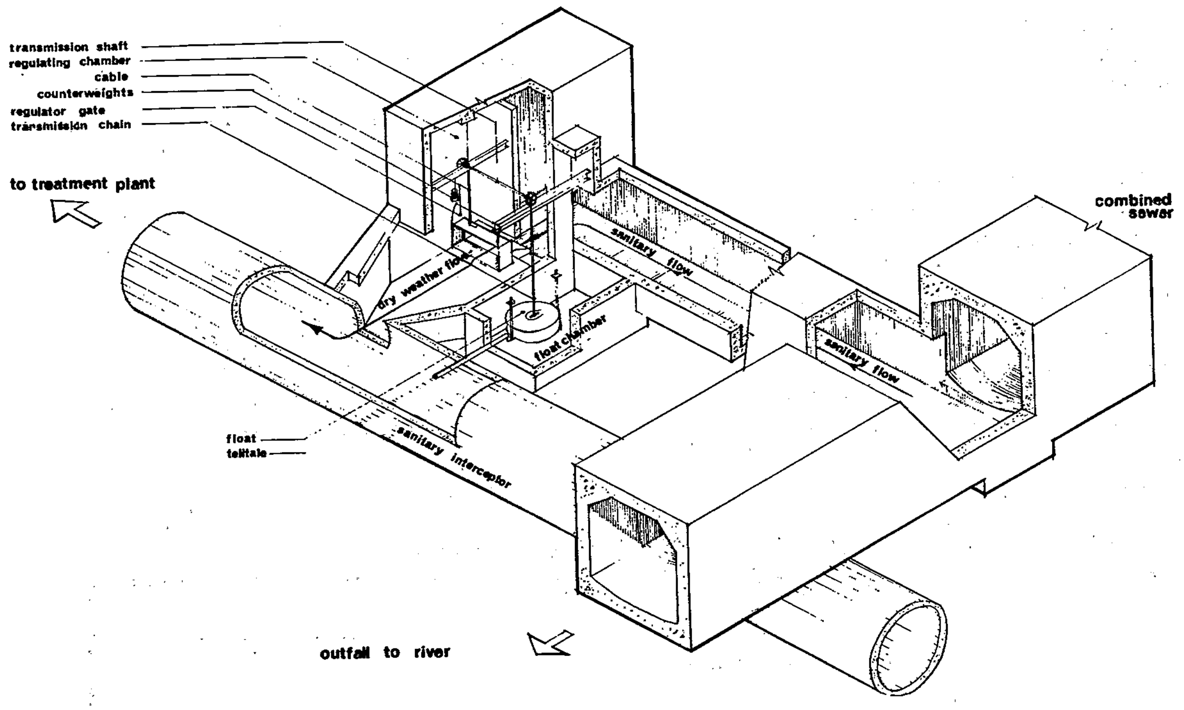
A. Float-Operated Gates

Function

Float-operated gates regulate the flow through an orifice. In its common application, a predetermined maximum flow of sewage is diverted from the collector sewer into the regulator chamber by means of a perpendicular weir placed across the sewer channel. The gate is directly controlled by a float placed in a separate well, with the water levels in this float well being determined by the flow level in either the collector or the interceptor, depending upon where the regulation is desired.

This is a semi-automatic device, which does not require any external energy source for operation. Figure 8 is an isometric view of a float controlled regulator as installed in Detroit. Figure 9 is a detailed

FIGURE 8



ISOMETRIC VIEW
FLOAT CONTROLLED SEWER REGULATOR

Courtesy Detroit Metropolitan Water Service

view of the regulator chamber.

Description

The regulator will consist of two, and in some instances three, chambers. The first, or diversion chamber, consists of a perpendicular weir with its crest a maximum of 6 inches above the invert of the combined collector sewer. The 6-inch crest height is usually chosen in flat areas to minimize backwater effects. The sewer invert may be depressed to increase the flow velocity to the interceptor. The 6-inch height is measured from the normal invert elevation. Peak dry-weather flow is diverted into the second, or regulating chamber by means of this weir which is low profiled, so as to reduce the hazard of backwater damage upstream. The collector channel may be depressed at the face of the weir, in order that peak dry-weather flow may be diverted without overtopping the dam. During periods of storm flow, quantities in excess of the desired WWF:DWF ratio are carried over the perpendicular weir and are discharged to overflow.

The second, or regulating chamber is subdivided into a float compartment and a gate compartment. If more than one regulator is used at the station, each should have its own float chamber. In most instances, the regulating equipment consists of: (1) A gate unit with a built-in wall casting leading from the combined sewer; (2) A float unit, including a float and float guides with collars for limiting float travel; and (3) A transmission unit, including a shaft with wheels and universal pillow blocks, supporting beams with wall brackets, adjustable transmission chains and counterweights, so positioned that the float itself overbalances the gate shutter when it is buoyed a predetermined distance. The gate shutter is a sector gate, facing upstream.

The float well is directly connected to the interceptor or the collector, i.e., the downstream flow or the upstream flow is connected to the well, thus determining the height of water in the well. In Detroit, each flow chamber is connected to the interceptor by a small-diameter pipe. This pipe is tapped into the interceptor near the bottom but high enough so that it will not be blocked by debris carried along the invert of the interceptor. The water level in the float chamber, therefore, is the same as that in the interceptor. The gate is held open by the float as long as the water level is less than seven-tenths of the diameter of the interceptor pipe. As the level rises above seven-tenths, the gate begins to close and when eight-tenths of the diameter is reached, it is in its closed position.

A third chamber may be employed if a tide gate is required.

Applicability

The orifice plate opening and the float travel is set so that all dry-weather flow and a portion of the wet-weather flow can be diverted to the interceptor.

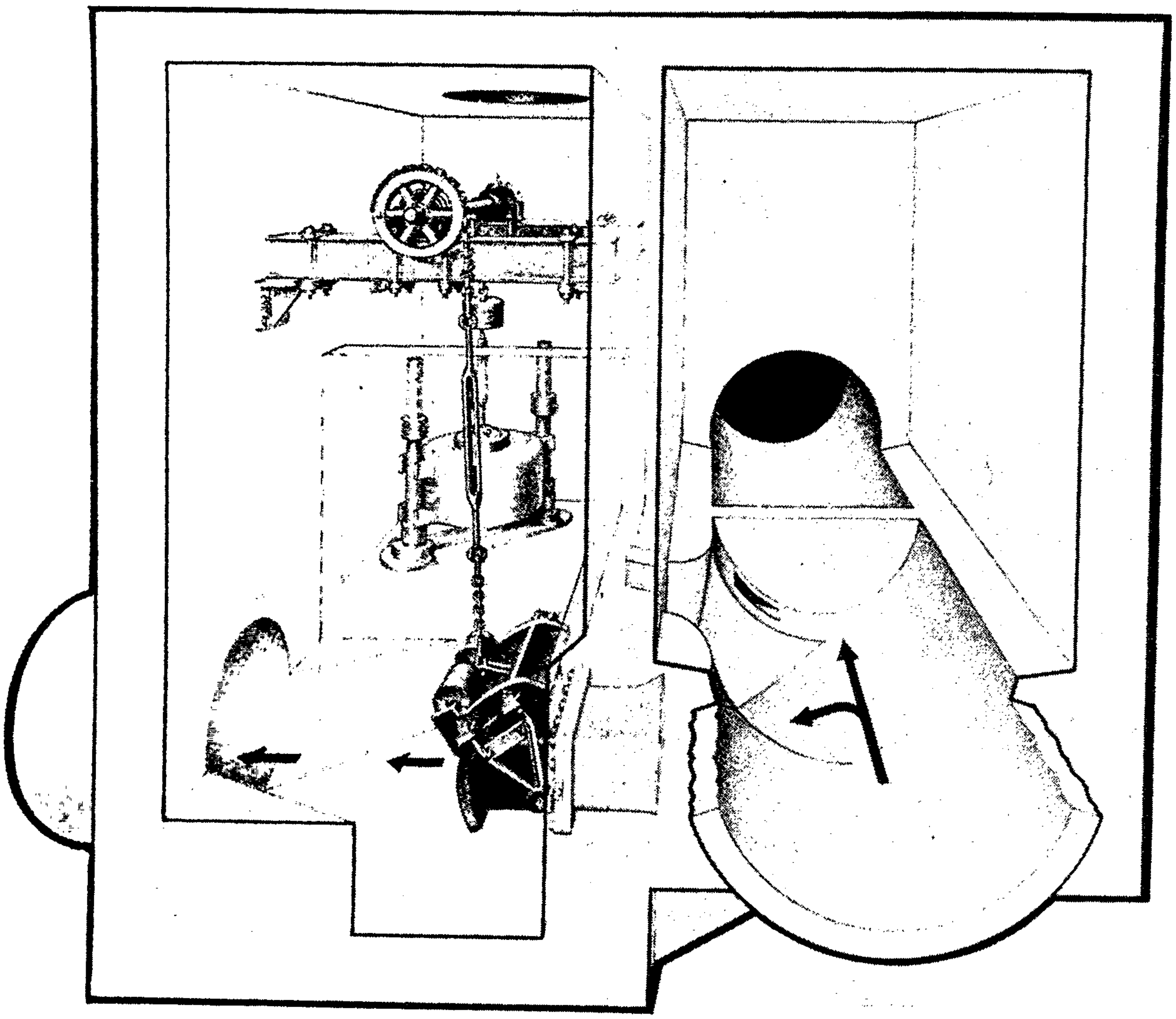
During storm flow periods, the velocity and depth of flow increase in the combined sewer, with a corresponding increase in flow into the regulating chamber. As the float rises, the transmission shaft begins to turn, causing the shutter gate to close. Since the travel of the float is limited by the top float stops on the guide pipes, the shutter gate will always be partly open when the float stops rising.

Depending on the purpose for which the regulator was installed, control of the regulator may be actuated in several ways:

1. If it is desired to restrict the flow to the interceptor when the downstream flow has reached a predetermined volume, the interconnection or telltale pipe connects the float chamber compartment directly to the combined sewer. This application is designed to control the volume of collector sewer flow delivered to the treatment plant facility. Usually, adjustments are made, so that a small opening will remain at the regulator gate, permitting partial flow to the interceptor at all times.
2. If control of intercepted volume is paramount, the type of control, such as in Detroit, connects the float well with a telltale pipe to the interceptor. Overflows do not occur until the interceptor has loaded to a predetermined limit.

FIGURE 9

VIEW OF FLOAT OPERATED REGULATOR CHAMBER



Courtesy Brown & Brown Inc.

3. If it is required to pass a specific quantity through the gate to the interceptor or the collector, the arrangement is similar to type 2, except that an orifice is installed between the regulator gate and the outfall pipe. The regulator is, therefore, acting as a governor, the float being actuated by the level in the regulator chamber, permitting the desired quantity to be controlled with ± 7 percent accuracy. This quantity control is most desirable.

4. The same purpose as described in (3) may also be accomplished by means of headwater actuation. In this instance, the float is retarded by weights which are automatically picked up at predetermined intervals. However, this control requires a float of such depth that it will not be submerged under maximum storm conditions.

Float-actuated regulators have been used for the following reasons:

1. No outside energy source is required;
2. Accurate flow control over a wide range of flow conditions on a presetting or semi-automatic basis can be obtained;
3. A wide range of sizes is available. One firm produces more than 30 different models; and
4. Replacement parts are readily available.

The principal disadvantage of the float-operated gate is that it requires a continuous preventive maintenance program in order to function properly. In Chicago, this problem was considered to be of such magnitude that all 127 float-operated gates were removed in order to reduce maintenance costs.

Practices in Surveyed Jurisdictions

A total of 216 operating units are presently in use in seven of the jurisdictions surveyed. Many of these units were installed more than 20 years ago. They were probably applied because designers favored regulators which operated without external energy requirements. These units were considered semi-automatic and capable of always diverting a portion of the flow to the interceptor. The mechanical operation of the regulator was intentionally kept simple in an attempt to reduce maintenance problems generated by the corrosive sewer atmosphere.

As the interception and overflow of sewage from a combined sewer is controlled at individual locations with this type of regulator, without regard to what may be happening in the rest of the system, the following problem occurred in one surveyed community where the regulators are actuated by interceptor flow.

A storm in the west part of the drainage basin caused a rise in the liquid level in the entire interceptor system. This caused regulator gates in the east part of the area to close and divert flow to the river. Thus, the treatment plant was treating storm water from the west side, while sanitary sewage from the east was being bypassed. It is recognized that this condition existed because the regulator was operated by conditions in the interceptor, but as these units are now of an age to be replaced, that community is studying the feasibility of replacing them with remote-controlled, motor-operated gates.

Originally, float-operated units were supplied with cast iron floats. These were so heavy that the shutter side of the pulley system required counterweights in order to operate effectively, and the bulky system required considerable maintenance. Such floats are now being manufactured of stainless steel and counterweights have been removed from the shutter side of the system and placed on the float side, producing a substantial increase in sensitivity of gate operation together with a significant reduction in weight of the apparatus.

The collection of debris in the float chamber results in the buildup of material beneath the float. In some cases, this has prevented the float from dropping to its seat, with the result that the regulator gate remained partly closed and needless overflow of sanitary or dry-weather flow occurred. To combat this problem inexpensively, regulator stations in some jurisdictions have had asphalt and tar placed on top of the float to add to its weight. In some cases, the regulator has been wired open, thus permitting the unit to operate as a restricted vertical orifice. This problem was especially prevalent in large-size regulators where float diameters were as much as five feet.

If the units are not properly greased, an increased depth of sewage is needed to overcome the initial inertia of the float system, resulting in early overflow of high-strength wastes. When the gate does move, it moves very quickly, causing a quick reaction in the regulator chamber and, to some extent, in the upstream sewer system.

Costs

In 1937, Detroit installed two No. 12 float-operated gates at a cost of $41,300. In 1967, two No. 12 float-operated gates and their special structures were installed at a cost of $168,000.

A regulator designed for an ultimate flow of 5 cfs was installed in an eastern city in 1964. The costs were as follows:

Excavation	$34,200
Chamber and regulator	23,000
Tide gates	12,000
Total Cost	$69,200

B. Tipping Gates

Function

The purpose of a tipping gate is to regulate flow through a fixed vertical orifice. Usually, the peak dry-weather flow is diverted from a collector sewer into a regulator chamber by means of a perpendicular weir placed across the collector sewer channel. The quantity of sewage passing through the regulating chamber, its outlet orifice and connecting conduit to the interceptor is determined by the position of the tipping gate. During periods of wet-weather flow, the surcharge is carried over the dam and permitted to overflow to receiving waters.

Description

The tipping gate regulator consists of two chambers. The first, or diversion chamber, consists of a perpendicular weir, the crest of which, where combined sewer gradients are less than 1 percent, is often a maximum of 6 inches above the invert of the combined collector sewer. Peak dry-weather flow is thus diverted into the second chamber. The weir is low-profiled so as to reduce the problems of backwater damage upstream. The collector channel may be depressed at the face of the weir, so that peak dry-weather flow will be diverted without overtopping the dam.

The second chamber houses the regulator. The tipping gate consists of a rectangular metal plate mounted on a horizontal axis and enclosed in a casting so that the flow diverted to the interceptor must pass under the plate. Stops on the casting permit manual adjustment of the maximum and minimum opening. In dry weather periods the resultant pressure of the water on the upstream side of the gate is below the horizontal pivot of the gate, thus keeping the gate in its maximum open position and permitting all flow to pass through the gate. In storm periods the increase in water level in the combined sewer raises the resultant pressure above the horizontal pivot of the gate, causing the gate to partially close and limiting the quantity of flow diverted to the interceptor. The gate opening is thus reduced but due to the greater head on the gate opening the discharge to the interceptor may be greater than when the gate is at its maximum opening. The gate is set to remain slightly open, permitting a reduced but continuous amount of combined sewage to be diverted to the interceptor.

Following the storm, as the flow rate diminishes, the water level in a diversion chamber lowers, the force against the tipping gate decreases and the unbalanced gate reopens. The tipping gate regulator is a semi-automatic device requiring no floats, pulleys or outside energy source for proper operation.

Applicability

Tipping gates have been used to advantage for flows greater than 4 cfs, where variable flow control is required without instrumentation or automation. The regulator may be adjusted easily in the field by adjusting the gate stop disk which controls the tailgate opening. This adjustment may accomodate diversion of increasing peak dry-weather flow in areas where additional domestic, commercial or industrial sewage is being generated, without increasing the rate of wet-weather flow diversion.

In order to function as designed, the tipping gate requires continual preventive maintenance, since the gates are located in a highly corrosive atmosphere which may cause deterioration of metal components. The pivot shaft must be lubricated frequently to prevent tightening or freezing. The device is also subject to clogging. The gate faces upstream. Its component parts are, therefore, on the dry side of the regulator chamber, facilitating maintenance.

In summary, the principal advantages of the tipping gate regulator are:

1. Moving parts are simple;
2. It is adjustable so that flows to be diverted may be altered to fit changing conditions;
3. Extraneous power source is not required; and
4. Maintenance can be performed on the dry side of the regulator.

The principal disadvantages of this device are:

1. The gate and orifice may frequently clog;
2. Maintenance costs may be high; and
3. The pivot shaft may be subject to sticking, and surcharging of the interceptor or excessive overflows to receiving waters may result.

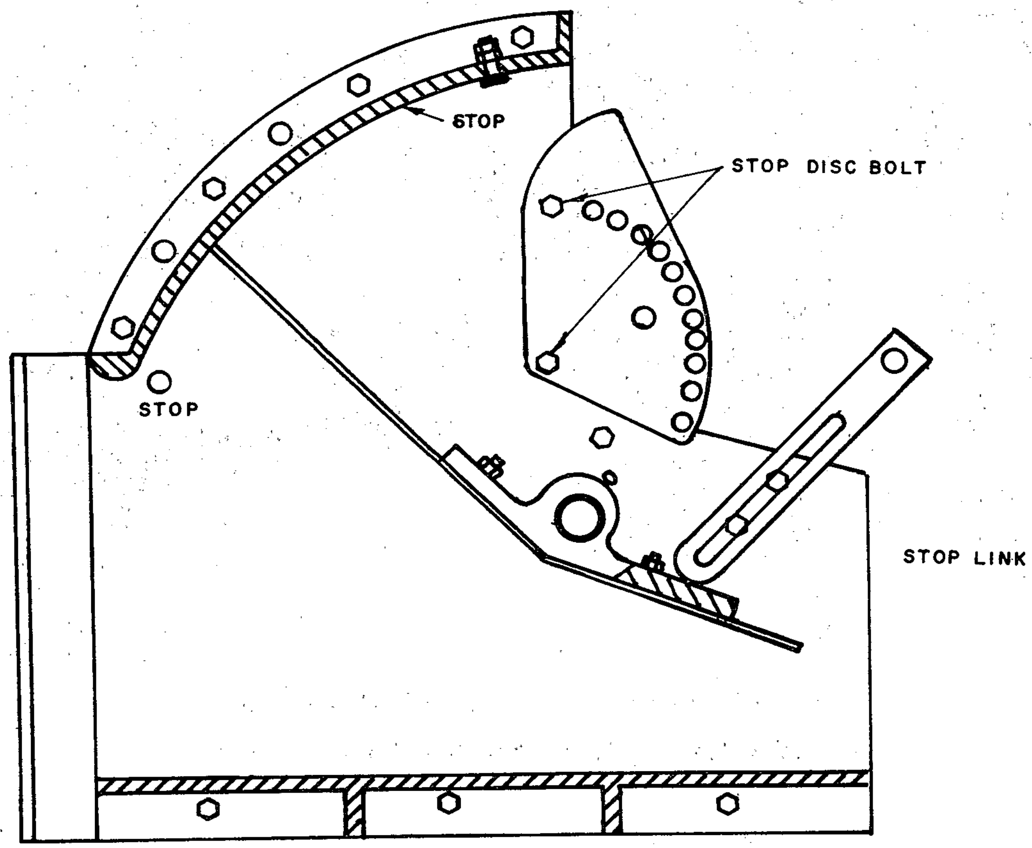
Practices in Surveyed Jurisdictions

In 1959, ALCOSAN installed 147 tipping gate regulators at major collector-interceptor sewer junctions. These were designed to divert 2.5 times dry-weather flow to the interceptor during periods of wet-weather flow. Under heavier wet-weather flows, the gates close, allowing 1.5 times dry-weather flow to be intercepted. The orifice height when opened is 3 to 9 inches and when closed is 1 to 3 inches. The latter restricted opening may cause these units to clog.

ALCOSAN reported the following reasons for choosing this type of regulator: simplicity of operation; adjustability of maximum and minimum discharge to the interceptor; servicing possible from the dry side; hydraulic application suitable for industrial development areas.

Experience has shown that debris collects in the side clearances between the tipping gate and the housing casting, although this does not prevent the gate from assuming a closed position. In some cases it would not open automatically as the flow decreased. In the original application, lubrication of the pivot

FIGURE 10

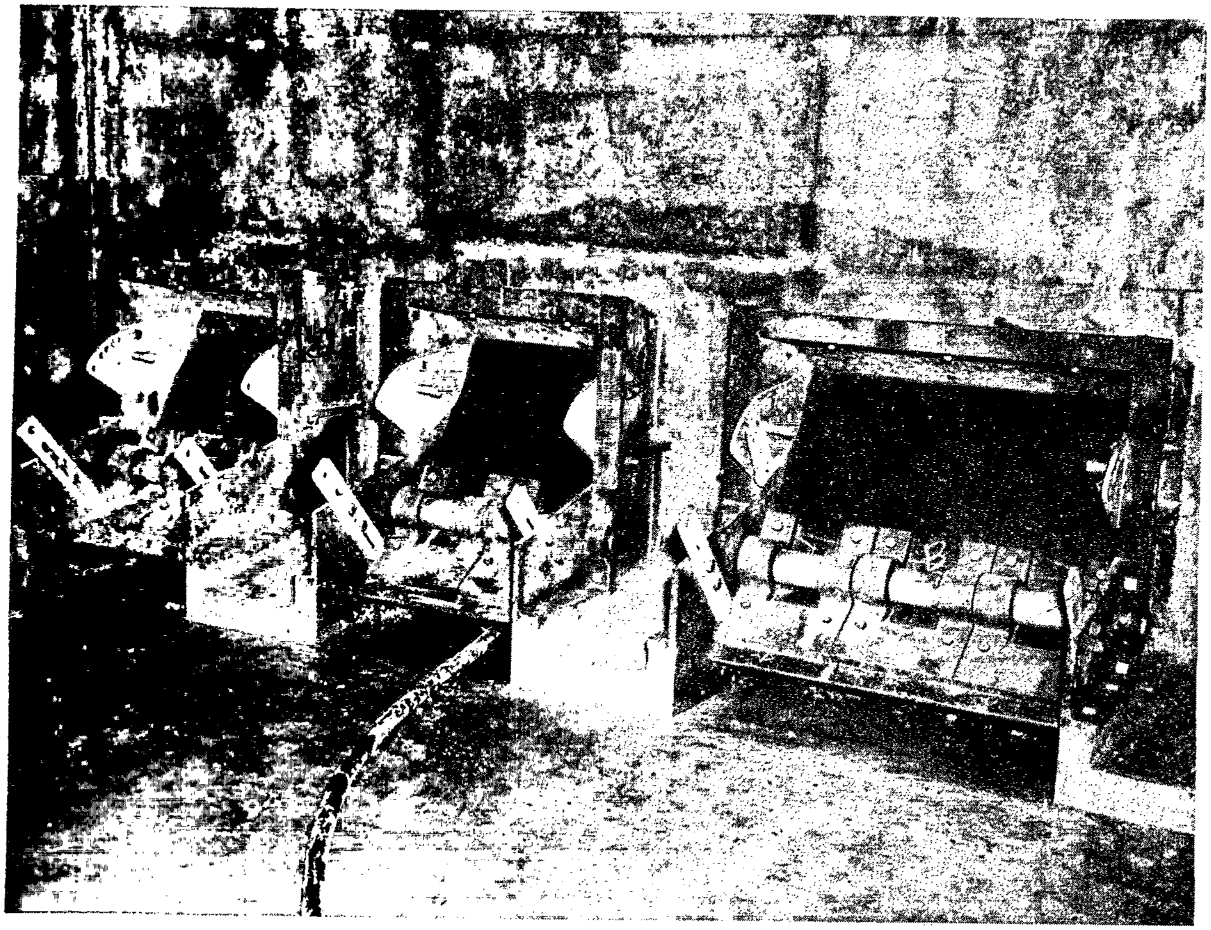


TIPPING GATE

USED BY ALLEGHENY COUNTY SANITARY AUTHORITY

Courtesy Rodney Hunt Co.

FIGURE 11



PHOTOGRAPH OF THREE TIPPING GATES,
ALLEGHENY COUNTY SANITARY AUTHORITY

shaft did not prevent it from corroding and impeding the operation of the gate. This problem has been diminished by using bronze bushings and stainless steel shafts. Figure 10, Tipping Gate Used by Allegheny County Sanitary Authority, shows a cross section of a typical gate. Figure 11 is a photograph of the gates.

Milwaukee Sewerage Commission has used 85 modified tilting gate regulating stations, but has found their maintenance so expensive that they are now replacing them with vertical fixed orifices. These regulators are not true tipping gates but function on the tipping gate principle and have historically been referred to as "The Milwaukee Regulator." In place of a sector gate, a leaf gate is used. Adjustment of the orifice may be accomplished by repositioning the lower plate stop or by adjusting the bottom plate.

Costs

The most recently installed tipping gates are those used by ALCOSAN. The following 1959 costs were reported by the Authority:

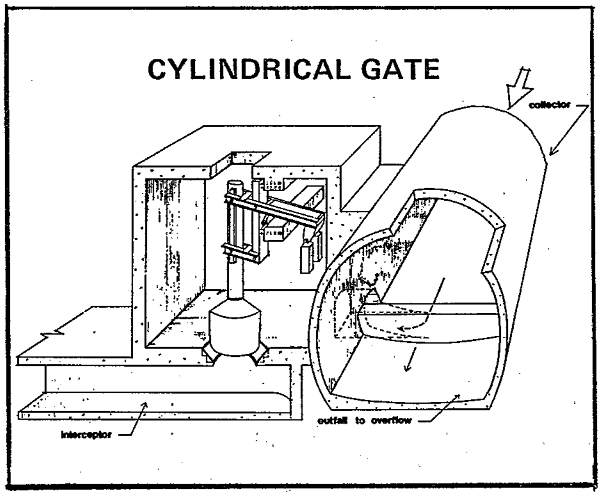
	Gate	Chamber
Tipping gates—12 inch	$1,000	$ 20,000–50,000
Tipping gates—24 inches	2,500	75,000
Two 24-inch & one 36-inch	7,500	170,000

C. Cylindrical Gates

Function

Cylindrical gate-type regulators consist of a dam placed perpendicularly across the channel at the invert of a combined sewer, which diverts peak dry-weather flow through a horizontal orifice located above the interceptor. The flow through the horizontal orifice may be varied by fully or partially closing a vertically oriented, cylindrical gate positioned above the orifice. During periods of

FIGURE 12



Courtesy Neyrpic Canada Ltd.

wet-weather flow, the surcharge is carried over the dam to the outfall.

Description

The cylindrical gate regulator normally consists of two chambers. The first houses the diversion equipment; the second, the cylindrical gate and its appurtenances. A third chamber may be used when a tide gate is required to protect the interceptor from in-flow from rising water levels in the receiving waters at the outfall. All chambers should have separate access points.

The diversion chamber contains a through channel and an overflow dam which diverts peak dry-weather flow to the adjacent regulator chamber.

The regulator chamber contains a vertical hydraulic cylinder, the diameter of which is slightly larger than the orifice below it. The orifice is an inverted truncated cone, which may be protected by a cast iron or stainless steel sleeve. The shape of the orifice permits closure of the gate, if required. The cylinder is connected to a stem and is controlled by two guide arms to a vertical fixed support. The upper guide arm continues past the support and a counterweight is suspended from its end. Neoprene pinions connect the guide arms to the cylindrical gate, the fixed support and the counterpoise, so that unrestricted movement is possible. Neoprene has been used because of its corrosion-resistant character. The gate is sensitive to variations in flow. Stop bars at the orifice will prevent total closure of the gate, permitting a predetermined flow to be intercepted under wet-weather conditions. Figure 12, Cylindrical Gate, illustrates the basic components of the regulator.

Gate closure has a tendency to be sudden and design modifications call for shock absorbers to be installed from the fixed support to the cylindrical gate to dampen the closure action.

Applicability

The cylindrical gate may be adjusted to be sensitive to upstream or downstream flow conditions. Upstream control is effected when the flow into the regulator chamber exceeds the rate exiting through the orifice. In this case, the sewage backs up in the chamber. As the water rises above the cylindrical gate head, its weight and the velocity of water rushing through the orifice overcomes the counterweight and the gate descends. The volume of flow diverted is controlled in design by the size of the orifice used and the weight of the counterpoise.

When in the closed position, the remaining wet-weather flow is permitted to flow over the diversion dam and discharge to the outfall. When the inflow recedes and the head of water above the cylinder diminishes, the counterweight opens the gate.

The interceptor flow may also be used to control the operation of the cylindrical gate. In this instance, an aspirator is linked between the cylinder gate in the regulator chamber and the interceptor, with the open end of the aspirator being located a predetermined distance below the crest of the interceptor sewer. The remaining configuration in the regulator chamber is as previously described. The gate is opened and balanced as long as the pipe to the interceptor can "breathe." When the flow level in the interceptor increases, covering the mouth of the aspirator, a partial vacuum occurs, pulling the cylinder down to close the orifice. In this application, the cylinder head is partially submerged under peak dry-weather flow conditions.

Some of the advantages of the cylindrical gate regulator are:

1. No mechanical moving parts are submerged;
2. No gear or chain-driven mechanical components are required;
3. Appurtenances are kept to a minimum and no floats or float chambers, and their required maintenance are needed;
4. Capital cost is low for an adjustable mechanical device; and
5. Maintenance costs are low, when compared to other mechanical gates.

The principal difficulties encountered in the application of these gates are:

1. Closure, unless restricted, can be violent, causing damage to the regulator, its components, or the orifice; and
2. The cylinder is very large in relation to other

mechanical devices. Adequate provision must be made for access from the surface in case the cylinder has to be removed or replaced.

Practices in Surveyed Jurisdictions

This is a newly developed regulator and presently is used only in Montreal on this continent. Four regulator stations each house from one to three cylinder gates in that city. They have been in use for three to four years and cost from $20,000 to $75,000, including all structures and special appurtenances. The units have been relatively maintenance-free.

3. Dynamic Regulators—Automatic

A. Motor-Operated Gates

Function

The regulator consists of a perpendicular weir constructed across the channel of a combined sewer, which permits peak dry-weather flow to be intercepted through an orifice. The orifice is sized to accept the maximum amount of combined sewage to be intercepted. Variations in this quantity are achieved by operating a motor-driven gate. During a storm, quantities of combined sewage greater than that acceptable to the regulator are discharged over the weir to the overflow. Figure 13, Motor-Operated Tainter Gate, is a photograph of a typical gate, usually constructed in a sewer to obtain the desired interception capacity.

Description

The motor-operated gate regulator consists of three chambers: one for diversion purposes; the second for housing the gate and the orifice; the third, vertically mounted above the regulator chamber for housing the energy sources. A fourth chamber is needed when tide gates are used.

The diversion chamber contains a perpendicular weir placed across the combined sewer channel, which is used to divert the flow into the regulating chamber. The height of this weir is restricted to prevent backflooding of the upstream system.

The regulator, or gate chamber, consists of a channel with a gate seated on the outlet orifice. The outlet orifice is connected by a branch conduit to the interceptor. The gate may be a sluice gate, connected by a stem through the roof of the chamber to the operating chamber.

The operating chamber contains a gearing assembly, an electrical impulse motor, such electrical hardware as is required, and a gas or diesel standby energy source. Corrosion can be troublesome in the humid, acid atmosphere of a combined sewer system.

FIGURE 13

MOTOR-OPERATED TAINTER GATE.
NEW YORK CITY

When this chamber is located below ground, it is forced-air ventilated. The use of dehumidifiers may also be a requirement. When possible, the chamber is located above grade. Since the motor mechanisms are separately housed apart from the regulator chamber, the regulator gate functions even if submerged. Figure 14, Motor-Operated Gate, Municipality of Metropolitan Seattle, is a detailed plan of a typical installation as used in Seattle.

The electric motor-driven gear assembly is of heavy cast iron mounted on a cast iron pedestal. The assembly system is so set that the motor will attain full-rated rpm before stem loading commences. Each gear assembly may also be provided with a handwheel or crank of manufacturer's specification relative to gate size, so that manual operation of the regulator is possible.

Limit switches are provided as an upper-limit torque-governor, to protect the stem and gate against damage if any obstruction is encountered during opening or closing operations of the regulator.

Originally, motor-operated gates were used where maintenance personnel had difficulty manually operating gates because of their size. More recently, they have been used as part of a system controlling flows by remote control monitoring.

The motor, and consequently the regulator, is activated by a sensing probe, which records the sewage level in the control section. When a predetermined maximum sewage level in the control section is reached, the sensor transmits a signal which excites the electric motor. The probe may also transmit a continuous signal to a remote location and provide a record of flow levels and gate operations. Indications of operating problems, thereby, may be transmitted to maintenance personnel as they occur.

Applicability

Operation of the gate may be controlled by downstream or upstream flow levels, the former being most commonly used. Under dry-weather flow, the gate is fully opened and peak dry-weather flow is intercepted. During periods of storm, additional flow passes through the opening to the interceptor and the sewage level rises. At a preset level, the sending probe signals to, and activates the electric motor. The gate then gradually closes off a portion of the opening, limiting the flow to the interceptor. If the water level in the interceptor continues to rise, the gate is closed further. This procedure continues until a stable condition exists in the interceptor. As the liquid level in the interceptor recedes below the previous level, the process is reversed and the gate is gradually opened. This operation is fully automatic, consequently the gate will continuously "hunt" for the most advantageous position with respect to interceptor flow conditions unless a time delay is imposed on the operating controls. Delays of three to five minutes have been used to decrease wear.

The motor-operated gate is used where large quantities of combined sewage are to be handled. It permits variation in interceptor flows and overflows depending on the particular operating condition, and is readily adaptable to remote control. It is used for flows greater than 4 cfs, where automatic regulation of intercepted flow is desired.

The ability to remotely control the interceptor system flows and the flows to pumping or sewage treatment facilities, through impulse sensitive regulators, permits maximum utilization of the interceptor and collection system storage capacity. This results in as full use of sewage treatment facilities as possible while reducing, within the absolute limits of the system, the quantity, and improving the quality of overflow discharged to receiving watercourses.

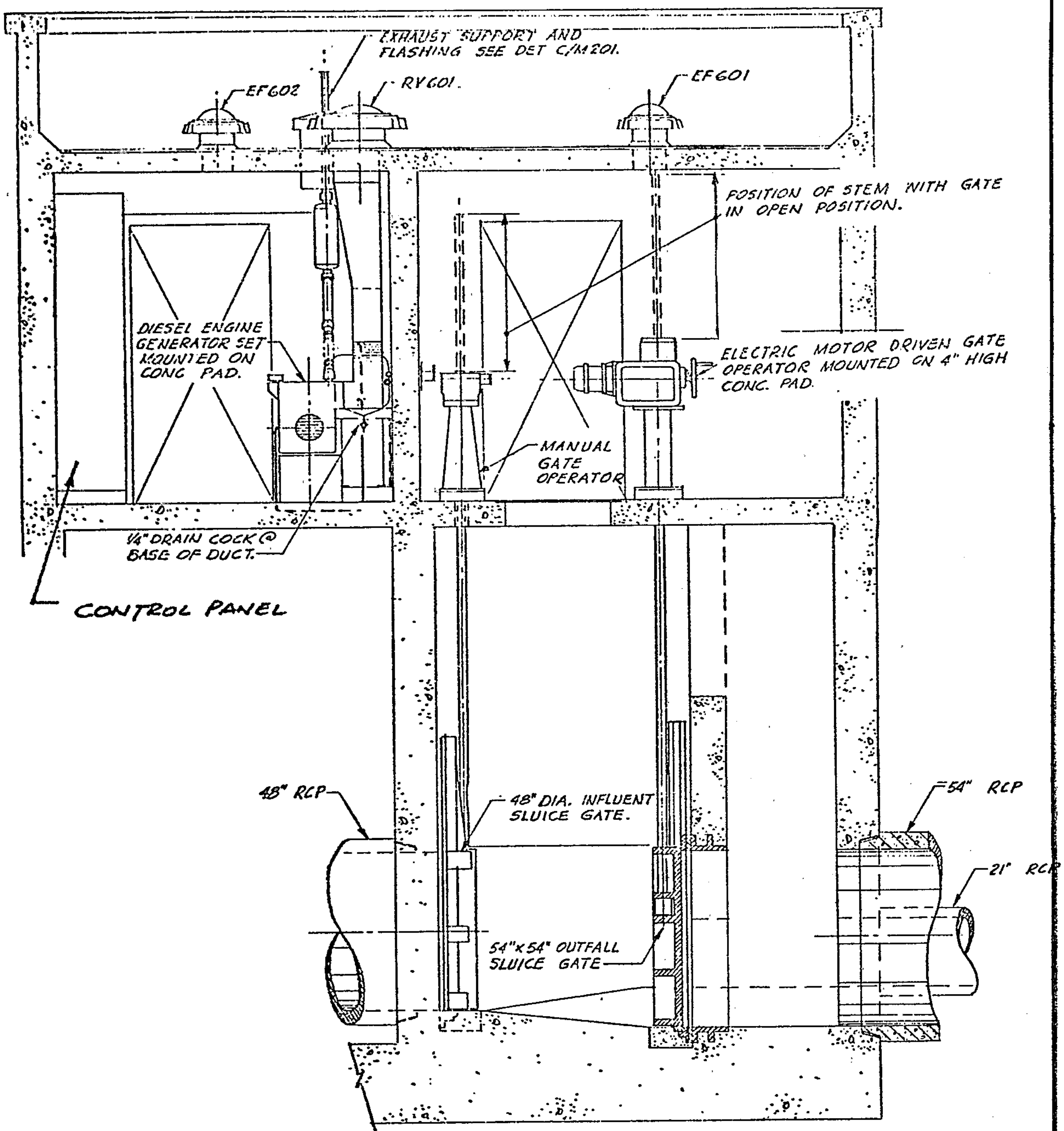
The benefit of this type of control is best exemplified in a test carried out by Seattle (Metro) where several motor-operated gate regulators are installed. Recently, an overflow was monitored at an existing side-spill regulator for a period of one month. The flow exceeds the downstream interceptor capacity eight times in five days during this period. The resultant overflow amounted to 6.4 million gallons. A mass hydrograph was prepared which revealed that if motorized gates had been installed, overflows would have been reduced to one occasion, with a 2.7-million-gallon discharge.

For small, locally concentrated storms of high intensity, overloading of the interceptor may be prevented by temporarily restraining downstream flows by remote control and by fully utilizing any available storage capacity in adjacent collectors. In a typical installation there are two gates—one to the interceptor and one to the overflow which will act as a tide gate. With both gates closed, collector storage capacity can be utilized. A weir at an appropriate elevation is used to prevent backflooding. The stored water can be bled into the interceptor as capacity in that main becomes available; when there is sufficient head differential the tide gate is activated.

Further advantages of the motor-operated gate are:

1. It offers ease of operation for large gates.
2. All major elements of the regulator are standard manufactured products, readily available from several sources.

FIGURE 14



Motor Operated Gate

MUNICIPALITY OF METROPOLITAN SEATTLE

3. Component parts for maintenance purposes are available from local stock supplies.

The disadvantages include:

1. The opening is subject to clogging.
2. Electrical circuitry will fail from time to time, consequently a standby generator must be provided.
3. Relatively high capital cost is involved.
4. Skilled technicians are required to perform maintenance functions.
5. Preventive maintenance programs must be established to insure continuing operation of sensory probes and their telemetric system.
6. Special additional structures are required.

Practices in Surveyed Jurisdictions

In Seattle (Metro), the regulator station at each collector sewer to be intercepted is provided with two automatically operated sluice gates. The regulator gate is located in a chamber on an orifice to the interceptor. The gate is controlled by a downstream sensor in the interceptor. A tide gate is located in either a separate chamber downstream of the regulator diversion chamber or in the main chamber. A sensory probe is located upstream of the gate in the interceptor and actuates the motor drive when a predetermined flow level is reached. Air bubblers are used as sensory devices in the Seattle system.

Under dry-weather flow conditions, the regulator gate is fully open and all sanitary sewage flow is diverted into the interceptor. Under storm flow conditions, the regulator gate is closed a sufficient amount to maintain a preset maximum flow level in the interceptor. As the level in the collector rises due to the flow restrictions through the regulator gate, a preset liquid level may be reached downstream of the diversion chamber, causing the tide gate to open. If the tide level is above the gate face, an override control is employed, preventing the gate from opening until the tide elevation has been exceeded by the head in the collector.

The Seattle (Metro) system is not yet fully operational. Some of the interceptors being used are part of an older system and are scheduled for replacement because they lack sufficient capacity. This has resulted in the regulator gate functioning several hundred times per day, constantly hunting to relieve surcharging on the interceptor and storing some of the flow in the collector until the interceptor flow subsides.

Seattle (Metro) has experienced difficulty in stations where tide gates are situated some distance from the regulator station. Air bubbler sensors could not function satisfactorily over the distance involved and, consequently, gates were not actuated. In addition, only one air line was provided and in the event it became clogged or ruptured, a total shutdown in the regulator station or the tide gate station resulted. Seattle officials recommended that operational units and gates be located as near to one another as possible, and that a standby air line be provided between sensory devices and the operation chamber as an operational fail-safe procedure.

Information about the system (power failures, high wet well, open overflow gates, telemetry failures) is now telemetered to a receiving-recording unit at a sewage treatment plant which is manned 24 hours per day. The system is being expanded to include much more data and future control by a process control computer at a different site as described in Section 10.

Chicago (MSD) operates 45 motor-operated gate regulator stations, six of which house tainter gates. The 39 remaining structures contain from one to four sluice gates. Eighteen of these regulator stations are remotely controlled. Local officials feel the use of remotely controlled gates provides considerable flexibility to the system and additional units are being planned. The remaining 21 regulator stations use motor-operated gates because the size of the gates involved precluded manual operation. The design criteria of the interceptor system are based on handling two times the average dry-weather flow.

Electrical failures at motor-operated regulator stations have been estimated to increase the incidence of malfunctions and to require expenditure of five percent of the general maintenance budget.

Costs

Cost estimates are inconclusive because of limited experience and the use of different cost bases for different systems. For example, Chicago (MSD) reported that regulator stations, including sensory devices but excluding monitoring and remote control, cost between $50,000 and $200,000 each. The estimate for a regulator station built in Seattle in 1968 indicated that the gate and frame, including labor, materials, and installation, cost $17,800. The substructures and the superstructure, including mechanical and electrical installations, plus normal overhead, profit and engineering costs, raised the total cost of a regulator station to $142,000.

B. Cylinder-Operated Gates

Function

This regulator device consists of a perpendicular weir constructed across a combined sewer invert, which diverts peak dry-weather flow through a vertical, fixed orifice with a variable opening to an intermediate conduit and a collector sewer or an interceptor. The dam is the diversionary device and the variable orifice controls the volume of combined sewage to be intercepted. During a storm, the excess wet-weather flow discharges over the weir to overflow.

Description

This regulator may consist of two to four chambers: one for diversion purposes; the second for regulation, containing a sluice gate, cylinder and float or bubbler tube; the third for an equipment chamber when electrical equipment is required; and the fourth for a flap gate or tide gate chamber. On some deep and large chambers the diversion and tide gate chambers may be combined, but the other chambers should remain separate. If possible, the equipment chamber should be located above ground.

The diversion chamber contains an overflow dam to divert the dry-weather flow by a 90-degree bend through an opening into the adjacent regulator chamber. The top of the diversion dam is usually set not more than 6 inches above the invert of the inlet sewer to minimize the raising of the flow line upstream of the regulator during storm flows. Other design considerations, however, may require the dam to be higher than this elevation if no damage will result upstream from raising the flow line. The diversion channel invert is established so that the peak dry-weather flow will be diverted without overtopping the dam. During wet-weather periods, the excess flow goes over the dam through the opening in the wall to the flap gate chamber and thence into the receiving waters. The opening between the diversion chamber and flap gate chamber is equipped with one or more flap gates.

The regulator chamber contains a cylinder-operated sluice gate which governs the amount of flow to the branch interceptor. The action of the cylinder is related to the sewage level in the sewer by a sensing device which can be used either upstream or downstream of the sluice gate. The latter location is used if the main objective of the regulator is to avoid overloading the interceptor and treatment plant. Generally, the sensing device is a float or a bubbler-tube through which compressed air is continually pumped. The cylinder is operated by pressure from either water, air or oil. Floats are used in conjunction with cylinders operated by water pressure to avoid the addition of compressed air equipment. During dry-weather periods, the sluice gate is wide open. In wet-weather periods, the rising sewage level will raise the float or pressure in the bubbler tube so that the gate will partially close. The float or bubbler tube is located in a float well connected to the flow channel by a telltale passage.

When the sensing device is located downstream of the gate it is generally necessary to install a control device to maintain subcritical flow in the regulator chamber. One type of control which is found to be satisfactory is the use of vertical timber stop logs to decrease the channel width. A vertical slide gate can also be used as a control to act either as a weir or an orifice on the bottom of the channel. The use of vertical wood stop logs has the following advantages: The width of channel opening can be adjusted in the field; and there is nothing to impede the discharge of debris which may be carried along the bottom of the channel or may be floating on the flow.

While the hydraulics of the regulator can be computed, adjustments are usually required in the field to suit actual flow conditions. Usually the float or bubbler-tube is set to act when the flow level is about one inch above the actual peak dry-weather flow line to make sure that all dry-weather sanitary flow will be diverted to the interceptor.

Water used as a medium is usually obtained by connection to a public water supply. Some engineers frown on such a connection even though provided with backflow preventive devices. Since the pressure in the water system may vary, the hydraulic cylinder is usually designed to operate on a minimum pressure of 25 psi. For small gates this pressure is adequate but for large gates this would require a very large hydraulic cylinder. None of the commercial hydraulic cylinder manufacturers will guarantee cylinders for water operation. Therefore, the gate manufacturer either builds the cylinder or goes to a specialty manufacturer. The chief advantage of the use of water is that no electrical power is required and hence the regulator will not stop functioning due to power failure; and a separate chamber is not needed for installation of air compressors or electrical equipment. The chief disadvantage is the required connection to a public water supply, the possibility of contaminating the system by such physical cross-connection and the possibility that the regulator will not function due to insufficient water pressure.

Tightening of the packings around the piston rod and tail rod, if overdone, may increase the friction forces. Sometimes valves become inoperative due to rust or scale in the water supply. To prevent this, a strainer should be installed in the supply line; however, clogging of the strainer may cause malfunction of the gate.

When air is used as a medium for operating the gate, a separate chamber should be provided for the air compressors and electrical equipment. Air has been used at pressures of 90 to 100 psi. The disadvantages of this system are that electrical power is required which is subject to failure; a separate chamber must be provided to house the electrical and compressed air equipment; and difficulty may be encountered in maintaining electrical equipment in subsurface chambers. Recently some cities using air pressure for cylinder operation have converted to oil pressure.

Recent practice in cylinder-operated gates tends to favor oil as a medium rather than air or water. Oil has been used at pressures of 350, 750, and 3,000 psi but pressures from 600 to 750 psi seem to be favored. To avoid corrosion, a separate chamber, preferably above ground, should be provided for electrical and pumping equipment. The use of oil results in less corrosion of valves and cylinders than the use of air or water. Smaller cylinders are needed to operate the gate due to the higher pressures used. The disadvantages are the same as those for air cylinders.

Applicability

The hydraulically operated gate is used for flows greater than 4 cfs, where automatic regulation of intercepted flows is desired. Since it is a self-enclosed system, it continues to operate even if submerged. In addition, in areas where peak sanitary flow is increasing due to additional domestic, commercial and industrial development, the regulator may be adjusted easily in the field by varying the float setting. The units have the additional advantage of operating automatically or being controlled remotely if the water-cylinder types are replaced with oil-cylinder units. This indicates a ready adaptability to total systems control.

The disadvantages of this type of installation center around the water requirement for operation purposes. The hazard of cross-connection to the public water supply system has been pointed out. Proper design of water actuating facilities can and must provide fail-safe protection against such cross-connection hazards. In many locations, making water available is a problem due to the remote location of the regulator unit. Since water supply systems also may be subject to breakdown, there will be times when adequate pressure may not be available for operation purposes. Problems of incrustation of cylinders may be experienced where water is used as the medium.

Practices In Surveyed Jurisdictions:

New York City operates 126 float-actuated, hydraulically operated cylinder gates for flows greater than 4 cfs. Usually, the structure consists of a diversion chamber; regulating chamber; and a tide gate chamber, if necessary. In some deeper and larger chambers, the diversion and tide gate chambers are combined. The regulator, however, is always housed separately.

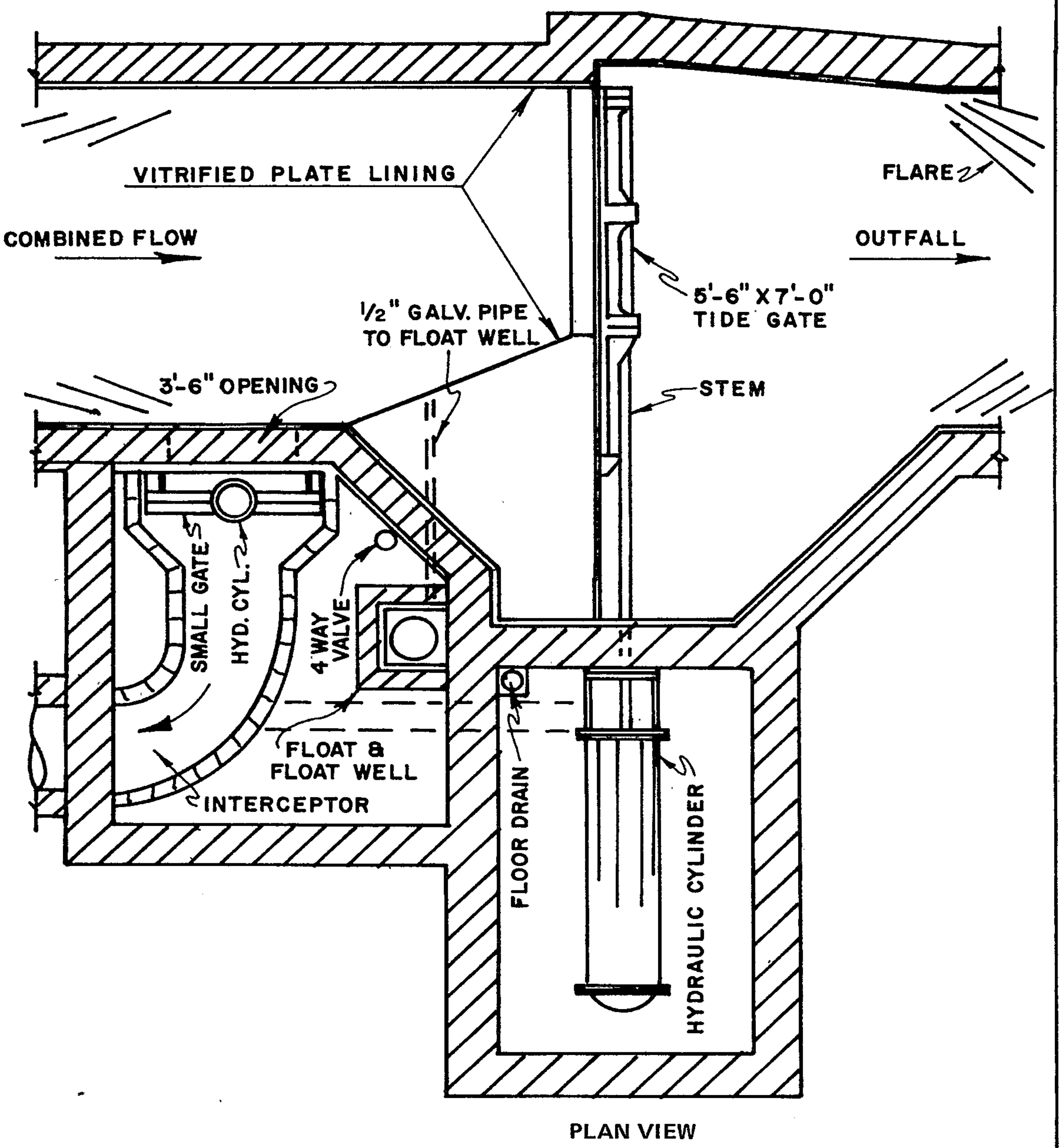
The crest of the diversion dam is set 6 inches above the invert of the combined sewer. The regulator is designed to intercept two times the average dry-weather flow. After completion, the regulator is adjusted so that it will start to close the gate when the flow level in the regulator chamber is one inch above the peak dry-weather flow. The hydraulic cylinder is operated by use of city water at a minimum pressure of 25 psi. Check valves and vacuum breakers provide adequate protection against any possible cross-connection hazard, in the opinion of the city's engineering personnel.

New York City is presently considering the use of telemetric monitoring equipment for central control of the interceptor system. Separate chambers at each regulator site will permit operator surveillance and control of gate positions, continuous monitoring and consequently, maximum utilization of the sewage treatment capacities. City officials oppose the housing of electrical equipment in the regulator chamber because it cannot be maintained in the corrosive atmosphere.

In Philadelphia, a number of units are in operation which have dual hydraulic cylinders for the operation of both sluice gates and tide gates. This use is shown in detail in Figure 15, Cylinder Operated Gate Regulator, Philadelphia. Under normal conditions, the small gate is open and the tide gate closed. With the rise in elevation of combined sewage in the float-controlled chamber during a storm, the float rises, allowing water pressure to be transmitted through the four-way valve to the top of the cylinder controlling the sluice gate, thus causing it to close. Simultaneously, water pressure is exerted on the head of the large cylinder, the stem of which is attached through the sewer wall to a tide gate. When pressure is exerted, the tide gate opens, causing an overflow. The procedure reverses as the flow rate decreases.

Eight modified float-operated hydraulic cylinders are also used in Philadelphia. These consist of a cast iron stand on which is mounted a four-way valve; on top of the stand is a counterweight arm attached to a float rod, and on the bottom of the stand another arm is attached to the float rod. Travel can be adjusted by a stem on the base of the stand. Water supply is connected to the four-way valve. A second line from the valve is attached to the top of the hydraulic cylinder, the third to the bottom of the

FIGURE 15



CYLINDER-OPERATED GATE REGULATOR
PHILADELPHIA

hydraulic cylinder, and the fourth acts as an exhaust, discharging to the regulator chamber channel. In the chamber, this unit is mounted on a bench alongside the float well. The float well is open. At the discharge end of the chamber, an adjustable orifice plate protects the fixed vertical orifice, controlling flows to the conduit connecting the chamber and the interceptor. This orifice plate may be manually adjusted to control the amount of combined sewage to be intercepted. When the inflow to the regulating chamber exceeds the outflow capacity, as restricted by the orifice plate, the water level in the float well rises, operating the float and actuating the hydraulic cylinders.

In Omaha, 28 oil-operated hydraulic gates are in service; 25 of these are at collector-interceptor junctions and three protect pumping stations. These bypass flows in excess of 3:1 WWF:DWF ratio are centrally controlled. It is the opinion of the city officials in Omaha that one dynamic, automatic regulating unit such as this can equal the performance of many static devices due to its flexibility. In addition, it utilizes the storage capacity of the system, with a resultant reduction in overflows and their pollutional effect on the receiving waters.

Costs

Capital costs of these devices in 1964 ranged from $25,000 for 4-cfs units, to $70,000 for 50-cfs units in the New York area. Omaha reported costs varying from $10,000 to $120,000, with the average cost in the $10,000 to $20,000 range. Costs for units associated with pumping facilities in that city averaged approximately $50,000.

Why Were Particular Regulators Selected?

Static devices were generally selected on the basis of their economy and on the presumption that they would be maintenance-free.

Semi-automatic, dynamic regulators were selected because they offered greater protection to the downstream interceptor system and the pumping stations at waste water treatment facilities by automatic partial closure of the gate, thereby restricting the orifice and reducing the effect of upstream head increases. Settings for gate positions could be adjusted by maintenance personnel to accomodate variations in sanitary sewage flows.

Remotely controlled automatic regulators were selected to provide flexibility in the system, positive control of intercepted flow and reduction of overflows.

What Were the Results of These Selections?

Static devices, on the whole, function best as overflow regulators in the upper regions of a collection system. They may be used economically to prevent surcharging of existing combined sewers. Dynamic regulators at these locations may be economically unjustifiable, and, generally, they are too space-consuming to be practical.

On the collector or interceptor system, static regulators may be used as overflow diversion structures, where backwater from the receiving body is not a problem. Best suited for this application would be siphons. They should be located well above invert level and below top water level to avoid, as far as possible, the carry-over of either heavy or floating solid matter. Use of a scum board could further reduce the carry-over of floating matter.

Semi-automatic regulators are true regulators, in that they can control the maximum amount of combined sewage being intercepted under low and high upstream head conditions by automatically assuming one of two gate positions without requiring external energy for operation.

Remote controlled automatic regulators can effectively utilize the full capacity of the interceptor and treatment facility while making use of the storage capacity of the collection system and reducing the quantity of overflow. Used with retention tanks, storage of first-flush flows for pumping back into the interception system when the storm flow recedes is also feasible. Fully automatic gates are also used on inlets to pumping stations and sewage treatment plants. In this case, they act not as regulators, but as protective overflow devices.

SECTION 5

PERFORMANCE OF REGULATOR FACILITIES IN SERVICE

A regulator should make as much use of the capacity of the interceptor as possible without surcharging it or causing dangerous hydraulic conditions in upstream collecting sewers. Flow variations through the interceptor should be as small as possible to prevent operational fluctuations at the treatment facility. Undiluted sewage should be delivered to the interceptor and sewage treatment facility. The regulator device should be sized and located to minimize malfunctions, such as clogging and jamming with the solids and debris indigenous to combined sewer flows. Frequent malfunctions can result in backflooding of collector sewers, dry-weather overflows, excessively long and over-frequent wet-weather spills and subsequent unnecessary pollution loading on the receiving stream.

A well-designed regulator station could make use of scum boards or overflow baffles or other facilities designed to prevent floating materials from discharging to the receiving stream during periods of overflow, and to improve the quality of waste waters discharged to receiving waters. Automatic regulators, such as motor-operated gates, have the advantage of being operated in the fully closed or fully open positions or at intermediate points depending on upstream and downstream flow conditions. By varying the orifice, any available storage capacity in the upstream collector system can be used temporarily until the flow level recedes in the interceptor. This type of operation, with central monitoring control, lends itself to "total systems" control of the collector-interceptor sewer network as a whole. This temporary storage has the effect of reducing the quantity of overflow and consequently reducing the pollution loading on the receiving waters at the outfall.

Location of Regulators

More than two-thirds of the regulator sites investigated in the National Survey were located at collector-interceptor junctions. Table 8, Locations of Regulators on Systems, indicates the locations of regulators on combined sewer systems. A total of 639 of 678 or 94 percent of the semi-automatic and automatic regulators, were located at the collector-interceptor junction points. Other regulator locations, such as on the collector, on the interceptor, at pumping stations, and at the treatment plant, demonstrate the use of these devices as an emergency measure to prevent local surcharging or overloading of treatment facilities. It is significant that 636 of 664, or 95.8 percent of the emergency diversion structures, located on the collector or on the interceptor, were inexpensive, non-controlled, static devices.

The National survey indicates that only 2 percent of the regulator devices are located at pumping stations or treatment facilities. It is probable that this percentage would be somewhat higher, if cognizance is taken of the existence of some form of emergency overflow protection at these locations. Since such devices at these locations were acting solely as diversion structures and not as regulators, they have only indirect bearing on the findings of the study of regulator practices.

Wet-Weather and Dry-Weather Design Factors and Performance

Table 9, Relationships Between Precipitation Events and Number of Overflows for Six-month Period, Allegheny County Sewage Authority, indicates that, although intensity and total rainfall are important factors, they are not the total cause of overflow events. Other factors, such as ground slope, elevation of the water table, length of time between rainfalls, the effect of freezing or near-freezing soil temperatures, the amount of impervious area in the collection basin and the characteristics and direction of the particular rainstorm, will all have an effect on the amount of wet-weather flow reaching the combined sewer system and, consequently, on the incidence of overflows. The accepted generality that a precipitation rate of 0.04 inch per hour will universally result in overflow spills can no longer be accepted, as evidenced by the Table and as corroborated in other sewer monitoring experiences investigated in the National Survey. For example, the Metropolitan Corporation of Greater Winnipeg reported that the critical precipitation rate was 0.08 inch per hour.

Each system and, in fact, each subsystem has its own individual characteristics. The condition which will prompt functioning of overflow devices requires individual engineered investigation.

The survey shows that ratios of wet-weather flow to average dry-weather flow were determined on the basis of hydraulic conditions for each system, rather than by regulator types. Design criteria for interceptor system and pumping station or treatment

TABLE 8
LOCATIONS OF REGULATORS ON SYSTEMS

Location of Regulator

Type of Regulator	On Collector	On Interceptor	Coll.-Inter. Junction	Pumping Station	Treatment Plant	Junction Other Sys.	Other Location	Total
Static								
Fixed-orifice (vert)	186	2	413	11	1	4		617
Drop Inlet	159	38	81	2				280
Leaping Weir	54	61	74					189
Man. Op. Gate		1	352		6		1	360
Side-Spill Weir	117	18	198	11	6	6	3	359
Siphon			26					26
Sub-total	516,	120	1144	24	13	10	4	1831
Dynamic								
Semi-Automatic								
Float-Operated		2	205	3				210
Tipping Gate			232					232
Cylinder Gate			6				1	7
Sub-total		2	443	3			1	449
Dynamic Automatic								
Cylinder Oper.		26	144	5		1		176
Motor Operated			52			1		53
Sub-total		26	196	5		2		229
Total Regulators	516	148	1783	32	13	12	5	2509
Percent of Total Regulators Per Location	20.6	5.9	71.0	1.3	0.5	0.5	.2	100

TABLE 9
RELATIONSHIP BETWEEN PRECIPITATION
EVENTS AND NUMBER OF OVERFLOWS
FOR SIX-MONTH PERIOD—
ALLEGHENY COUNTY SEWAGE AUTHORITY

Precipitation				
Total Rainfall (in.)	Maximum Intensity (in/hr.)	Number of Structures Inspected	Number That Did Not Overflow	Percent Not Overflowing
.03"	.01"	10	8	80
.05"	.02"	42	13	30
.07"	.03"	37	29	78
.07"	.07"	37	10	27
.09"	.05"	39	22	57
.11"	.11"	20	8	40
.12"	.08"	33	19	58
.13"	.11"	65	24	37
.14"	.14"	37	14	38
.15"	.08"	83	47	56
.17"	.17"	58	37	64
.19"	.05"	59	31	53
.21"	.13"	67	28	42
.21"	.08"	58	12	20
.25"	.14"	26	3	12
.27"	.13"	37	20	54
.28"	.05"	45	19	42
.31"	.14"	22	10	45
.49"	.32"	55	13	24
.51"	.09"	57	31	54
.53"	.25"	82	18	22
.60"	.47"	57	4	7
.64"	.12"	86	30	35
.64"	.11"	87	31	36
.66"	.52"	40	3	7.5
.73"	.57"	57	12	21.5
1.13"	.55"	51	0	0
1.35"	.61"	85	8	10
1.76"	.29"	80	2	2.5

plant capacity were determined without respect to the type of regulator being used. For example, ALCOSAN uses tipping gates and vertical orifices. Tipping gates are designed to deliver 2.5 times the ultimate design average dry-weather flow during peak flow periods. Orifices intercept 2.5 times the average dry-weather flow to the interceptor and throttle down to 1.5 times the dry-weather flow during peak runoff periods.

The City of New York utilizes cylinder-operated gates, manually-operated gates and vertical orifices. All are designed to divert two times dry-weather flow to the interceptor system. Detroit uses float-operated gates, orifices, cylinder-operated gates, and manually-operated gates. All are designed to intercept 1.5 DWF. The determination of WWF:DWF ratio by system rather than by regulator type was common to each surveyed community.

Characteristically, the volume of flow diverted by a static regulator is a function of the head on the device. As the surcharge on the regulator increases, the flow increases at the treatment facility. For example, New York has found that its vertical orifices, although designed to intercept 2 x DWF, actually intercept five to 6 x DWF during periods of runoff. Cleveland designed its side-spill weirs to divert 2.5 x DWF, but recent measurements indicate that flows of 9 x DWF have been intercepted during wet-weather periods. This type of experience is typical for the static regulators encountered in the survey.

Semi-automatic regulators are set for dry-weather and wet-weather flow conditions, and will automatically hunt for either position depending on the flow rate. As stated, at ALCOSAN, tipping gates are set to divert 2.5 x DWF to the interceptor; when wet-weather flows exceed this design limit, the gate automatically "tips," partly closing the orifice and throttling the flow to 1.5 x DWF. As the surcharge on the upstream side of the regulator increases, the added head may increase the WWF:DWF ratio above 1.5, but the interceptor system design rate is not exceeded.

Cylinder-operated gates used in New York City similarly throttle the regulator gates. These are actuated automatically by a float control upstream of the regulator gate in order to prevent surcharge of the downstream system.

Automatic regulators which are remotely controlled and equipped with level sensors upstream and downstream of the regulator station may be paced or actuated by flow levels in the interceptor and in the collector system.

To varying degrees, all regulators are capable of dividing the flow between the interceptor and the receiving waters, but none has the capability as presently designed and operated to divert only sanitary sewage, suspended solids, and floating solids to the interceptor system and permit clearer, more dilute liquids to overflow. An engineering approach to this type of separation has been tried in Minneapolis. It involves the installation of a "sewer within a sewer," with the sanitary flow carried in a lower quadrant of the dual line and the higher flows of the storm water runoff jumping vertically to the upper sewer section.

Evaluation of Regulator Performance by Jurisdictional Personnel

Information obtained from surveyed jurisdictions concerning the performance and operation of regulators indicates the inadequacy of attention given to this service problem. A total of 414 questions were asked of respondents concerning performance at the local government level. These inquiries could have been answered if observations and measurements were being made on such systems. Less than 50 percent (187) of these queries were answered and many of the responses were of such general nature that they were neither qualitative nor quantitative in character. Table 10, Evaluation of Performance and Operations of Regulators by Types, as reported by Surveyed Jurisdiction Personnel, presents the expressed opinions by surveyed system personnel on the performance of regulators currently in use. It represents their satisfaction or dissatisfaction with their maintenance practices and the ability of regulators to effect control of the flows intercepted and the flows diverted to receiving waters.

The findings indicate that static regulators give limited satisfaction, that semi-automatic regulators give average performance, and that automatic devices perform most satisfactorily.

Relationship between Types of Regulators and Precipitation

Table 11, Relationship Between Types of Regulators and Annual Precipitation, and Table 12, Relationship Between Types of Regulators and Maximum Rainfall, represent an effort to correlate the selection and performance of regulators, by types, with average annual precipitation and maximum rainfall rates.

The total annual rainfall in the surveyed jurisdictions varied from 20 to 60 inches per year. However, no indications were given that regulator selection was made on the basis of expected precipitation experiences. Comparison of data in

TABLE 10
EVALUATION OF PERFORMANCE AND OPERATION OF REGULATORS BY TYPES, AS REPORTED BY SURVEYED JURISDICTION PERSONNEL

Location of Jurisdictional Sewer System Agency	Orifices	Drop Inlets	Leaping Weirs	Side-Spill Weirs	Manually Oper. Gates	Siphons Internal Self-Priing	Float Operated Gates	Tipping Gates	Cylindrical Gates	Cylinder-Operated Gates	Motor Operated Gates
Akron		L									
Boston				L			U				
Chicago	L				S		R				S
Cincinnati	S	L	S	S			L				
Cleveland	S	L	L	L			U				
Detroit	SL				SL		SL			S	
Milwaukee	S		S					SL			
Montreal							L		S		
New York	SL		SL	SL	S		U			S	
Omaha		L				U				S	
Philadelphia			U		SL		S			SL	
Pittsburgh	SL				SL			S			
San Francisco	SL										
St. Louis		SL									
Seattle											S
Washington	U			SL			U				
TOTAL	18	6	9	9	12	0	7	4	3	8	9
Av. Opinion Rating 1969 Survey (Unweighted)	2	1.2	1.8	1.8	2.4	0	0.9	2	3	2.7	3
Av. Opinion Rating 1967 Survey (Unweighted)	2.2	1.8	2.0	2.3	2.1	—	1.6	1.8	—	1.9	2.1

Legend	Rating	Legend	Rating
S—Satisfactory	3	L—Limited	1
SL—Satisfactory within limitations	2	U—Unsatisfactory	0

TABLE 11
RELATIONSHIP BETWEEN TYPES OF REGULATORS AND ANNUAL PRECIPITATION

Type of Regulator	Annual Rainfall (Inches) 0–20	21–30	31–40	41–50	51–60	Unknown	Total
Static							
Fixed Orifice (Vert.)	40 (1)		309 (6)	104 (1)	61 (1)	3 (1)	617
Drop Inlet		25 (1)	217 (3)		38 (1)		280
Leaping Weir			108 (2)	75 (2)	6 (1)		189
Man. Oper. Gate			290 (2)	67 (2)		3 (1)	360
Side-Spill Weir			334 (5)	25 (1)			359
Siphon		26 (1)					26
Semi-Automatic							
Float Oper. Gate		4 (1)	76 (3)	85 (2)		44 (1)	210
Tipping Gate			147 (1)		85 (1)		232
Cylindrical Gate		7 (1)					7
Automatic							
Cylinder-Oper. Gate		28 (1)		147 (3)		1 (1)	176
Motor-Oper. Gate			45 (1)	8 (1)			53
Total Regulators	40	90	1627	511	190	51	2509
Percent of Total	1.6	3.6	64.8	20.4	7.6	2.0	100

NOTE: Number of reporting jurisdictions shown in brackets.

TABLE 12
RELATIONSHIP BETWEEN TYPES OF REGULATORS AND MAXIMUM RAINFALL

	Maximum Rainfall Rate (Inches/Hr.)							
Type of Regulator	0–1.00	1.01–1.50	1.51–2.00	2.01–2.50	2.51–3.00	3.00	Unknown	Total
Static								
Orifice			208 (2)		104 (1)	233 (3)	72 (4)	617
Drop Inlet				25 (1)		199 (2)	56 (2)	280
Leaping Weir			6 (1)		75 (2)	103 (1)	5 (1)	189
Man. Oper. Gate			7 (1)		67 (2)		286 (2)	360
Side-Spill Weir				11 (1)	14 (1)	316 (3)	18 (1)	359
Siphon				26 (1)				26
Semi-Automatic								
Float Oper. Gate		4 (1)			85 (2)	77 (3)	44 (1)	210
Tipping Gate			232 (2)					232
Cylindrical Gate		7 (1)						7
Automatic								
Cylinder-Oper. Gate	6 (1)			28 (1)	141 (2)		1 (1)	176
Motor-Oper. Gate	8 (1)						45 (1)	53
Total Regulators	14	11	453	90	486	928	527	2509
Percent of Total	0.6	0.4	18.0	3.6	19.4	37.0	21.0	100

NOTE: Number of reporting jurisdictions shown in brackets.

Table 11 with the evaluation of regulator performance in Table 10 indicates that total annual rainfall in the ranges experienced does not, in itself, influence the performance of the different types of regulators used.

Table 12 demonstrates no apparent selectivity pattern for a particular type of regulator to meet rainfall rate conditions. Furthermore, no reactions were expressed by the personnel of surveyed jurisdictions as to the performance of devices under different rainfall intensities.

Effect of Infiltration on Regulator Performance

The report on "Problems of Combined Sewer Facilities and Overflows, 1967," indicated that infiltration in excess of design criteria is widespread, but follows no particular pattern. In 85 communities, representing 14 percent of the total respondents, ground water infiltration was listed as a problem in dry-weather flow periods. Wet-weather ground water infiltration was reported as a problem by 331 jurisdictions, representing 53 percent of those responding to the query. Twenty-nine percent of those reporting indicated that infiltration exceeded code or design limits; 36 percent stated that it did not; and 35 percent had not established the degree of infiltration and were unable to evaluate the effect of infiltration on the frequency or period of duration of overflows.

By accepted definition, ground water infiltration does not include water entry into the collection system via actual sewer connections, such as roof leaders and basement and foundation drains, or through manhole covers.

If infiltration is occurring during dry-weather flow periods, dilution of sewage directed to the interceptor system will occur, sewage treatment operation costs will increase, and dry-weather overflows may occur during peak-flow hours. Infiltration occurring during wet-weather flow will increase the volume of overflows and produce further dilution in the flow to the treatment facility.

In summary, reduction of infiltration by better sewer design and construction methods, better jointing practices, and other efforts to create watertight sewers in modern design would result in fewer overflow incidents, and of lesser duration.

Role of Regulators in Projects Sponsored by FWPQA

The Federal Water Quality Administration, (FWQA), in recognition of the pollution problem caused by untreated waste waters discharged from combined sewers, has provided financial aid through grants and contracts to stimulate the development of projects which will demonstrate new or improved methods of controlling the discharge of untreated or inadequately treated sewage or other wastes from sewers which carry storm water. The main thrust of this research and development program to resolve the combined sewer problem has been the development and demonstration of techniques and hardware to improve system efficiency and minimize, if not completely control, overflow discharges.

The demonstration projects being carried out involve the application of two new regulating devices.

Fluidic Devices

A study is presently being carried out on development of a flow separator operating on the fluidic principle that a jet stream attaches itself to the wall of a flat nozzle and remains there because of the stable, dynamically formed and sustained pressure gradient across the fluid stream.

The three basic elements of a fluidic device are:

1. The bi-stable diverter, basically a Y-shaped element, the throat of which by design acts as the nozzle and the legs of which enable a single stream to be diverted to either or to variations thereof;
2. The control ports, one on either side of the throat, and immediately in front of the Y diversion. Fluid from the nozzle is diverted into either of the two output legs by varying the atmospheric pressure at either control port; and
3. The discharge weirs, which are located at the end of the legs of the Y and dampen the flow from critical to normal velocity.

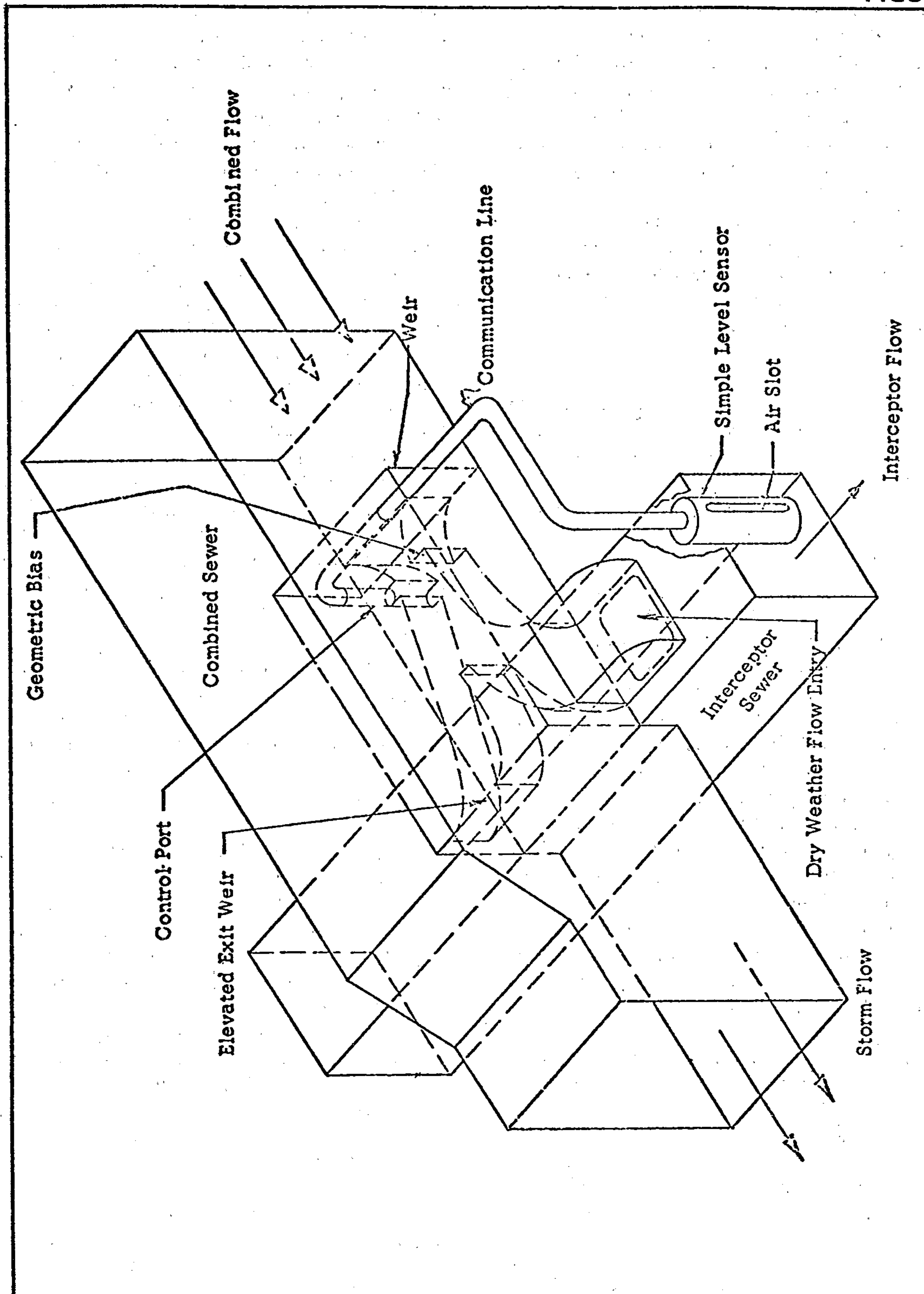
Figure 16, Schematic Arrangement—Fluidic Interceptor Sewer Flow Control—Single Sensor, illustrates a possible configuration for the use of this device.

The principal identifying characteristic of a fluidic device is the elimination or great reduction in the number of moving mechanical parts. Given the proper natural fluid-dynamic conditions, physical phenomena perform functions normally requiring moving parts. Preliminary investigations indicate that the physical operating principles of a fluidic system are not size-limited; in fact, some become more effective as size increases. Consequently, there may be a particular advantage to the application of a fluidic device to separate normal combined sewer flows, particularly with respect to materials used in construction, size of apertures, omission of mechanical parts, and suitability for replacement of existing regulator devices.

Inflatable Fabric Dams

A demonstration grant project is being carried out by the Minneapolis-St. Paul Sanitary District

FIGURE 16



SCHEMATIC ARRANGEMENT - FLUIDIC INTERCEPTOR
SEWER FLOW CONTROL - SINGLE SENSOR

Courtesy Bowles Fluidic Corp.

providing for the use of inflatable and deflatable dams of rubberized fabric which, by remote control, can utilize the storage capacity of the collector system as a direct means of controlling the amounts of wet-weather flows to regulator structures and thereby limit the volumes overflowing to receiving waters. By coordinating the operation of these fabric dams, the maximum in-system storage possible may be utilized by taking advantage of the hydraulic capacity in the "total" system.

Demonstrating Improvement in Overflow Quality

Demonstration grant projects also are being sponsored by FWQA to ascertain the feasibility of processes for improving the quality of the overflows from combined sewers. These projects include the following:

Retention Tanks

Projects involving retention or storage of combined sewer overflows are located at Chippewa Falls and Milwaukee, Wisconsin, Boston, Massachusetts, and Shelbyville, Illinois. In-system storage in deep tunnels in Chicago will accomplish a reduction in receiving water pollution while reducing local flooding.

Microscreening

Microscreening, using a nominal 23-micron aperture screen, is reported to have removed up to 98 percent of the suspended solids from a combined sewer overflow. The sewer, which has an average sanitary sewage flow of 1,000 gph, serves a residential area of 11 acres in the City of Philadelphia, Pa. The maximum combined sewer flow recorded during rainstorms in one year of operation has been 305,000 gph. Volatile suspended solid removals have averaged 68 and 71 percent during different test periods. BOD removals and coliform bacteria concentrations in the microstrained effluent have varied widely and chlorination of the effluent appears necessary for disinfection. First costs indicate this technique will be approximately 50 percent cheaper than sewer separation in the 11-acre district studied.

Void Space Storage

The City of Akron recently has been granted funds for a demonstration project to install a gravel-filled, rubber-lined retention tank. The rubber lining at the base and over the gravel acts as a membrane seal, forming an enclosed filter bed tank. Tank capacities are created in the interstices of the aggregate particles. The necessary intakes, outlets and valving are provided within the tank. The upper membrane is covered with soil; the surface of the underground facility may be used for park and recreational areas.

These efforts to develop and demonstrate workable methods for the improvement of the quality of waste waters which overflow from combined sewer systems indicate the growing realization of the need to incorporate quality control with the quantity control provided by regulator devices. This concept has been outlined in Section 2 of the report and described as the "Two Q" concept. They also have indicated the important role that the regulator must perform to assure proper functioning of the combined sewer overflow treatment facilities.

Automatic-Automation Instrumentation Applications

To reduce backwater flooding of building basements and surcharging of pumping stations and treatment facilities, and to prevent unnecessary overflows, centrally monitored information is required concerning precipitation events within the natural drainage basin of a combined sewer system, as well as flow conditions at critical points within the collector-interceptor system. This information, coupled with the ability to regulate the combined sewer flow by remote control, could offer the greatest possible utilization of the combined sewer collection-interception system. Some of the potential benefits derived from the application and use of automatic-automation-instrumentation procedures and devices are:

1. Malfunctioning regulators may be detected quickly and repaired.
2. Regulator gate ports may be adjusted remotely, providing optimum utilization of interceptor and treatment plant capacities.
3. The flow to the interceptor from various collection system locations can be coordinated to fully use interceptor capacity and thereby limit surcharging downstream.
4. The first-flush phenomenon, if present, or some variation of the solid-slugging phenomenon, can be delayed in the collector, with heavy solids diverted to treatment when interceptor capacity is available.
5. In-sewer flow routing is possible to divert runoff from overloaded sewer sections to conduits simultaneously experiencing less loading. This would minimize local surcharges due to small spot storms which may not affect the system's entire contributary area, and would prevent pollutional impacts of overflows.

Instrumentation and remote control of a combined sewer regulator system could lead to greater utilization of each part of the system, and result in fewer overflows, better and more economical sewage treatment plant operation, and a general reduction in pollution loading of receiving waters, all at costs far below that of sewer separation.

An engineering study of each combined sewer system would be required to indicate the equipment and operating procedures which are most applicable to that particular system.

The elements of total system control are:

1. *Measurement*–A probe or sensor is used to gather specific information such as water levels in collectors or interceptors, flow rates, regulator gate position, and rainfall intensity.
2. *Data Communication*–The specific system information is transmitted over some type of communication channel; the telephone system is most frequently the most available and economical medium of communication.
3. *Data Collection*–The specific information is received by recorders or computers so that it may be summarized and collated. Emergency information is often translated to some form of alarm system to institute immediate attention.
4. *Decision*–On the basis of the collated information, a reaction decision is necessary. This may be made manually by the operating personnel; or by means of computer program control of such functions as the activation of pumps, the chlorination of the overflow, the utilization of the interceptor capacity, or the opening or closing of tide gates by operating personnel or remote control means.
5. *Evaluation*–On the basis of the revised information, conditions are deemed to be satisfactory or the data show that further control is required.
6. *Feed-Back*–The system probes or sensors measure the changes that have taken place due to the above corrective action.

Ponsar Siphon

The Ponsar Siphon was developed in France and is named for its inventor. It operates on the principle that flows through the siphon are controlled by the presence or absence of air pressure at the siphon head. The Ponsar regulator is essentially a vacuum-operated, balanced air valve, which responds to the vacuum intensity and liquid level in the siphon chamber. The air valve is normally closed and opens only in response to siphon conditions as required to maintain the design flow-through by admitting air, thereby preventing vacuum intensity in excess of desired design conditions. It consists of two basic elements: a regulator valve which has a floater at the top of the valve immersed in oil over a mercury seal, with a connecting shaft to an air inlet valve at the bottom; and a level-sensing pipe assembly with its lower end inside the separate chamber where a water-filled plastic bag is attached at the bottom. A level-sensing tube is installed inside the level-sensing pipe. The water-filled bag is sensitive to variations in air pressure and the level tube rises or falls with similar changes in liquid level. Figure 17, External Self-Priming Siphon, indicates the various components of this type of regulator.

This regulator is in use in France and Switzerland. Construction of a demonstration unit in this country has not been undertaken.

Existing Practices

Caught and ever-increasing demands for controlling pollution in receiving waters, a number of jurisdictions have either installed, or are in the process of installing, some type of remote control system.

In Akron, all the interceptor inlet locations and pumping stations which serve the sewer system are monitored by a supervisory system comprised essentially of sensing probes set at predetermined high-water level; remote transmission units to send signals over telephone lines to the central station; and a central receiving station.

Incoming signals are indicated on a graphic panel equipped with audible alarms and recorders. By this means maintenance department personnel can be made aware that the flow depth has come up to the level of the probe, that overflows are occurring, and corrective action may be required.

In Detroit, a monitoring and reporting system is being constructed in order that information will be made available on what is occurring in the system, and sewer system personnel will be able, on the basis of such knowledge, to control the system as a whole.

This system will monitor the rainfall and its intensity at a number of points throughout the city; monitor the depth of flow in all the major combined sewers at various points; measure the depth of flow along the interceptors, and control pumping stations.

This information will be transmitted to a central station, along with continuous data on the condition and operation of the various pumping stations. The system has been designed so that reports will be transmitted normally on an hourly basis, but this will be increased to 15-minute intervals when the rain at any station exceeds 0.03 inch per hour. If the flow in any combined sewer exceeds the dry-weather flow, the interval will be reduced to five minutes. The controller will then be able to follow the course of the storm across an area and determine how the various collectors and interceptors react to this condition. On the basis of this information, decisions can then be made concerning system changes. Further reference to the Detroit system is contained in Section 10 of this report.

A total system control program is being developed by the Municipality of Metropolitan Seattle. The Minneapolis-St.Paul Sanitary District control program has already been placed in operation. These are also discussed in Section 10.

Field Survey Results

Performance and Operation

Questions asked in the National Survey on regulator performance were concerned with malfunctions and overflow durations and characteristics. Many of the responses were of a general nature, based only on estimates by the personnel of the surveyed jurisdictions, rather than on actual operation records.

The type and frequency of a malfunction of the various types of regulators is an important indication of their performance capability. Malfunctions were, in the majority of cases, due to clogging. Table 13, Summary of Regulator Malfunction Experiences, by Types, summarizes the frequency of malfunctions per year for the various types of regulators. The findings by regulator type were erratic and in 42.7 percent of the regulator installations the frequency of malfunctioning was unknown.

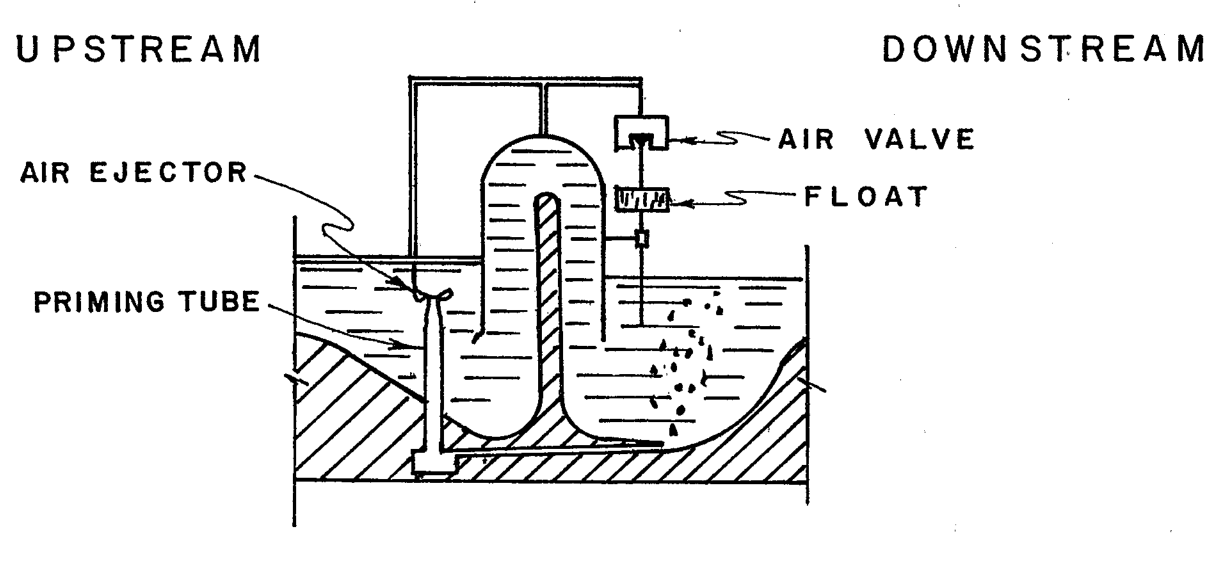
Tables 14 through 22 summarize performance and operation data obtained for various types of regulators in the jurisdictions surveyed during the course of the project.

Perpendicular Weirs, Orifices and Drop Inlets

Due to the similarity of operation of drop inlets, perpendicular weirs, and vertical and horizontal orifices, they have been grouped together for the purposes of evaluation. Although all of these regulating devices are susceptible to the problem of clogging, the field results indicated that the vertical orifices were deemed to perform more effectively than the drop inlet type of regulator. In part, this may be due to the increased frequency of drop inlet malfunctions.

The information as tabulated in Table 14, Performance and Operation of Orifice Regulator, covering the surveys concerning the frequency and duration of overflows, indicated a range of 30 to 100

FIGURE 17



EXTERNAL SELF - PRIMING SIPHON

TABLE 13
SUMMARY OF REGULATOR MALFUNCTION EXPERIENCES, BY TYPE

Type of Regulator	Frequency of Malfunctions/Yr. 0–5	6–10	11–15	16–25	25–100	100	Unknown	Total
Static								
Orifice	173 (3)	122 (1)			5 (1)		317 (5)	617
Drop Inlet						38 (1)	242 (4)	280
Leaping Weir							189 (5)	189
Mannually Oper. Gate	345 (2)						15 (3)	360
Side-Spill Weir	14 (1)				245 (2)		100 (3)	359
Siphon							26 (1)	26
Sub-Total	532	122	–	–	250	38	889	1831
Semi-Automatic								
Float-Operated Gate			4 (1)	52 (2)			154 (4)	210
Tipping Gate	85 (1)	147 (1)						232
Cylindrical Gate	7 (1)							7
Automatic								
Cylinder Oper. Gate	154 (2)						22 (3)	176
Motor Oper. Gate	45 (1)						8 (1)	53
Sub-Total	291	147	4	52	–	–	184	678
Total Regulators	832	269	4	52	250	38	1073	2509
Percent of Total	32.8	10.7	0.2	2.1	10.0	1.5	42.7	100

NOTE: Number of reporting jurisdictions shown in brackets.

TABLE 14
PERFORMANCE AND OPERATION OF ORIFICE REGULATOR

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Type	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Yr.	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Akron, Ohio	38	3	Clog	365/yr	—	—	—	Alarm System	1 hr	—	Est.
Chicago, Ill.	4	4	Clog	1-2 yr	—	—	—	Insp.	—	—	—
Cincinnati, Ohio	146	3,4	Clog	—	90	Yes	Each Rain 90	Est.	2 days	Several days	Est.
Cleveland, Ohio	221	2,4	Clog	—	100—	300-365 per yr	100-150 per yr	Insp.	2-3 hrs per day	3/4 hr	Est. & Insp.
Detroit, Michigan	3	2	—	—	—	—	—	—	—	—	—
Milwaukee, Wisc.	61	2	Clog	1/yr	56/yr	—	—	Est.	—	—	—
New York, N.Y.	104	2	Clog	1-2 yr	—	—	—	—	—	—	—
Omaha, Nebraska	25	3	Clog	3/yr	—	—	—	—	—	3-24 hrs	Est.
Pittsburgh, Pa.	116	2	Clog	10/yr	—	0	Little or none	Insp.	—	seldom	Insp.
San Francisco, Ca.	40	2	Clog	Infreq. (rare)	30	0	30	Insp. & Recorded	—	170 hrs max.	—
St. Paul, Minn.	43	1,2,3	Clog	—	—	—	—	—	—	—	—
Washington, D. C.	65	3,4	Clog	—	—	—	—	Insp.	—	—	Insp.

Orifices
1. Horizontal
2. Vertical
3. Drop Inlet
4. Perpendicular Weir

Abbreviations
Dry W. (D.W.) Dry Weather
Wet W. (W.W.) Wet Weather
H. D. How Determined
Insp. (I) Inspection

Est. (E) Estimate
— No Data

occurrences per year, some of these overflows lasting as long as several days. In one instance, a 170-hour wet-weather overflow was recorded. In the majority of cases, duration and frequency were determined by means of inspection, although an alarm system was in use in one of the surveyed systems. The National Survey disclosed the limited information that is available on this subject. Although 11 of the surveyed jurisdictions had one or more of these alarm devices in use, only five of these communities had information concerning the duration and frequency of overflows during dry-weather and wet-weather periods. Even in some of these limited cases, the data that were provided by the local personnel were based solely on estimates. Better record keeping practices are needed.

Leaping Weirs

Leaping weirs were rated satisfactory, within certain limitations, in the surveyed systems although one community reported this type of regulating device to be unsatisfactory.

Since the information pertaining to the performance of this type of regulator was available from only one of the five communities in which it was used, the results must be considered to be of only limited value and dependability. As indicated in Table 15, Performance and Operation of Leaping Weirs—Cleveland, malfunctions occurred 40 to 50 times per year and were attributed mainly to clogging, a problem that was common to all jurisdictions surveyed.

Side-Spill Weirs

With regard to performance, the side—spill weir was regarded as similar to the leaping weir in the surveyed communities. In no case, however, was this regulator felt to be unsatisfactory.

There was a wide variation in frequency of malfunction of this type of device, ranging from "rarely" in one case, to 90 incidents per year in another community as indicated in Table 16, Performance and Operation of Side-Spill weirs. Similarly, a wide discrepancy was reported, ranging from "never" to daily during periods of dry-weather, and "seldom" to 150 per year during wet-weather. Duration of overflows ranged from several hours to several days. Because of the wide differences in local condition and the limited data, the information is of limited value.

Float-Operated Gates

Generally, float-operated gates were not considered to perform satisfactorily. Three of the seven surveyed jurisdictions regarded this type of regulator to be in the category of "unsatisfactory." One jurisdiction has replaced these units, due to the frequency of malfunction, and in others the gates have been wired open so that they perform like vertical orifices.

The most common complaint, once again, was clogging; the frequency of this problem averaged approximately once per week as shown in Table 17, Performance and Operation of Float-Operated Gates.

Wet-weather overflows varied from 15 per year in Montreal to a maximum of 150 per year in Cleveland. The validity of national conclusions is doubtful, since few surveyed jurisdictions had information available on this phase of regulator practice. The information that was gathered in the field surveys was the result of a combination of both inspection and estimation. No automatic recording devices were reported to be in use in the surveyed communities. The duration of both the dry-weather and wet-weather overflows ranged from a fraction of an hour to several days, an experience quite similar to that reported for the other types of regulators.

Manually Operated Gates

The five surveyed jurisdictions that utilize this type of regulator considered it to be satisfactory, although several did express the opinion that it has certain limitations with regard to performance. In rating the various regulators surveyed in the cities, this device was generally considered to be as acceptable as fully automatic devices.

Table 18, Performance and Operation of Manually Operated Gates, indicates that malfunctions due to clogging were reported to be once or twice per year by two of the surveyed jurisdictions. This estimate was assumed to be a reasonable approximation for malfunction expectation of this device. The lack of dependable information concerning frequency and duration of overflows makes any more definitive evaluation unwarranted.

Siphons (Internal Self-Priming)

The single surveyed jurisdiction which commented on siphon regulators reported that they were an unsatisfactory means for diversion and regulation. The survey data indicated that clogging problems were responsible for malfunctions, but no data were available on the frequency of this condition, nor was any information disclosed on the duration or frequency of overflows during dry-weather and wet-weather periods.

Cylindrical Gates

This type of regulator has been in service for approximately four years, and has been tested in only one surveyed community. Consequently, performance evaluations must be considered only

TABLE 15
PERFORMANCE AND OPERATION OF LEAPING WEIRS

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions		Overflows Per Year			How Determined	Duration Overflows		
		Type	Freq.	Events Per Year	Dry Wea.	Wet Wea.		Dry W.	Wet W.	H.D.
Cleveland, Ohio	103	Clog	40-50 per yr	—	300-365	100-150	Insp.	2-3 hrs per day	3/4 hrs	Est. Insp.
Milwaukee, Wisc.	6	Clog	—	56	—	—	Est.	—	—	—
New York, N. Y.	2	Clog	—	—	—	—	—	—	—	—
Philadelphia, Pa.	73	Clog	—	—	—	—	—	—	—	—
St. Paul, Minn.	5	Clog	—	—	—	—	—	—	—	—

TABLE 16
PERFORMANCE AND OPERATION OF SIDE-SPILL WEIRS

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Events Per Year	Dry Wea.	Wet Wea.	How Determined	Dry W.	Wet W.	H.D.
Boston, Mass.	11	Clog	—	—	Never	Seldom	Insp.	0	—	—
Cincinnati, Ohio	68	Clog	90	90	Yes	Each Rain		2 days	Several	Est.
Cleveland, Ohio	234	Clog	40-50 yr	100	300-365	100-150	Insp.	2-3 hrs per day	3/4 hr	Est. Insp.
New York, N.Y.	14	Clog	1-2 yr	—	—	—	—	—	0	—
St. Paul, Minn.	18	Clog	—	—	—	—	—	—	—	—
Washington, D. C.	14	Clog	—	—	—	—	Insp.	—	—	Insp.

Abbreviations
Insp. — Inspection
Est. —Estimate
H. D. — How Determined
— — No Data

TABLE 17
PERFORMANCE AND OPERATION OF FLOAT-OPERATED GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year: Events Per Year	Overflows Per Year: Dry Wea.	Overflows Per Year: Wet Wea.	How Determined	Duration Overflows: Dry W.	Duration Overflows: Wet W.	Duration Overflows: H.D.
Cincinnati, Ohio	48	Clog	90	90	—	90	Est.	In some cases several	Several days	Insp.
Cleveland, Ohio	16	Clog	40-50	50	300-365	100-150	Insp.	2-3 hrs/day	3/4 hr	Est.
Detroit, Michigan	44	Clog	—	—	—	—	—	—	—	—
Montreal, Canada	4	Clog	—	15	0	15/yr	Insp.	—	—	—
New York, N. Y.	4	Clog	15	50	0	50	Est.	0	—	—
Philadelphia, Pa.	81	Clog	—	—	—	—	—	—	—	—
Washington, D. C.	13	Clog	12 min.	—	—	—	Insp.	—	—	—
Boston, Mass.	Removed due to frequency of malfunctions: maintenance inadequate, gates wired open, regulating as a vertical orifice									

TABLE 18
PERFORMANCE AND OPERATION OF MANUALLY OPERATED GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year: Events Per Year	Overflows Per Year: Dry Wea.	Overflows Per Year: Wet Wea.	How Determined	Duration Overflows: Dry W.	Duration Overflows: Wet W.	Duration Overflows: H.D.
Chicago, Illinois	283	Clog	1-2/yr	—	when blocked	—	Insp.	—	—	—
Detroit, Michigan	3	—	—	—	—	—	—	Continuous wired open		
New York, N. Y.	62	Clog	1-2/yr	—	0	—	—	0	—	—
Philadelphia, Pa.	5	Clog	—	—	—	—	—	—	—	—
Pittsburgh, Pa.	7	—	—	—	—	—	—	—	—	—

preliminary in nature. Because of the size and shearing force of the gate, and because of the shape of the opening to the interceptor sewer, few problems have been experienced in relation to regulator clogging. Infrequently, these regulators have been jammed open by a large obstruction, permitting excessive diversion to the interceptor.

At the WWF:DWF settings currently employed in Montreal, as indicated in Table 19, Performance and Operation of Cylindrical Gates, approximately five overflow events have occurred per year at each installation. These events are split evenly between summer rainfall, and spring thaws accompanied by rainfall.

To date, no dry-weather overflows have occurred there. Monitoring reveals if the regulator has been actuated.

Tipping Gates

Table 20, Performance and Operation of Tipping Gates, indicates that the two surveyed jurisdictions utilizing tipping gate regulators regard them as satisfactory. Clogging was reported to be the most common cause of malfunction, the frequency being reported as an average of five instances per year. Additional information concerning overflows was not available, although one jurisdiction reported that overflows during dry-weather periods seldom occurred and were of limited duration.

Motor-Operated Gates

The two jurisdictions which utilized this type of regulator considered it to be satisfactory. The frequency of malfunction was reported to vary as indicated in Table 21, Performance and Operations of Motor-Operated Gates. One system reported only one to two occurrences per year, and the third reported the frequency of malfunction to be approximately three times per month. In one jurisdiction an alarm system was utilized to record the frequency and duration of wet-weather overflows. Records indicated that the duration ranged between 6 and 15 hours.

Cylinder Gates

This fully automatic device was, on the average, considered satisfactory in performance by the five surveyed jurisdictions in which it was used. One jurisdiction reported it to be quite effective. Malfunctions, due to clogging, lack of water supply and mechanical breakdown, were considered possible. Although little information was available regarding frequency of malfunctions, as indicated in Table 22, Performance and Operations of Cylinder-Operated Gates, the satisfaction with which these units are viewed would seem to indicate that such difficulties are relatively infrequent. Two Jurisdictions reported malfunctions once or twice per year. Two reported that overflows occurred during wet-weather periods, but additional information concerning duration and frequency of overflows for other installations was not available.

TABLE 19
PERFORMANCE AND OPERATION OF SIPHONS

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Year	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Omaha, Nebraska	26	Clog	—	—	—	—	—	—	—	—

Abbreviations
Insp. — Inspection
Est. — Estimate
H.D. — How Determined
— — No Data

TABLE 20
PERFORMANCE AND OPERATION OF CYLINDER-OPERATED GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Year	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Detroit, Michigan	1	—	—	—	—	—	—	—	—	—
New York, N. Y.	126	Clog	1-2/yr	50	0	50	—	0	—	—
Philadelphia, Pa.	15	Clog	...	—	—	—	—	—	—	—
Omaha, Nebraska	28	F	1/yr	Depends on precipitation, snow melt & thaw	none	often	Setting calibrated for over-		6-24	Insp. and recorded
Seattle, Washington	6	No records since units relatively new								

TABLE 21
PERFORMANCE AND OPERATION OF TIPPING GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Year	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Milwaukee, Wisc.	85	Clog	1/yr	56	—	—	—	—	—	—
Pittsburgh, Pa.	147	Clog	5-10/yr	—	None Recorded Seldom	—	Insp.	Minimal	—	—

Abbreviations
Insp. — Inspection
Est. — Estimate
H.D. — How Determined
— — No Data
F — System failure due to excessive grit which results in pumping stations being bypassed

TABLE 22
PERFORMANCE AND OPERATION OF MOTOR-OPERATED GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Year	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Chicago, Illinois	45	Clog	1-2/yr	—	—	—	Insp.	—	—	—
Seattle, Washington	8	—	35/yr	—	Seldom	—	Alarm System	Seldom	6-51 hrs.	Alarm Sys.

TABLE 23
PERFORMANCE AND OPERATION OF CYLINDRICAL GATES

Location of Jurisdictional Sewer System Agency	Surveyed No. In Service	Malfunctions Type	Malfunctions Freq.	Overflows Per Year Events Per Year	Overflows Per Year Dry Wea.	Overflows Per Year Wet Wea.	How Determined	Duration Overflows Dry W.	Duration Overflows Wet W.	Duration Overflows H.D.
Montreal, Canada	7	Jam	Seldom 1-2/yr	5/yr	Nil	5/yr	Monitoring	—	—	—

Abbreviations
Insp. — Inspection
Est. — Estimate
H.D. — How Determined
— — No Data

SECTION 6

MAINTENANCE OF REGULATORS

To the extent that maintenance determines the capabilities of its performance, no device is better than its maintenance. In the case of regulators installed in combined sewer systems, the nature of their location, the characteristics of the liquids they handle, the conditions under which they must operate and other factors make maintenance practices of great importance. One of the determining factors—but not the only factor—in the choice of regulator equipment must be the anticipated nature, frequency and cost of maintenance, and the resulting performance of the chosen device. For this reason, the National Survey placed great emphasis on national maintenance experiences and practices.

One of the findings of the survey was that few jurisdictions vary their maintenance practices for different types of regulating devices. Rather, maintenance policies for all regulators, regardless of type, have been arbitrarily established. Maintenance costs, when reported, were frequently given in lump-sum amounts. Unit costs related to specific functions were unavailable or undependable.

As a rule a specific number of work crews follow a routine maintenance performance check for each regulator and its appurtenances. Preventive maintenance programs were reported by several surveyed jurisdictions, but this was not a universal practice. The value of preventive scheduling of regulator inspections and attention, and sewer system cleaning and maintenance work was demonstrated by the national survey.

The number of visits per year to each regulator station depends upon the community's policy for inspecting its system; this policy rarely bases its inspection requirements on the types of regulators in service. Frequency of maintenance varies widely. For example, two jurisdictions surveyed, located within three hundred miles of each other and having similar climatological conditions, utilize similar design criteria for combined sewers and their appurtenances. A particular regulator type is common to the two communities, both maintained with two- or three-man crews; and both express satisfaction with the total performance of the regulator. However, the policy of one jurisdiction is to inspect its regulator sites on the average of seventy-five times per year, regardless of regulator type, while the policy of the other is to check each regulator site from twenty to thirty-five times per year.

As a consequence of these differences in maintenance procedures, annual cost of maintenance by regulator type and scheduled number of maintenance visits per year by regulator type is difficult to analyze and evaluate. The national survey brought to light many weaknesses in maintenance procedures and a significant lack of authentic data on costs, practices and results. Actual maintenance practices, by regulator types, are summarized in Table 24, Frequency of Regulator Maintenance-Inspection—by Types. The annual maintenance cost per regulator unit, by types, is reported in Table 25 Summary of Annual Unit Maintenance Costs—by Types. The data on costs contained in this section have been derived in many cases, from local operational and manpower estimates.

A. Static Regulators

Vertical Fixed Orifices and Siphons

Reasons for Malfunctions

The principal problem encountered with both vertical fixed orifices and siphons is the clogging of their openings. This is particularly serious within the curved throat of a siphon, since clearing of debris is often difficult and time-consuming and it cannot be carried out during wet-weather flow conditions. During periods of malfunction little or no combined sewage can be discharged to the interceptor and excessive overflows result. Figure 18, Clogging of Orifice, illustrates a typical situation where a grate became clogged and a dry-weather overflow occurred. Figure 19, Overflow Screens, shows the clogging of an open wire mesh placed to attempt to catch debris on the overflow.

Maintenance Requirements

These types of static regulators may be effectively maintained by a crew of two or three men who visit each regulator site 30 to 35 times per year on a regular basis, and following each storm. Hooks may be used to advantage to remove debris and unblock the orifice. The regulator chamber usually requires cleaning after a storm. Three effective cleaning procedures encountered in the national survey are: washing down the chamber with water from the city supply; using a compressor and air nozzles to blow small debris into the dry-weather channel; and using a vacuum tank truck of the type used to remove debris from catch basins.

TABLE 24
FREQUENCY OF REGULATOR MAINTENANCE-INSPECTION, BY TYPES

Type of Regulator	Maintenance Insp./yr.							Total
	0-15	16-30	31-45	46-60	61-75	>75	Unknown	
Static								
Orifice		129 (2)			150 (2)		338 (6)	617
Drop Inlet						38	242 (4)	280
Leaping Weir		7 (2)				73	109 (2)	189
Manually Oper. Gate		345 (2)					15 (3)	360
Side-Spill Weir	11	32 (2)				14	302 (2)	359
Siphon							26	26
Sub-total	11	513			150	125	1032	1831
Semi-Automatic								
Float-Oper. Gate		56 (3)			44	13	97 (2)	210
Tipping Gate					147		85	232
Cylindrical Gate		7						7
Automatic								
Cylinder-Oper. Gate			126			6	44 (3)	176
Motor-Oper. Gate		45				8		53
Sub-total		108	126	—	191	27	226	678
Total Regulators	11	621	126	—	341	152	1258	2509
Percent of Total	.4	24.8	5.0		13.6	6.1	50.1	100

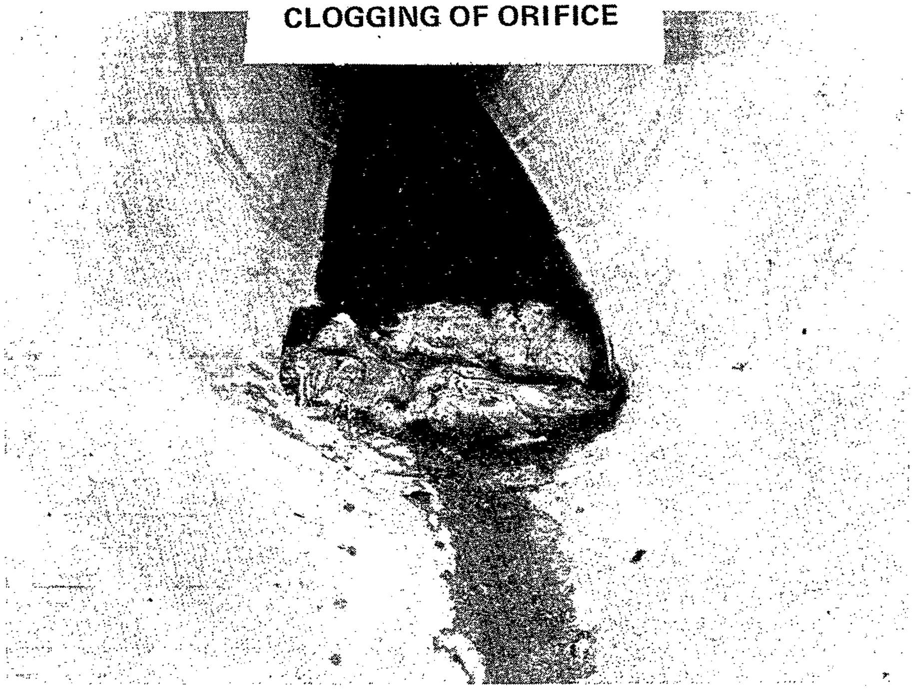
TABLE 25
SUMMARY OF ANNUAL UNIT MAINTENANCE COSTS, BY TYPES

Type of Regulator	Annual Maintenance Cost Unit							Total
	0–$200	$201–$400	$401–$600	$601–$800	$801–$1000	>$1000	Unknown	
Static								
Orifice		67		254 (3)			296 (6)	617
Drop Inlet		58			141	38	43 (2)	280
Leaping Weir		6			73		110 (3)	189
Manually Oper. Gate				3	288 (2)	62	7	360
Side-Spill Weir		14		79 (2)			266 (3)	359
Siphon							26	26
Semi-Automatic								
Float-Operated				44	129 (2)	17 (2)	20 (2)	210
Tipping Gate		85		147				232
Cylindrical Gate							7	7
Automatic								
Cylinder-Oper. Gate				1	21	126	28	176
Motor-Oper. Gate					53 (2)			53
Total Regulators	—	230	—	528	705	243	803	2509
Percent of Total	—	9.2	—	21.0	28.1	9.7	32.0	100

NOTE: Number of Reporting Jurisdictions Shown in Brackets

FIGURE 18

CLOGGING OF ORIFICE



Cost of Maintenance

The annual maintenance cost for these regulators was consistently reported in the order of $700 to $900 per unit per year.

Horizontal Fixed Orifices (Drop Inlets)

In all applications surveyed where drop inlets were used, except at the Minneapolis-St. Paul Sanitary District, the orifice was protected by a grate. Comments hereafter take that fact into consideration.

Reasons for Malfunctions

The drop inlet regulator grating is particularly susceptible to frequent clogging with leaves, rags, plastics, sticks and other debris.

Maintenance Requirements

Operating personnel reported that drop inlets require almost constant maintenance. In Akron, each unit is serviced daily and some large drop inlets require cleaning even more frequently. Maintenance personnel reported that they had no assurance that clogging would not recur immediately after cleaning.

Two- to three-man crews are used to maintain these regulators. A two-man crew consists of two laborers, while a three-man crew consists of two laborers and a technician. Their principal function is to scrape the grates clean. In this case, the debris must be lifted to the surface for final disposal. As a minimum, grills and chambers must be cleaned on a weekly or bi-weekly basis.

Cost of Maintenance

Because of the need for regular maintenance, the annual service cost is relatively high. Cost estimates in the order of $1,200 to $1,500 per unit per year were reported to be not unusual.

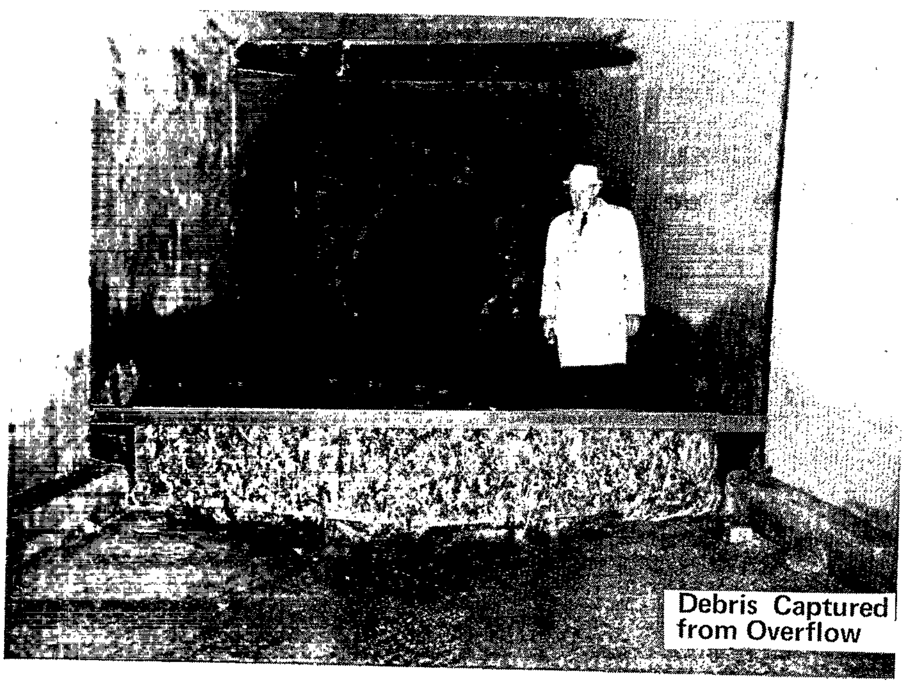
Recent and Proposed Changes

In order to reduce the maintenance burden and to improve operating characteristics, two recent proposals should be considered: that the space between bars of the grating be increased, so that at least smaller objects will not cause malfunction; and that flow levels in the regulator chamber be monitored so that maintenance personnel may be alerted in case of blockage during periods of dry-weather flow, thus eliminating prolonged overflows of sanitary sewage.

FIGURE 19

OVERFLOW SCREENS


Before Overflow


Debris Captured from Overflow

Side-Spill Weirs

Reasons for Malfunctions

Side-spill weirs are subject to an accumulation of trash on the upstream face and on the downstream end at the toe. Since these regulators are usually equipped with an outlet pipe, clogging of this conduit is also a problem. The weir crest must be rebuilt from time to time and can be damaged by large heavy objects carried in wet-weather flows.

Maintenance Requirements

The side-spill weir regulator is relatively maintenance-free, requiring only periodic cleaning and removal of accumulated debris. When the crest of the weir is damaged, reconstruction of the brick course or other material is necessary. The procedures may be performed by a two-man labor crew.

Cost of Maintenance

On the average, side-spill weirs cost $400 to $500 per annum to maintain.

Manually Operated Gates

The principal maintenance problem encountered with manually operated gates is clogging of the orifice.

Maintenance Requirements

This regulator may be adequately maintained with a two-man labor crew, or a three-man crew consisting of two laborers and one technician. Repairs and adjustments to the device are minimal, although the gearing and gate stem must be kept well lubricated. Wall brackets are particularly susceptible to corrosion and require frequent attention. Clearing of blockages in the orifice can often be accomplished by raising the gate. If this is not successful, a hook may be used to dislodge the blockage. General cleaning of the regulator chamber is usually required following every storm.

Inspections are carried out on a regular basis, on the order of 15 to 30 times per year.

Cost of Maintenance

The average cost of maintaining a manually operated gate regulator and chamber was reported to be from $900 to $1,000 per year.

B. Dynamic Regulators—Semi-Automatic

Float-Operated Gates

Reasons for Malfunctions

Float-operated gate-regulators have many components and consequently require a preventive maintenance program carried out on a regular basis in order to assure proper functioning. Some of the types of malfunctions common to this device are: blockage of the gate with wood; accumulations of rags or other storm debris; clogging of the float well, causing the gate to rest continuously in its closed position; accumulation of sludge on the float, preventing the float from rising and resulting in the gate remaining in its open position at all times; guide chains slipping off gear wheels; breakage of the chain; corrosion or incrustation between moving and stationary parts of the gate; rusting of chains and pinions, causing gear wheels to jam; and clogging in the telltale pipe.

With the exception of clogging in the float well or at the gate, these problems do not occur frequently, provided maintenance is carried out on a regular or preventive basis.

Maintenance Requirements

Float-operated gates can be maintained by a three-man crew, consisting of two laborers and a technician, plus a supervisor who oversees several similar operations. The additional technical assistance is required due to the complexity of the regulator. Typical maintenance operations include removal of blockage and debris; cleaning of grit and grease from the float well; lubricating of metal parts, particularly friction areas; repairing or replacing chain links; and general cleaning of the regulator chamber. Large gates, because of their weight, should provide clear access directly above the gate so that adequate rigging or a truck-mounted crane can operate the gate or remove it if this is required.

Regular inspections should follow each rainstorm because clogging and debris problems will be most common at those times. Detroit reported that approximately five percent of their units require servicing after each rainfall. Regular weekly inspections should also be made, to serve as the basis for a preventive maintenance program.

Cost of Maintenance

The annual maintenance cost for a float-operated gate was reported to be approximately $1,000 to $1,200 per station.

General Comments

Local authorities stressed the degree of maintenance required to keep these units in good functioning condition, and the cost of this maintenance. Three jurisdictions, in particular, expressed concern over this type of regulator. The first estimated an annual maintenance cost of $350 per float-operated gate unit. The second community had operated these regulator units for 50 years and for the past ten has wired them open. In the third jurisdiction, the units were more than 30 years old and were given only sporadic maintenance.

The national survey indicated that semi-automatic or automatic regulators are not successfully maintained for less than $800 per year, as compared with successful maintenance programs on static devices at a cost of approximately $350 per year.

The effective life expectancy of mechanical equipment housed within a sewer system and subjected to its corrosive atmosphere may not be more than 25 years. However, 80 percent of the float-operated gates in service in the surveyed communities were reported to be more than 30 years old. These devices may not be in serviceable condition. Approximately 50 percent were described as more than 40 years old.

Tipping Gates

Reasons for Malfunctions

The most common maintenance problem associated with this type of regulator is blocking of the gate orifice. This occurs most frequently during and after heavy storms. In addition, debris may collect between the tipping gate and its side wall casting. This is difficult to remove by hand. Friction on the leaf pivot shaft due to lack of lubrication is a problem peculiar to the tipping gate regulator. Although lubrication may be carried out frequently, the pivot shaft is alternately submerged and exposed to the air. Alternate wetting and drying in this particularly corrosive atmosphere damages the lubricant and results in deterioration of the shaft and the potential freezing of the gate. Malfunctions occur most frequently after heavy rains.

Maintenance Requirements

The most successful tipping gate application surveyed is at ALCOSAN, where the maintenance program requires that each regulator structure be visited at least every other week. The average frequency of servicing is 75 to 100 times per year. Authority representatives reported that maintenance work was required to restore operation on an average of 10 percent of the maintenance visits. The crew was reported to have removed large pieces of wood, tin cans, and other debris in front of the gate opening. Some debris which had become jammed between the gate and the sidewall casting required compressed air jetting for removal. Removal of other debris was carried out with a rodding tool or hook. The pivot shaft was greased regularly.

The maintenance crew used for all regulator installations at ALCOSAN is comprised of one maintenance superintendent, one maintenance foreman and 18 maintenance men.

Because of the corrosion problem of the leaf (gate) pivot shaft, ALCOSAN specifications have provided for the use of bronze brushings on stainless steel shafts. This has corrected the problem effectively.

Cylindrical Gates

Cylindrical gates are recent developments and have only lately been used on the American continent. Experience is limited to six units in Montreal which have been in operation less than three years. As a consequence, insufficient maintenance data upon which to base a valid assessment of this type of regulator are available at this time.

To date, clogging of the orifice has not been as great a problem as experienced in that city with float-operated gates. This is probably due to the fact that the orifice is circular and the gate is poised a minimum of 5 inches above it. With the cylinder restriction at the centre of the orifice, its diameter is large in relation to the flow-through. Consequently, partial blockage may occur but complete blockage is rare. The weight of the cylinder makes it possible to shear off any partial obstruction when closing, or if further opened, the size of the orifice can usually pass all but larger timbers. No instance of complete blockage was reported at any Montreal regulator station.

The gate cylinder is particulary heavy and cumbersome, and consequently, special trap doors are required at the roof of the chamber for removal of the equipment or for special maintenance purposes.

C. Dynamic Regulators-Automatic

Motor Operated Gates

Reasons for Malfunctions

The most common causes of malfunction of this device is clogging or blocking at the gate opening, electrical failure due to corrosion on circuit contacts, partial blockage or collapse of compressed air lines, and power failure where standby generators have not been provided.

Maintenance Requirements

One community is working with the motor-operated gate on a systems control basis; another is using motor-operated gates in another form of control. Maintenance practices on both systems are described here.

At Metropolitan Seattle, gate operation is fully checked once a week and emergency power is tested for a one-hour period. Originally, the emergency power was set by a time clock to operate one hour per week. However, this system did not test the gate operation under hydraulic loading. This has been rectified. The telemetry system is checked every three weeks and the drive gears on the Limitorque are checked on a six-month preventive maintenance schedule.

Potential problems with the air compressor used as part of the air-bubbler sensing system are anticipated by determining if there is an increase in the hours of compressor operation per day.

At the Metropolitan Sanitary District of Greater Chicago, the motor-operated gates are remotely and/or locally controlled. Remote control permits the treatment plant or pumping station operator to limit the amount of combined flow to be intercepted. Each installation is checked monthly and following all major storms. Additionally, overflows are checked by boat and helicopter to disclose regulator malfunctions and improper discharges.

Regular maintenance visits require the testing of dehumidifiers, heaters, water level recorders, telemetry equipment, and other facilities. Gate openings are reset at design requirements on an annual basis.

Cost of Maintenance

The devices reported in the Chicago and Seattle systems are relatively new and, consequently, annual cost of maintenance as reported is probably lower than will be the case after several years of service. Seattle reported five hours of maintenance work per month per regulator station and Chicago reported a cost of $60,000 per year to maintain a total of 660 regulator stations, 328 of which are tide gate installations.

Cylinder-Operated Gates

Reasons for Malfunctions

The types of malfunctions encountered with the cylinder-operated gates are: clogging of the orifice; clogging of the float control, preventing the gate from closing; excess weight from accumulations of grease, rags and other debris which prevent the float from rising, thus keeping the gate in closed position; clogging of the strainer on the water supply line to the four-way valve; breaks or leaks in the water supply line; wear and leaking of the four-way valve and its appurtenant items; leakage of the hydraulic cylinder;and insufficient water pressure—less than 25 psi—from the public water supply. Such conditions as accumulations of debris on floats can be minimized by proper design and effective maintenance.

The sensing devices and their electronic or air compressor systems are subject to corrosion and clogging of bubbler-tubes.

Maintenance Requirements

Cylinder-operated gates are maintained by a four or five-man crew: a foreman, technician and laborers.

In New York City, each crew uses a specially designed truck with winch, generator, blowers, pumps and safety equipment. They spend approximately 85 percent of their time on regulator maintenance.

Special inspections follow each rainstorm when the regulator and its appurtenances are checked for damage. A general check of all sensing equipment, cleaning of gate orifice of any clogging, and general cleaning of the regulator structure are required. Twice a month, preventive maintenance is carried out on the operating devices.

Cost of Maintenance

New York City's budget appropriation in 1969 for operation and maintenance of regulators was $300,000. Of this amount, $159,000 was provided to maintain 126 float-operated gates.

Proposed Changes

New York City is considering installation of telemetering in connection with one regulator in which the water cylinder layout will be replaced with oil-cylinders. Since the city feels electrical equipment cannot be maintained in a regulator chamber, this equipment will be separately housed. If below grade, the chamber requires heating and forced ventilation and dehumidification equipment. Because of this, some communities locate the chamber above grade, wherever possible.

Maintenance personnel have suggested that operating pressures of no more than 600 psi be used to facilitate maintenance procedures.

Equipment Used for Maintenance Work

Although regulator maintenance practices and policies vary from city to city, the equipment supplied to maintenance crews follows a common pattern. The following items are typical of a well-equipped maintenance program:

- A specially designed 1½-ton panel truck with winch and A-frame
- 110-220-volt portable generator
- 1 or 2-hp blower unit
- Various chains, ropes, hoses, ladders, pike poles, sewer hooks, sewer rods, chain jacks, tool kits, and related items
- An oxygen deficiency meter, an explosive and toxic gas meter, safety equipment, helmets, harnesses, first aid kits, danger flags, signs, barricades, life jackets, flares, gas masks, gas detector lamps, fire extinguishers, extension cords, rubber jackets, pants, boots, and waders.
- Equipment such as air compressors, truck pumps, diagraph pumps bucket sewer cleaning machines, and chain saws may be available from an equipment pool.

Some jurisdictions also provide their maintenance crews with air packs.

Figure 20, Derrick Barge and Boat for Regulator Maintenance, is a photograph of equipment used by ALCOSAN to maintain regulators which are accessible only from the river. Figure 21, Loaded Derrick Barge, shows the variety of equipment used for maintenance, including a bucket-cleaning machine.

Figure 22, Swamp Buggy, is a photograph of a vehicle used by the Metropolitan Sewer District of Greater Cincinnati to maintain structures located along streams. The wheels of the Buggy are the flotation units. A small crane is mounted on the rear and a large pump is mounted on the frame.

Structural Design to Facilitate Maintenance

Maintenance personnel are critical of regulator structures which provide inadequate space for safe and effective maintenance work. The survey disclosed that, too frequently, capital cost economies are given major priority and the cost of maintenance and operation is left to the maintenance superintendent to work out as best he can once the installation has been completed. This was characterized by respondents to the survey as an expensive and futile procedure. As an example, the use of stairways or portable ladders should be considered wherever possible, instead of manhole steps.

A significant number of regulator stations observed in the 18 interviewed jurisdictions were inaccessible, could only be reached by boat, or could be entered only by descending 30 feet into a 30-inch diameter manhole section. It is obvious that regulator devices in these difficult locations suffer from lack of maintenance.

The following conclusions can be drawn from the evaluation of the regulator maintenance practices disclosed in the national survey.

1. Components of regulator stations should be housed in separate chambers. For example, a float-operated gate regulator station should consist of a chamber for the regulator, with separate housing for its float control; a diversion chamber for directing the combined sewer flow to the regulator; and a tide gate chamber, if required. All chambers should be readily accessible.

2. Access to the chambers should be unobstructed. There should be adequate space to admit personnel freely while carrying equipment they may require to perform their duties. An access opening should be located above any heavy or bulky mechanical device, so that, if necessary, it can be removed and replaced without excavation, or so that it may be repaired

FIGURE 20

DERRICK BARGE AND BOAT

ALLEGHENY COUNTY SANITARY AUTHORITY

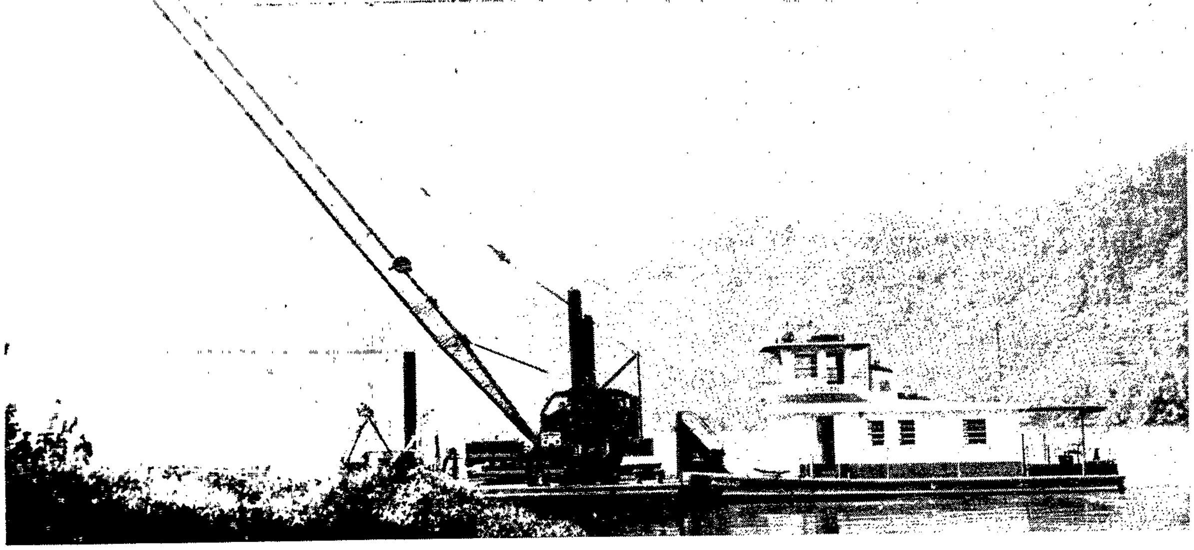
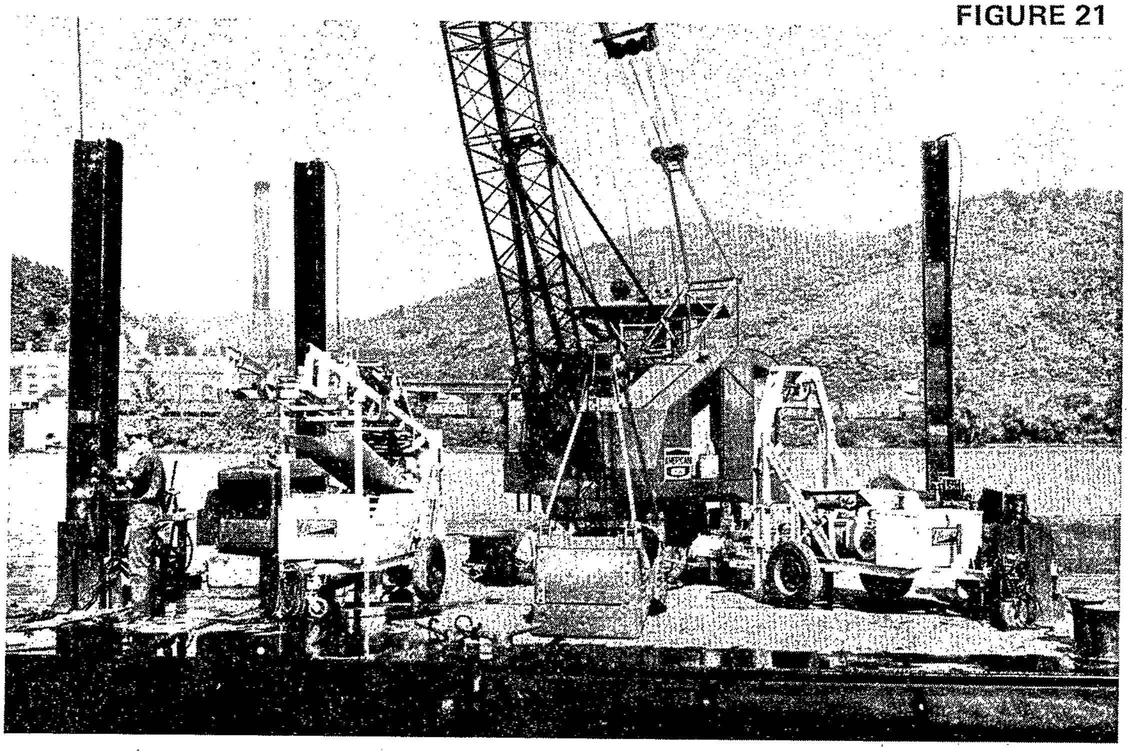
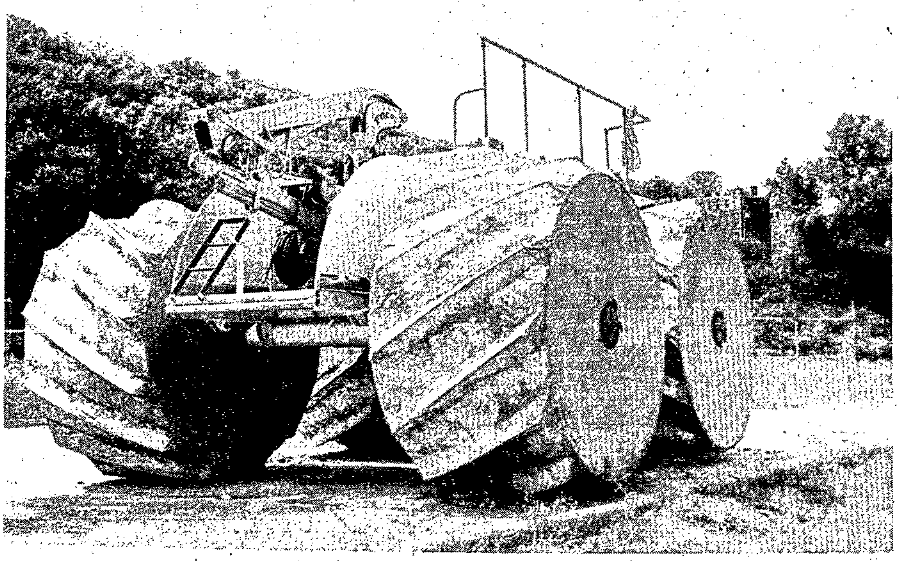


FIGURE 21



LOADED DERRICK BARGE
ALLEGHENY COUNTY SANITARY AUTHORITY

FIGURE 22



Courtesy Metropolitan Sewer District of Greater Cincinnati

SWAMP BUGGY

in the relative comfort and security of an above-grade location.

3. The environment of an overflow chamber is likely to be damp and corrosive, so mechanical equipment should be fabricated of corrosion-resistant materials. Special care should be paid to bearings and other friction or contact surfaces. In this respect, the use of neoprene may be of benefit. Electrical gear should be housed in a separate chamber, situated above grade, if possible. If it is absolutely necessary to install electrical equipment in conjunction with the regulator chamber, it should comply with National Board of Fire Underwriters specifications for hazardous locations. The chamber should be protected by forced-air ventilation.

4. All chambers associated with sewer systems should have ample ventilation capabilities, preferably at two points, to provide cross ventilation.

5. Convenient and non-corrosive ladders and steps should be provided.

6. Reasonable headroom is essential within the chamber.

7. A well-defined, adequate, large landing area should be provided in the chamber. Where possible, it should be so located as to give convenient access to all key maintenance points and allow inspection of the incoming and outflowing combined sewage.

8. If at all possible, the chamber should be lighted. Only explosion-proof fixtures should be used.

9. Guard rails should be provided. However, New York City, for example, does not favor railings in regulator stations, since they feel that reliance on a railing which may fail due to corrosion is more hazardous than the omission of the railing. Where conditions are particularly hazardous and where a fall might mean death or serious injury, railings have been constructed of structural steel encased in concrete.

10. A ceiling hook over float gates, small gate assemblies, and screens is a simple but often useful facility.

11. Simplicity in cleanability and design are essential. Projections and small gaps where rags, sticks and floating material can collect, should be carefully avoided.

12. Adequate size in the regulator chamber must be provided to prevent blockage by deposits of sewage solids, and oddities such as bicycle frames or long timbers, which are not infrequently found in combined sewers.

Provision of such structural and equipment facilities will enable the maintenance department to maintain regulator facilities in a manner that will assure effective performance.

Preparing a Regulator Chamber for Inspection

There are dangers associated with sewer maintenance procedures, both in the sewers and their access chambers below grade, and from the traffic above grade. Basic safety precautions are applicable to maintenance crews across the country. The instructions given to maintenance crews in Philadelphia are an example of standard safety practice:

1. Truck should be parked so as not to obstruct traffic but, if possible, it should be used to protect men working near open manholes. If a truck is used for this purpose, suitable flashing lights must be used on the truck.
2. Warning cones, flags, signs, and lights should be used to make areas safe for both vehicles and pedestrians.
3. A manhole cover should be raised with a safe and proper tool and a bar placed under it, so that it can be rolled to one side.
4. A manhole guard should be placed around the open manhole.
5. A chamber or sewer should be given adequate ventilation before entry is made.
6. The air in both sewer and chamber should be checked for explosive mixtures, oxygen deficiency, and hydrogen sulfide content.
7. If there is an indication of gases, a portable blower should be used to clear the area.

Effect of Automatic-Automation Systems on Maintenance Procedures

The experience reported by one jurisdiction indicates that overflow of dry-weather sanitary flow has been reduced by 50 to 75 percent because of improved use of manpower and methods, without taking into consideration the instrumented-automated system. A study made of 1962 raw-waste data compared the average plant load received on dry days versus runoff days. This study concluded that, "The average annual BPD would possibly be 15 percent greater, the suspended solids 6 to 10 percent higher, and the total solids 3 to 6 percent greater if the sewer system were not affected by runoff."[1] Since improved manual surveillance methods were implemented and revisions made to regulators utilizing the automated system, average annual plant load has increased markedly. The increases are due, in part, to a number of factors, but a substantial portion of the increased load is due to better regulator performance. The added increase in plant load has been from 5 to 15 percent above past growth projection curves.[2,3]

An instrumented or automated regulator maintenance system may be defined as one which provides continuous information at a central location concerning status and performance of the combined sewer overflow regulators. The information may include rain gauge readings, trunk and interceptor sewer flow or level, regulator gate position, and possibly robot water quality monitoring data, or it may be limited to on-off, yes-no information as to whether or not a regulator is overflowing. To date, there have been only a few installations using instrumented systems. Among these, few have provided for remote control of the regulators. In some cases, the surveillance system causes an alarm indication so that a crew may be dispatched to correct the malfunction. The systems installed at Minneapolis–Saint Paul Sanitary District and Detroit, and now being finalized at the Municipality of Metropolitan Seattle, provide for remote control of regulator devices so that overflows can be corrected immediately from the central location.

Also, for the purposes of this report, a definition of regulator maintenance is necessary. There are two kinds of maintenance which will be described here. Normal maintenance is inspection and servicing of the regulator equipment to correct unnecessary overflow due to blockage, stoppage, and equipment malfunction. This kind of regulator maintenance in a sense is a part of operation of the system.

The second kind of maintenance is equipment maintenance or repair maintenance required because of wear, deterioration, and equipment failures which require a rebuilding or repairing of the equipment. This kind of maintenance normally requires shop facilities and tools and equipment such as welding devices. For the purposes of this report the latter will be designated as repair maintenance, and the former as routine maintenance.

One of the functions of routine maintenance is the regular inspection of regulators on either a periodic basis or following each use of the regulator system by storm flow. With an instrumented system, the number of routine inspections required can be reduced significantly. For example, in one jurisdiction, inspection of 125 miles of river front, required two and a half days' time for a four-man crew to complete. Of these regulators, approximately 20 percent caused most of the operational difficulties. Routine inspection of regulators was reduced substantially and almost eliminated when the major—and the most troublesome ones—could be continuously monitored. By providing remote control of these troublesome regulators, corrections could be made from a central location within a matter of minutes, compared with hours when a crew had to be dispatched to the site.

Not all of the savings from routine maintenance can be credited to the use of an instrumented system. In exchange for reduced routine maintenance, additional control facility maintenance is required. After the original problems in the instrumentation system are eliminated, this maintenance is rather minimal, requiring only a fraction of one man's time for 40 instrumented locations.

Manpower Requirements

Manpower requirements for automated, combined sewer, overflow-regulator facilities maintenance differ considerably from those for static systems, both in kinds and numbers of personnel required.

For static regulators, maintenance requires at least one man for each 10 to 20 regulators. These men must be willing to spend a good deal of their time in the sewers, working under unpleasant conditions with their main duty consisting of clearing clogged facilities. Periodically, they may be required to adjust weir levels and gate settings. The cleaning work will require removal of debris and shoveling or flushing grit and heavy sediment. Typically, the worst conditions are in the larger regulators carrying heavy flow, usually containing industrial wastes. Typically, these large regulators cause the most overflow, and

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[1] *Anderson, J. J., "Analysis of Operating Data from a Full-Scale Primary Sedimentation Plant at the Minneapolis-Saint Paul Sanitary District," A Thesis Submitted to the Faculty of the Graduate School of the University of Minnesota, April 1967.*

[2] *Toltz, King, Duvall, Anderson and Associates, Inc., St. Paul, Minnesota, "Report on the Expansion of the Sewage Treatment Plant–Minneapolis-Saint Paul Sanitary District."*

[3] *Anderson, J. J., "Computer Control of Combined Sewers," Presented at American Society of Civil Engineers Annual and Environmental Engineering Meeting, October 13-17, 1968.*

should be given the closest checking and most prompt attention. Much of the sewer crew's time is spent in travel between locations looking for problems and in setup and cleanup operations if proper safety and work methods are used.

At the opposite extreme, modern, well-designed remote-controlled regulators can substantially reduce the amount of unappealing and hazardous work in sewers. Inspection is done remotely by an operator or instrument at the central location. Repair maintenance will be of a different nature and somewhat increased. Various types of equipment will require such crafts as electricians, electronic technicians, pipe fitters, mechanics, and possibly computer specialists. In most major jurisdictions the work load in each specialty will not require full time attention, particularly after any faults in the system have been corrected.

Primary coordination must be effected between central regulator operations, routine maintenance, and repair maintenance. Maintenance personnel must make known to central operations their presence in areas where the activation of operations might cause injury or death to such personnel. At the same time there should be a "lockout" of such equipment. Frequently, the three functions must provide a coordinated effort. Thus, the maintenance crew might provide the safety equipment, hoisting facilities and other paraphernalia for the repair crew while they are in the sewer or control chamber.

Subsequent to repair and prior to departure from a particular site, the central operations personnel will make tests to insure that a return trip will not be necessary. Operating personnel can inform maintenance personnel of problems whether at an automated location or other location, by inferential judgment. Maintenance personnel can assist operating and maintenance personnel in checking calibrations of systems and preventive testing.

The maintenance personnel should be given the most extensive safety training and equipment, since they will spend the most time under hazardous conditions. They should also be given prime responsibility for protecting other personnel who infrequently will be in hazardous locations. Cooperation with sewer cleaning and maintenance crews will also be necessary.

Effective utilization of personnel in a remotely controlled system is essential. Because of wide geographic distribution of equipment and the interconnection of mechanical, electrical, and electronic systems, considerable time can be spent diagnosing problems and removing, repairing, and replacing defective equipment. For example, it is conceivable that several days might elapse before it is determined whether a defect is in the telemetry, the electrical or mechanical system, if a craftsman of each class was sent sequentially to investigate. Sending all three craftsmen to each trouble area is also wasteful.

Several solutions of this problem are available. In the design of a system, modular plug-in units can be used for easy replacement by the maintenance men. For example, small air compressors can be installed using plug-in power cords and quick-disconnects on air lines. Similar techniques are available for telemetry, power units, and instruments. Judicious inclusion of test points, gauges, and indicating lights also can be of benefit as a repairing aid.

In order to avoid excessive travel-and-turnaround time by repair crews to obtain parts, equipment or additional aid, a support team with a suitably equipped and stocked vehicle should be provided to serve such crews when required. Since manholes and underground structures are not easily identifiable on the ground, adequate maps and location drawings must be readily available for the crews.

In some cases, it is not practicable for the operating agency to provide the depth and range of skills in-house for maintaining an automated system. Increasingly, therefore, use has been made of contractual services on a yearly, or on-call basis when required.

The management of an automated regulator control system requires cooperation with other organizations. A partial list of these for a typical system might include the: telephone company; power company; gas company; weather bureau; street department; engineering department; water department; and fire department.

It is advisable to have a key person for contact with all of these agencies. Normal contact will be minimal with some agencies and continuous with others. The Weather Bureau will usually be very cooperative in providing information on rainfall conditions. This information will be helpful in the planning of operations. Troubles with telemetry systems will be minimal if the proper person is found within the local telephone company. A number of the other organizations will assist in spotting overflows and also can provide significant data and technical assistance. Equipment used by other utilities can be examined for possible use in regulator management.

Fixed equipment required at a central site for maintenance of an automated system will generally be electric or electronic in nature. A number of sophisticated test instruments are available for checking leased telephone lines. Shop facilities may or may not be required depending on the equipment and methods used. Replacement of defective modules with substitutes makes it possible to send the defective unit to the factory or depot for repair. Good truck and equipment washing facilities are desirable, and periodically all portable and central site equipment should be inspected, inventoried, and cleaned.

Communication is needed between the central dispatcher and all field units, as well as between personnel working in regulator chambers, sewers and vaults and those remaining outside. For calibration purposes, the telemetry system can be used for communications but two-way radio is more useful. Speaker and microphone extensions can be used to allow personnel to use the radio while in a shallow chamber or in a field structure. Where this is not possible, hand-held transceivers can be used to relay messages between the site and the vehicle and thence to the central site. Communications between underground personnel and those remaining at the surface can be by sound-powered telephones, switchless intercoms, or by transistorized megaphones. Revisions to the equipment can be made for use in the sewers. A direct outside telephone should be provided at the central control site, in addition to the normal business extension telephones. The central site should also have means for direct radio communication with the field.

The organization and administration of regulator maintenance operations obviously should be tailored to the operating agency's needs. Typically, maintenance has been largely ignored, with dependence on random complaints for determination of unnecessary overflow. With or without the automated system, the maintenance function should be given prime consideration. Separating the regulator maintenance from sewer maintenance facilitates the development of the specialized capability needed for reduction of pollution from overflows and development of the information and technology necessary to improve the operation of the regulators and thus the entire sewer system.

Example of Maintenance Practices in an Advanced System

The Minneapolis-Saint Paul Sanitary District maintains approximately 150 regulators which discharge to about 80 river outlets. Automated regulator equipment is provided at 15 locations which control about 80 percent of the system's dry-weather flow. In addition, there are approximately 25 other locations where equipment has been placed to measure interceptor sewer levels, rainfall, and river quality. About 140 measurements are telemetered to a central location; 34 gates and 15 inflatable fabric dams are subject to control.

An engineer is responsible for the maintenance of the system, which was placed in operation in the spring of 1969. Under his supervision, the maintenance crew consists of five men. Prior to the District's assumption of maintenance, 18 sewer workers from the two cities worked part-time on the

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The following is a suggested organizational chart for regulator maintenance.

SUGGESTED ORGANIZATION CHART
REGULATOR MAINTENANCE

MANAGEMENT

ENGINEER
(PART TIME)

OTHER ADMINISTRATIVE AND MANAGEMENT FUNCTIONS

OPERATION	ROUTINE MAINTENANCE	REPAIR MAINTENANCE
Records	Field Crew	(Part Time)
Calibration		Electrician
		Fitter
		Electronics Technician
		Instrument Repair

---

regulators.

Computer equipment is maintained under contract by the contractor who installed the system. The telemetry system is maintained by a plant electrician who is assigned to work part-time on the system. Mechanical repairs have been minimal and have been performed part-time by help from the plant machine shop. In-sewer replacements of bubbler tubes have been accomplished by the maintenance crew. The maintenance function at major automated regulators is performed by the computer at variable time intervals. Typically, each of the 40 gates is checked every 4 hours during dry-weather to determine gate position. The measured position is compared with the desired position and, if necessary, the gates are readjusted. A complete report is automatically typed showing initial and final gate positions, as well as notations of inoperative gates or telemetry system failures. During storm flows the gates can be adjusted individually by remote control or by establishing new gate settings in the computer system. In the latter case, the gates will be reset to the new positions when the periodic check is made. In addition to the periodic check of gates, a complete computer check of all gates can be initiated at the central site by operation of a single select button.

The remaining overflows are given periodic routine checks by the maintenance crew. A very few locations known to be troublesome, are visited more frequently. Depending on the work load of the crew, the periodic checks are made once or twice monthly during dry weather. A full check of outlets requires 2½ days on the ground. The same information can be obtained in a little more than one hour by helicopter. Before a helicopter trip is ordered after a rainfall, the local weather bureau is asked for a current weather prediction. A checkoff sheet of overflowing locations is prepared and usually all overflow can be stopped in one shift. Helicopter flights are only ordered if a detectable increase in flow due to runoff is observed on one of a number of sewer level or flow meter charts.

Thunderstorm activity occurs frequently at night in the Twin Cities. By using the helicopter flight and based on information from the instrumented system, all overflows are cleared by the end of the normal working day. By comparison, using old methods, overflow often continued for several days after such storms.

Regulator Maintenance as a Specialty

In many jurisdictions there is a division of responsibility for collection and treatment of sewage. In some of the larger jurisdictions, the collection system frequently is under the control of the sewer division in the public works department. The responsibility for interception of the dry-weather flow in the combined sewers often rests with a larger agency, such as a countywide sanitary district, which also has responsibility for treatment of the conveyed wastes before disposal to the receiving stream. The exact point where each agency's responsibility begins and ends is often not clearly defined. Traditionally, cities have performed minimal regulator maintenance, with the main emphasis on getting rid of the waste water and avoiding local area and basement flooding. Often the cities are charged for operation and maintenance of a more comprehensive district, based on flow volume delivered to it, and there is little incentive for the contributing communities to capture the maximum flow. In such cases excessive overflows from collector lines, prior to their junction with the interceptors of the agency which serves multiple jurisdictions, is encouraged. Engineering departments usually are not anxious to raise the height of permanent weirs or dams to increase the capture of runoff since this may affect the hydraulic functioning of the combined trunk sewer system during times of peak flows. The impediment of flow by high permanent dams may cause serious backups and health hazards in basements.

In order to satisfy the often conflicting requirements of maximum diversion to interceptors and protection of upstream sewers from discharge, regulators in which a weir or dam height can be adjusted with complete reliability is required. The adjustments must be made frequently, based upon knowledge of the capacity of the interceptor downstream from the regulator, upon flow depths in the combined sewer leading into the regulator and on comparisons of strength and quantities intercepted and spilled at other regulators in the system. Knowledge of reserve treatment plant capacity for quantities of polluted storm runoff must be considered.

In most operations, sewer maintenance crews spend their time immediately after a storm answering complaints of flooded basements and plugged catch basins. After the majority of the post-storm complaint work is completed, the regulators are visited. In some cases, due to the large number of regulators, the last regulator may not be cleared for as long as two weeks after a storm.

Because of these difficulties, a dedicated crew that is committed totally to a routine and regular surveillance program is a must to improve operations.

The logical agency to handle this function is usually a larger or regional multi-community agency. With the many limitations on local budgets, the larger district responsible for treatment and pollution abatement may be able to more easily obtain funds for manning and equipping the regulator crew and operating the instrumented systems. If this assignment of authority is to be provided by a local community to a regional agency, it must be clearly defined by agreement or regulations.

Most of the employees on an average sewer crew are laborers with limited knowledge or experience in the functioning of the hydraulic, electrical, mechanical, and pneumatic equipment that is now being used on more sophisticated regulators. The most efficient use of manpower is to assign to the regulator crew those men having some of the training and skills necessary to ensure the routine continuous maintenance of the control equipment in service in the system.

The ideal situation would be for the supervisor to assign to the sewer crew a man or men with a knowledge of electrical and mechanical systems where they are in use. The men should be able to read and understand instruction manuals, drawings, and other written materials. They should also be able to maintain necessary records and to prepare reports and written memoranda. They should be required to maintain an inventory to requisition necessary supplies and replacements, and to recommend field revisions.

Improvement of regulator maintenance procedures requires the proper manpower selection and training; establishment of standards of manual surveillance methods, accurate record-keeping; and availability of certain special equipment.

The critera for selecting manpower for a regulator crew are important. The men should have considerable agility to enable them to climb in and out of manholes and small spaces without physical injury. The men selected should be willing to enter the sewer when assured that adequate safety precautions have been satisfied, and they should be sufficiently intelligent to understand the dangers of the work.

Regulator crews, like other skilled team workers, should be constantly trained to carry out their jobs effectively. They must have the essential elements of their jobs clearly identified to carry out their mission in the most efficient manner. Knowing the general objectives of their jobs, they must be carefully trained to realize these goals with ease and safety. Their training should be adequate to ensure that all reasonable precautions for their safety and the safety of others are being provided. They must be well trained in the use of hazard detection equipment and capable of developing needed contingent plans for unexpected situations.

Training should be sufficiently complete to allow them to perform simple tests of any mechanical, pneumatic, or electrical equipment used in the operation of the regulator devices. A contingent plan should be developed for any anticipated malfunctions to assure the least possible damage while the malfunction is occurring and to provide for the speedy correction of any difficulties. The crew must understand fail-safe systems employed to provide for the least serious consequences, in the several options of operation, coincident with power failures. In some instances, fail-safe operation would require the lowering of adjustable dams during power failure and the crew must be able, at the more important regulators, to provide emergency power by connecting portable power units to enable the regulator to return it to operation at the earliest possible time.

By using improved manual surveillance methods, a more effective policing job can be done with reduced manpower. A number of jurisdictions hire helicoptors to expedite the location and reporting of overflows and malfunctions. By reviewing existing manual inspection methods, an improved program can usually be established to improve response time and utilize manpower more effectively. The improved program may require minor system modifications, such as installation of new manholes or ladders for inspection or access. In areas where many outfalls exist, those which are connected to regulators should be easily identified from air, ground or water by adequate marking and numbering. An outfall checkoff list can be prepared, referring to nearby landmarks and including a list of contributing regulators if more than one is tributary.

Record-keeping in any successful regulator maintenance program should be simple, yet contain the essential information that would be required for improved management. In establishing a new or revised regulator maintenance program, the usual first-step requirement is generation of, or updating the inventory of regulators and assembling all pertinent drawings and records. All drawings and records should be field-checked by the regulator crew. New drawings and records should be made where necessary. A duplicate file system, one for field use and one for office use, should be made with all information for each regulator assembled and grouped by regulator location.

Standard forms should be developed for routine record-keeping. Preferably, these should be arranged in a manner suitable for later analysis by data processing methods. The best approach is to use a simple form for making the notations, with boxes to check, requiring a minimum of writing by the field crews. However, there should be room on the form for remarks to permit the field men to make notations not covered in the standard form. Some of the simple data to be included on the form are: (a) Location of the regulator; (b) identification of regulator; (c) time of day; (d) day of week; (e) date; (f) condition—working or clogged; (g) if clogged, how many inches going over the dam spilling into waterway; (h) condition of the orifice—any blockage, hangings, etc.; (i) anything unusual about the quantity or quality of flow coming to the regulator; and (j) any unusual odors or discoloration in the flow.

In order to implement improved methods of regulator maintenance, special equipment must be provided. The current high cost of labor easily justifies the purchase of all tools and equipment needed to expedite the work and minimize working time. A complete list of all equipment needed is rather extensive. Items of major significance can be grouped in three categories—safety, descent and ascent, and working equipment.

All equipment must be evaluated from a safety standpoint. Special safety equipment should include sophisticated electronic and chemical testing devices for explosive or noxious gas, for oxygen deficiency, and for toxic fumes. Testing equipment should include battery-operated sampling pumps to insure reliable results. Duplicate equipment should be provided for oxygen deficiency and explosive gases. Nylon parachute harnesses should be furnished for all personnel, with sufficient spares, and it should be the established rule that a harness is worn at all times below ground to facilitate rescue in case of accident. Special rescue devices should also be available at the surface. A small portable self-contained breathing apparatus, usually with a 10 capacity, is available and should be provided. Standard procedure should be to have at least one breathing apparatus available at all times when the men are underground. Procedure should also require that a breathing apparatus be lowered into a hole before a man enters.

Equipment for ascent or descent should include hoists, one powered and one manual. During ascent and descent in deep manholes, a safety harness connected to a nylon safety line should be used. This safety line can be snubbed around an appropriate part of the truck and attended by a person on the ground.

Working equipment should include temporary working platforms and supports, flushing equipment, tools for cutting and removing clogged materials and numerous other items. Modern self-contained blower generators can be used for power and ventilation when maintenance work other than short time inspection or the clearing of debris is being performed. Battery-operated tools are now available for use in hazardous locations to eliminate shock and explosion hazards. Non-sparking tools and equipment will reduce explosion hazards.

SECTION 7

TIDE GATES: APPLICATIONS, DESIGN AND PERFORMANCE

Tide, or backwater gates, or flap gates are employed to protect collector sewers and interceptor systems from the inflow of tidal or high river-stage waters. Without such control devices, backflows would surcharge interceptors, pumping stations and treatment plants and adversely affect treatment processes. The inflow of such receiving waters into combined sewer systems at some points would ultimately result in uncontrollable overflows and the bypassing of excessive volumes of waste waters to receiving waters at treatment plants.

Tide gates are intended to open and permit discharge at the outfall when the flow line in the sewer system regulator chamber produces a small differential head on the upstream face of the gate. Conversely, backwater gates are designed to close when the stage or tide level in the receiving waters produces a small differential head on the downstream side of the gate. Some types of gates are sufficiently heavy to close automatically, ahead of any water level rise in the receiving body. With careful installation and balancing, coupled with an effective preventive maintenance program, the ability of the gate to open during overflow periods is not impaired because of this additional weight.

Types and Sizes of Tide Gates

Tide gates are available in a wide variety of sizes; they may be rectangular, square or circular in shape, depending on the requirement.

Tide gates are manufactured in three basic types, depending on the construction of the flap, as follows:

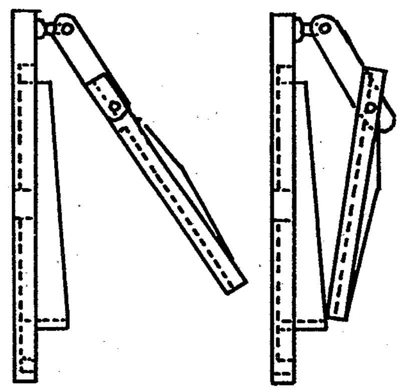
1. Cast iron,
2. Sheet metal plates, and
3. Timber.

Cast iron gates are available in sizes varying from 4 to 96 inches in diameter, when circular, and 8 x 8 inches to 96 x 96 inches when square, or variations in rectangular shapes within these limits.

Sheet metal is used to fabricate a lightweight tide gate shutter, which is a double-walled structure with interior air cells. This lightweight application offers a more positive opening response to small differential outfall heads. This is of particular advantage over heavier cast iron models, which may, particularly with age, require a significant upstream head to swing open. When the waste water flows on the receiving water courses are corrosive, pontoon tide gates have had a life expectancy of only 10 to 12 years unless carefully protected with inert, corrosion-resistant coatings or constructed of corrosion-resistant materials. These "pontoon" shutters of sheet metal are available in circular style from 48 to 120 inches in diameter. Square and rectangular gates are available in dimensions from 48 to 120 inches.

An important feature of such metal tide gates is their hinge arrangement. Except for very large sizes, instead of hinging the shutter at the top only, a second set of hinges of a linkage type are attached at the sides of the shutter. This linkage is devised in a way that will permit it to open at the top if its bottom has become jammed in the closed position by the weight of debris deposited at the downstream side during periods of high river levels or high tides. Figure 23, Hinged-Type Tide Gate, illustrates a typical hinging configuration.

FIGURE 23



POSITION A　　POSITION B

HINGED TYPE
TIDE OR BACKWATER GATE

Position A shows the normal full opening attained when the outlet channel is unobstructed. Position B indicates the advantage of the second set of hinges, which permits the shutter to open at the top when the lower body of the gate is blocked by debris. The resulting outflow may then wash away the debris and permit the gate to function fully, as in Position A.

Early tide gates were made of timber or wooden planks, and were either hinged at the top or double-leafed with hinges at the side similar to a double barn door, with the gate frame inclined at the top. Gates of this latter type were installed in the

Boston area.

Timber tide gates suffered a decline in popularity during the early part of the century. However, they are again being used in large sizes. Such gates are economical in sizes larger than 7 x 7 feet or in odd dimensions. A typical timber tide gate is shown in Figure 24, Timber-Type Tide Gate.

The construction features of this gate are as follows:

1. A gate frame made of cast iron in securely bolted sections;
2. Shutter, with timbers laid in the vertical position;
3. Carrying bars inserted between particular timbers to act as reinforcement or stiffeners for the shutter and for connection with the hinge blocks;
4. Horizontal stiffeners and tie rods provided to prevent warping, to structurally stabilize the shutter, and to prevent flotation;
5. Hinge arrangement to permit the attachment of the gate to the gate frame and structure;
6. Hinge bracket anchor bolts set in oversize pipe sleeves to provide slight adjustment; and
7. Lifting bolts provided at the base of the shutter to enable the gate to be operated manually when required.

The tide gate should be cured before machine fitting.

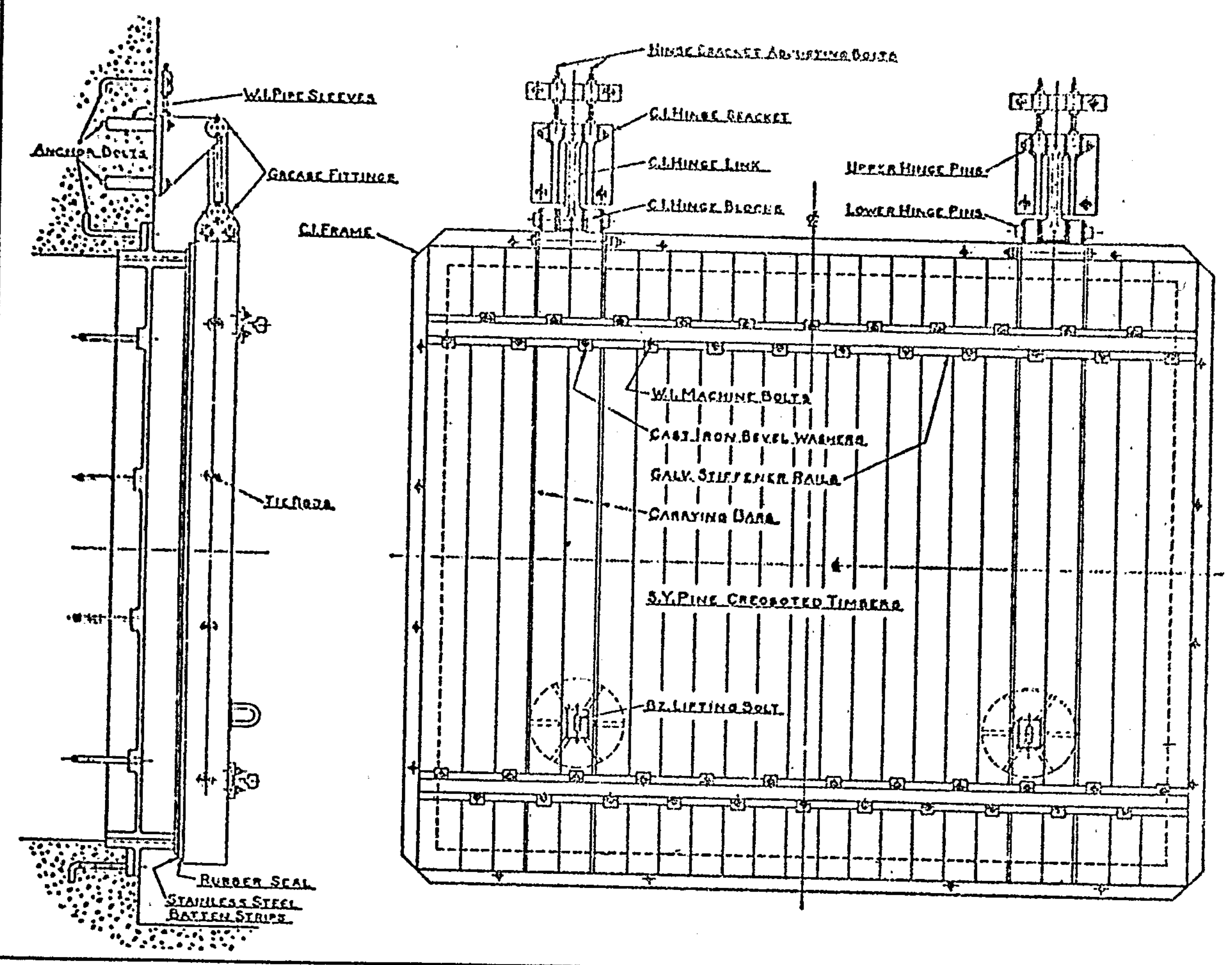
Use of timber gates which are alternately wetted and dried may accelerate deterioration.

Dense structural Southern yellow pine is the most common timber material used for such gates. Cypress and Douglas fir have also been used. These woods require creosote treatment to prevent rapid deterioration.

In New York, greenheart timber is now being used. This structural timber requires no

FIGURE 24

TIMBER-TYPE TIDE GATE



Courtesy Brown & Brown Inc.

wood-preservative treatment, and is resistant to marine borers and wood-destroying fungi. It is extremely dense (approximately 70 pounds per cubic foot so that little additional weight is required to offset buoyancy. It is resistant to seasoning splits and checks that are common to other structural wood, it machines well, and has a high resistance to warping or distortion. Table 26, Allowable Working Stresses for Timber, compares the working stresses for greenheart and other structural woods.

TABLE 26
ALLOWABLE WORKING STRESSES OF TIMBER

Timber	Parallel to Grain-PSI			Perpendicular to Grain-PSI
	Compression	Tension	Shear	Compression
Yellow Pine	1550	2000	135	455
Cypress	1466	1733	133	300
Douglas Fir	1100	1450	95	390
Greenheart	3000	3300	400	1500

In some of the jurisdictions surveyed, tide gates are of shear or sluice gate type, motor-operated or hydraulically actuated. This type of application lends itself to remote control of the rate of tide gate operation, as required. Information is transmitted to the central monitoring station by bubbler-type level sensors located upstream and downstream of the tide gate in order to provide regulator control of the interceptor system.

Installation of Tide Gates

Tide gates usually are installed at the head of the outfall sewer line, as part of the regulator station, or in series, at a selected site within the outfall sewer line, at a point between the outfall discharge and the regulator station. Installation of the tide gate structure at the outfall discharge point may have the advantage of lower capital cost, and the availability of sufficient space to permit the construction of an outfall structure protected by several small gates, as opposed to one large control unit. The use of several smaller parallel tide gates permits the opening of the gate flap under a relatively small head differential. Because of their smaller individual bulk, they are more readily operated by maintenance personnel when jammed with debris.

The disadvantages of tide gate installation at the outfall discharge point are:

1. Boats and boat crews will be required to effect maintenance, since the gates may be partly or fully submerged during high river stages or high tides.
2. In tidal waters, severe wave action may overbalance the pressure behind the gate shutter, thereby forcing the gate to close abruptly with considerable force. Repetition of this cycle at short intervals may produce objectionable noise levels, especially in residential areas.
3. During periods of high river stages, or high tides in coastal or estuary waters, the trapped sewage in the barrel of the outfall sewer between the regulator station and the tide gate may become septic. This pollution load eventually will be discharged into the receiving stream.
4. In the "total systems" concept of combined sewer interceptor operation, the tide gate should function in a coordinated manner with the operations of its upstream regulator, a condition which may not be attainable if the tide gate is located at a distance from the regulator structure.

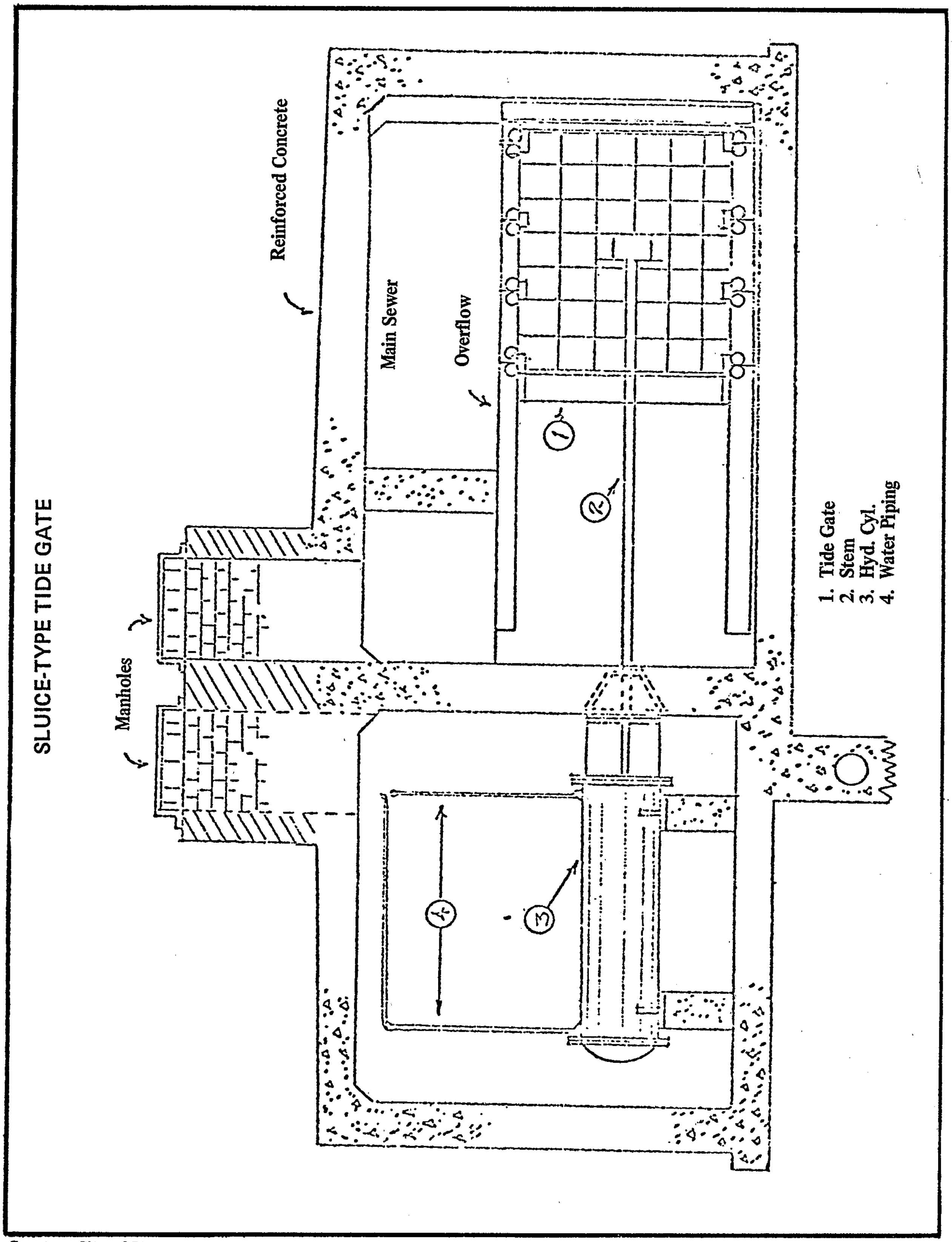
Tide gates that are installed within the barrel of the outfall, in tandem, at a predetermined point between the outfall and the regulator station, provide an additional safeguard to the interceptor system, particularly when the crest of the diversion dam at the regulator station is only slightly higher than the normal water level at the point of outfall. This point of installation also may be used in locations where very high tides or severe variations in river stages are experienced for extended periods of time. Where wave action causes slapping of the flap against the gate seat, tide gates have been installed upstream in the barrel of the overflow pipe at a point where the wave energy will have been dissipated.

Figure 25, Sluice Gate-Type Tide Gate, shows a typical installation for a sluice type-gate in a two-chamber facility. Figure 26, Tandem Tide Gate Installation, shows a tandem tide gate installation, with a stop-plank arrangement for shutting off the outfall line at the downstream face of the gates to permit servicing of the gates.

Tide gates have been installed to advantage at the outfall connection of a regulator station at the head of the overflow pipe, as was shown in Figure 15. This type of installation has the following advantages:

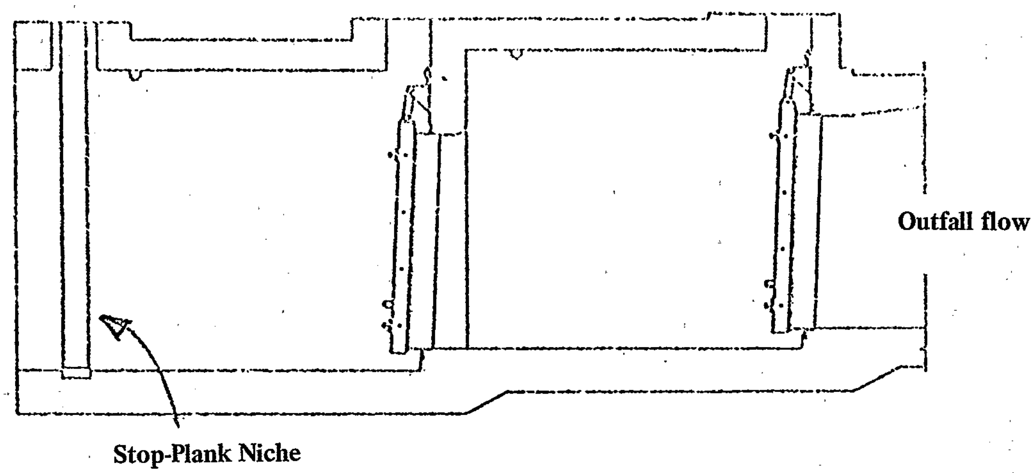
1. Routine preventive maintenance and inspection can be carried out in conjunction with regular visits to the regulator chamber.
2. Major repairs, such as shutter removal for hinge replacement and shutter repair or replacement, are facilitated because of increased accessibility.
3. Motorized equipment, such as hoists, can be located vertically above the gate for more efficient maintenance.

FIGURE 25



Courtesy City of Philadelphia

TANDEM TIDE GATE INSTALLATION



4. Stop-planks may be placed in a preformed channel in the tide gate chamber, so that major repairs and inspections can be carried out under dry conditions.
5. Remote control in conjunction with the adjacent regulator operation may be used.

The capital cost of a tide gate installation at a regulator station will frequently be higher than at the outfall discharge point, particularly if the regulator is located in a congested area of the community. If the flow being discharged to the outfall is large, sufficient space may not be available to install smaller and more sensitive tide gates in parallel. In such cases, the larger single gate installation will often require an auxiliary power source to operate effectively.

Operation and Maintenance of Tide Gates

To evaluate the operation and maintenance characteristics of tide gate facilities, the project survey investigators made an effort to obtain specific information from personnel experienced with these devices. The following design, application and operation guidelines were obtained:

1. Periodic inspections are necessary to insure free rotational movement at the pivot points; lubrication is a regular requirement. Permanently lubricated bushings are now available which greatly reduce this lubrication requirement.
2. Hinge arms and gate openings must be checked regularly to be sure that they are free of trash, timber, or other obstructions which lock the shutter in the partly open position, allowing inflow.
3. Metal seating surfaces should be scoured regularly if evidence of surface corrosion exists. This will enable tight closure of the shutter.
4. Neoprene gaskets or buta-N rubber gaskets improve the sealing characteristics of the seat between the shutter and its frame. These are inert and not subject to corrosion.
5. In locations where tide gate installations are subjected to particularly corrosive waters, brass fittings will require periodic replacement. Some systems use stainless steel fittings in this kind of service.
6. New York City's experience demonstrated that wrought iron pontoon tide gates had a life expectancy of only 10 to 12 years because of rapid corrosion. The metal pitted through and the air cells subsequently filled with water. The loss of buoyancy affected gate operation. Redesign of the gates in terms of material and buoyancy characteristics has corrected this condition.
7. The base of the gate should be equipped with one or more lifting eyes, depending on gate size. A chain should be attached through the lifting eye to a readily accessible maintenance area, so that the gate can be lifted with comparative ease.
8. A careful selection of the tide gate site or structural modification of the site and the tide gate, can facilitate maintenance and reduce its cost.

Field Survey Results

Activation of tide gates is most commonly set to occur at approximately a 6-inch hydraulic differential. The information on tide gates obtained from the surveys is summarized in Table No. 27, Field Survey Findings on Tide Gate Practices. Although the data obtained were relatively meager, a number of important points were disclosed in some of the surveyed jurisdictions. These merit special attention.

TABLE 27
FIELD SURVEY FINDINGS ON TIDE GATE PRACTICES

Location of Jurisdictional Sewer Agency	Number	Type	Location	Cost	Operational Problems	Activation Criteria
New York City	292	104 cast iron 40 timber 148 pontoon	2: on interceptor 276: coll-inter. junct. 10: pumping sta. 2: trt. plant 2: other locations	3′ x 4′ = $10,000 5′ x 4′ = $15,000 (1964)	clogging; broken hinges; corrosion; warping	6″ head differential
Philadelphia	Yes	15 timber +	on all float operated regulators (81) with leaping weirs 2 with hydraulic cylinder	$12,000 for K & P units in one intercepting chamber		
Montreal	1	circular metal	separate chamber			
Seattle	8				difficulty with septicity of overflows	4″ head differential
Detroit	48	timber (3′ x 4½ to 10′ x 12′)				
Pittsburgh	186	143 metal 43 wood	diversion structures; pumping stations; treatment plants			
Omaha	28					
St. Louis	Yes					
Boston	1	originally timber				
Chicago	328			up to $100,00	maintain 12 times/yr.	
Milwaukee	18	timber	10 horiz. orifice 8 vert. orifice			
Washington	30	timber unless outlet 24″ or less	25: on interceptor 2: pumping station 1: trt. plant 1: at outfall		debris removal replacement of bronze bolts & hinges with stainless steel	6″ head differential
San Francisco	Yes		at the outlets (15 major overflow discharge points)		sand backup at gates	require 12″ weirs set so that they are submerged with 7 ½ tide 4 times/yr
Cincinnati	40					
Cleveland	4					
Total Reported	797+					

In New York City, although some outlets in the higher areas are not provided with tide gates, the proximity of the city to the tidal waters of New York Harbor and tributary rivers makes the use of tide gates essential at the majority of the regulator chamber overflows. Selection is on the basis of 10 to 15 percent greater area of opening than the combined sewer, to reduce the head loss and to compensate for the fact that the perpendicular dam in the sewer is six inches higher than the invert of the inlet sewer to the diversion chamber. Because of the relatively low elevation of the combined sewer, there are several locations in the city where tide gates are used in series; a chamber in one instance contained two banks in series, each bank with eight gates.

The present practice in New York City is to use cast iron gates with neoprene gaskets for sizes up to 4 x 4 feet and greenheart timber from British Guiana for the larger gates. Timber gates are reinforced with steel rails to prevent warping, and they are furnished with lifting chains which are accessible from above the structure for lifting the device.

In Detroit, timber gates are mounted in walls which are battered ½ inch per foot. Variations in the design of these units include frame castings which have been made in a single piece, and frames with an inclined seating face, made for mounting on walls with vertical faces.

In Washington, D.C., planned maintenance of tide gates is carried out by a special crew, on a schedule of once a year at the treatment plant and twice a year where the units are in service on the interceptor system.

In Philadelphia, two horizontally-operated tide gates are in use. A large hydraulic cylinder, with cylinder stem in a separate chamber, is used to power the gates. Activation of the cylinder is by means of water pressure. Under normal dry-weather conditions, the small regulator gate is opened and the tide gate is closed, with all sewage passing through to the operating chamber and ultimately to the interceptor. Under wet-weather conditions, the water elevation rises and, by means of the interconnecting telltale pipe, the float commences to rise. As the float rises, the regulating collar on the float stem contacts the pilot arm and raises it, changing the position of the four-way valve. This changes the position of the port and allows the water to pass onto the top of the small cylinder and commence closing the regulating gate. At the same time, the water passes through the front of the large cylinder and the tide gate starts to open. With the small gate closed and the tide gate now open, the combined sewer overflow is diverted to the river via the outfall sewer.

When the period of wet-weather flow is over, or the elevation in the main sewer drops, a corresponding drop occurs in the float well, and the reverse procedure closes the tide gate and the small gate opening.

SECTION 8

EUROPEAN REGULATOR PRACTICES

The use of combined sewers in urban areas is not peculiar to the United States and Canada. Combined sewers are in general use in many other countries. Those nations with older communities make greater use of such combined facilities, just as the older cities on the American continent are served by combined systems.

The technical literature on this subject indicates that only a limited number of cities have advanced their water pollution control programs to the point where sewer separation, or the control or treatment of overflows has become essential. However, in some cases efforts have been made to reduce the strength of the overflow waste water, and to retain and treat flows which are carried in interceptor systems.

As part of the present study, an investigation was made of conditions and practices in specific areas of Great Britain, France, Switzerland and Germany. These countries were chosen on the basis of regulator and control practices disclosed in literature reviews; on the personal knowledge of the project staff and advisory members; and on information contained in replies to letters of inquiry on regulator practices which were sent to governmental agencies in several countries.

In general, the study of foreign practices indicated the following general policies and practices which are at variance with recent trends and developments in the United States and Canada:

1. The number of combined sewer overflow regulator facilities are limited to restrict the number of overflow points.
2. Standards of practice require the use of storm water detention tanks in conjunction with regulator devices to minimize the pollutional impact of overflows on receiving waters.
3. There has been somewhat greater effort in some foreign areas to control the quality, as well as the quantity, of overflow wastes, by means of in-sewer design features and devices. (This is referred to in the current project as the "Two Q" concept—control of both quantity and quality of overflow wastes.)

European practice is generally based upon lower per capita sanitary sewage flows and somewhat lower rainfall intensities than those experienced in American communities. Local officials during personal interviews in European cities did not indicate any problems with oversize debris such as timbers, automobiles, etc., such as have been reported in several major jurisdictions of this country.

The following abstracts of European survey data are intended to illustrate some of the foreign regulator overflow practices which will be of interest to officials and engineers in the United States and Canada.

1. German Practices

Each state within the German Republic is almost completely autonomous with regard to water pollution control practices. Secondary treatment of sanitary sewage and industrial wastes is generally specified. Mechanical devices are not widely used in conjunction with combined sewer overflow regulation.

General criteria[4] require that:

1. Storm overflow structures in combined sewer systems should be applied if this seems to be useful under technical and economical aspects. Generally, this would be the case for sewers with a large cross section area, from a nominal diameter of 60 cm. (24 in.) upwards.
2. If it can be avoided, several sewers should not be tributary to one storm overflow structure. If necessary, a connecting structure should be inserted ahead of the overflow structure and the conduit leading to the storm overflow structure should be designed as a region of steady flow. The length of the calm region should be at least 20 times the nominal diameter of the sewer.
3. Nominal width and slope of invert of the calm region should be selected so that the conduit is completely filled for the design storm and that the velocity of flow does not exceed 1.0 to 1.5 m/sec (3-4.5 ft/sec).
4. The contraction of the through-trough should be continuous from approach conduit to discharge conduit.
5. It may become necessary to design the discharge conduit as a throttling pipe. In this case its nominal diameter shall be at least 20 cm. (16 in) in order to avoid clogging. If possible, the invert slope of the throttling pipe should be selected to allow twice the dry-weather flow to be discharged into the continuing conduit so that open-channel flow conditions will be maintained in the discharge conduit. The minimum velocity of flow should be 0.5 m/sec (approximately 1.5

[4] *Note: Edited general translation*

ft/sec).

6. The weir crest should be constructed horizontally over its (active) length. The elevation of the weir crest should be high enough to avoid backwater from the discharge channel to the receiving water. The weir height should be at least 25 cm. (8 in) above the invert of the through-trough.

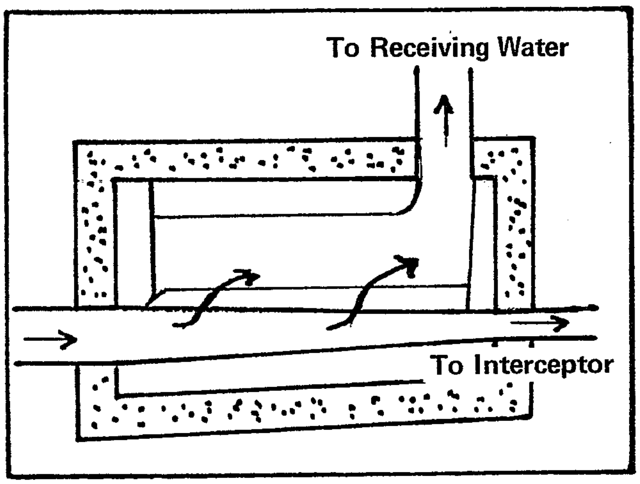
7. A service platform should be constructed along the through-trough. Clearance between the floor of the service platform and the ceiling of the structure should be not less than 1.80 m (5½ ft). A sufficient number of manholes should be provided in order that all parts of the sewer system can be maintained and cleaned. In larger storm overflow structures, lighting facilities of moisture-proof type should be provided.

8. Generally, it is recommended that the storm overflow be constructed as a side-spill weir on one side. If local conditions require a shortened length of the structure, this can be achieved by constructing side-spill weirs on both sides.

9. Within fenced-in areas of treatment plants, storm overflow facilities can be designed as open structures.

10. When double side-spill weirs are used, only 75 percent of the weir length should be considered usable. A minimum depth of 20 cm (6 in) should be maintained under the through-pipe.

FIGURE 27



STORM OVERFLOW IN THE FORM OF A SIDE WEIR

Figure 27, Storm Overflow in the Form of a Side-Spill Weir, is a sketch of a typical German installation. The flow to the treatment plant is usually controlled by the use of a "throttle pipe" which, under overflow conditions, acts as a pressure system. With this type of control, excellent gauging of flows to the treatment plant is reported. As with any system which is dependent upon the inherent hydraulic characteristics of the system, it is important that approach grades to the facility be such that a hydraulic jump does not occur in the chamber. This would make part of the weir length unusable and raise the water elevation in the facility.

Regulator installations were visited by project personnel in Mainz, Rhineland-Platz. All were of single high side-spill weir overflow design. The design of access and maintenance facilities was excellent. For one large facility under an arterial street, a stairway has been constructed with its entrance from the parkway. This provided ease of entrance, without any restriction to street traffic.

2. Swiss Practices

The national policy in Switzerland permits the continued construction of combined sewer systems. The usual design is to carry two times DWF to the treatment plant and to store the remaining flow in storm water retention tanks for eventual pump-back to treatment processes, or to storm water clarification tanks for partial treatment of flows in excess of the available storage capacity.

Water quality rules have been established which specify the settleable solids, BOD, and nitrogen to be removed from the combined sewer overflow. Research has been carried out to ascertain the retention time required in clarification tanks to achieve the desired degree of removal.

The economics of constructing and operating either retention or clarification tanks requires that the regulator and tank be placed on the interceptor sewer at a point where sufficient flow occurs to justify the facility, rather than increase the interceptor size and carry the entire flow to the waste water treatment works.

In Geneva, all of the combined sewer flow is taken to a central waste water treatment plant which provides the following facilities:

1. Screens and detritors are designed to receive up to 90,000 cu m/hr, or 570 mgd; this represents the total summer sanitary flow, plus storm water runoff.
2. Siphons automatically distribute half of this flow (45,000 cu m/hr or 285 mgd) equally to eight primary tanks in parallel, or equally up to this rate to any other number which happen to be in operation. The flow of 285 mgd is 4.9 times the average annual daily water consumption and

three times the average daily summer water consumption.

3. When flows exceed 285 mgd (3 times the summer average DWF) the siphons automatically and equally distribute 285 mgd to six of the eight primary tanks and the flow in excess of this rate, up to an additional 285 mgd is diverted to the remaining primary tanks. This provides from 10- to 15-minute detention time for this additional flow.

4. After leaving the primary tanks, the flow is distributed automatically and equally by means of Ponsar siphons, up to a rate of 127 mgd (20,000 cu m/hr) 2.25 times the average annual daily water consumption and 1.34 times the average daily summer water consumption), to the secondary units which consist of eight aerators and eight final clarifiers. All flow in excess of 127 mgd (20,000 cu m/hr) is automatically diverted to the River Rhone, ahead of the secondary facilities. In all, 49 automatic Ponsar siphons are utilized in this plant.

3. French Practices

The practice in Paris and environs indicates that very few automatic regulators or other mechanical devices are currently utilized for control of overflows from combined sewers. Fixed weir overflows have been used most commonly for this purpose. In a very few cases, these are manually adjustable. Automatic regulation by adaptation of the Ponsar siphon is provided at Clichy, a major screening and control station on the Paris sewer system. At several treatment plants outside of Paris, such as at Calais, the Ponsar siphon is used at the plant inlet to limit flows entering the plant from combined sewer interceptors to a fixed rate.

4. English Practices

The Minister of Housing and Local Government appointed a Technical Committee on Storm Overflows and the Disposal of Storm Water in 1955. Since that time the committee has conducted extensive research into the design and operation of several types of combined sewer overflow regulator devices, described in an interim report in 1963. In 1969 the committee was continuing preparation of its final report. The preliminary conclusions of the committee, as expressed in the interim report, were as follows:

1. There is a better method than that traditionally used for determining the setting for overflows. Instead of setting them at a multiple rate, usually six times the dry-weather flow, it is better to set them so that a fixed volume of surface water will be retained in the sewer in addition to the dry-weather flow. This allows for the variations in dry-weather flow from place to place, and for the fact that surface water does not vary proportionately.

2. Many overflows are set at levels far less than six times the dry-weather flow. Unnecessary pollution could be prevented in many places without the need for new sewers by raising the overflow setting; where this is possible it should be done immediately.

3. New sewer systems are usually planned to provide for expected increases in sewage flow as a result of growing population, industrial demands and water consumption, and full use should be made of spare sewer capacity as long as it is available, for the retention of additional surface water.

4. Some types of overflow (specified in the report) are unsatisfactory in themselves, and their use should be discontinued.

5. The practicability, of incorporating storage in new systems to contain as much as possible of the "first flush" of storm sewage should be considered.

6. Sewer system authorities should assess the performance of their present overflow systems as a basis for deciding what improvements are necessary and economically practicable. What is needed for this assessment is an examination of the existing sewers and sewage treatment facilities, an evaluation of the population that is served and expected to be served; of the sewage flow, and of the local rainfall. The impact on the water courses into which overflows discharge must also be considered.

The results of the model and field studies conducted for the committee were published, following a Symposium on Storm Sewage Overflows, conducted by the Institution of Civil Engineers, May 4, 1967. This excellent set of 11 papers described:

1. Field studies on the flow and composition of storm sewage (Northampton, Bradford and Brighouse)
2. Effect of storm overflow on river quality
3. The treatment of storm sewage
4. Laboratory studies of storm overflows with unsteady flow
5. The performance of stilling ponds in handling solids
6. Storm overflow performance studies using

crude sewage

7. Secondary motions applied to storm sewage overflows

8. Design, construction and performance of vortex overflows

9. Reconstruction of overflows

10. Practical design of storm sewage overflows, and

11. The storage and discharge capacities of sewer systems and the operating frequency of storm overflows: Dutch methods of calculation.

The laboratory experiments (No. 4) were used to determine the operating characteristics of: low side-weirs; stilling ponds; vortex; and storage overflow. The models apparently had many limitations and in some cases they did not incorporate provisions found desirable in existing field installations. Both the Storage-type Regulator, and the Stilling Pond Regulator, Figure 28, exhibited good operating characteristics. The Vortex Regulator, Figure 29, had inconsistent characteristics.

Field experiments (No. 6) were conducted using crude sewage and a low double side-spill weir, a stilling pond, a vortex overflow, and a high level side-spill weir with position flow control. The low side-spill weir was found to be generally unacceptable. The other three types exhibited various favorable qualities. The high side-spill weir and vortex overflows, both with outlet control, gave good control of flow to treatment facilities.

The field tests, in contrast to the model tests, gave little indication of pollution improvement of the overflow by type of regulator, except for the vortex at high flows. This lack of overflow quality enhancement was thought to be a characteristic of the constraints at the testing facility inasmuch as the results of actual test installations indicated overflow quality improvement.

Of particular interest is the work which was done involving secondary motions (No.7) with regard to liquid flow. Research was carried out with the development of helical flow. It was found that a short bend, or a series of short bends can be used to separate the solids from the flow discharging to the overflow. The formation of a helix or a system of helices exist in any flow of liquid within curved boundaries. Solids are concentrated on the inside of the bend. The flow with the concentrated solids load can be bled off with siphons or slots, or the overflow can be permitted to take place along a high side-spill weir on the outside of the bend. Figure 30 Spiral Flow Helical Regulator, illustrates a typical unit configuration.

The circular vortex overflow is another form of secondary motion device. Two such regulator devices have been constructed at Bristol. The results obtained with full-scale units were reported to be far superior to the results obtained from the model and test facilities.

Interviews were conducted in England with both national and local officials. These interviews revealed that:

1. Stilling ponds and high side-spill weir overflows are the two general types of overflows now being constructed. Many of these regulators use a penstock control (mechanical sluice gate) to control discharge to the interceptor.

2. Mechanical screens are in general use, (see Fig. 31) to screen solids from the overflow and return solids to the interceptor sewer.

3. The number of overflow points is being reduced in order that detention or treatment facilities can economically be constructed for the overflows.

Regulator installation in Coventry, Manchester and Bristol were visited by project personnel. Highlights of practices at each jurisdiction follow:

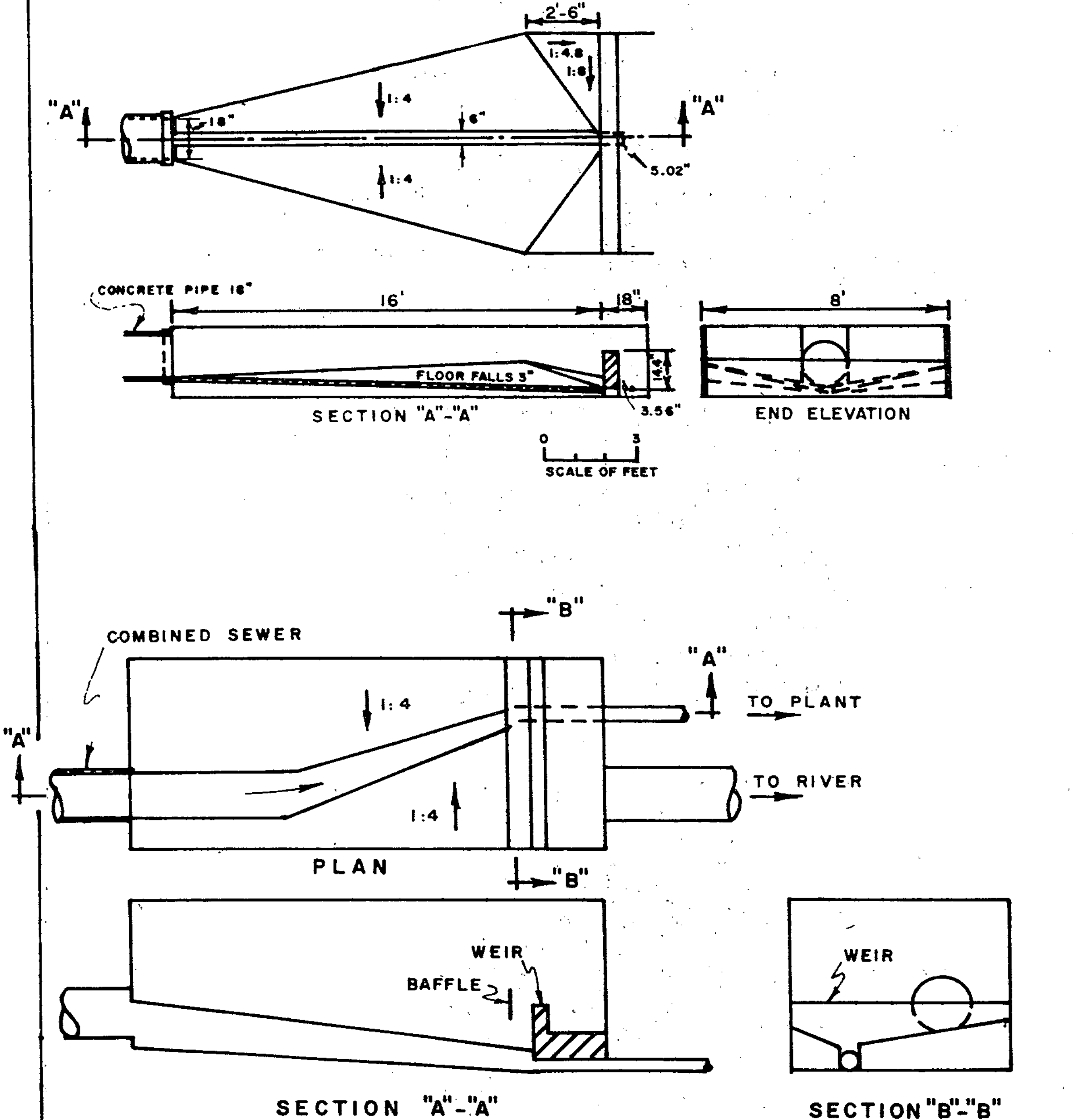
Coventry: Coventry has recently established three storm water stations. All of the combined sewage is taken into one of the three stations where the flow in excess of the sewage treatment facilities is overflowed to a series of three storm water tanks, with a capacity of approximately 20 times the dry-weather flow. At the regulator facility, "Parkwood" screens are used to minimize the amount of floating solids overflowing to the tanks.

Figure 31, Mechanical Screens, illustrates a typical installation on a side-spill weir. The storm water tanks overflow approximately three times a year. They provide good primary settling. Solids are removed in a conventional manner. The overflow weirs have penstock controls to limit the outflow to the treatment facility; however, this is based on a calculated rate and is controlled only by the incoming flow. The tanks are pumped back into the interceptor line whenever the flow to the treatment plant is less than the plant capacity.

The storm water stations are landscaped and located adjacent to new developments. In one case, a golf course abuts the facility and another station is adjacent to a university housing project.

Along the orifice outlet of the regulator an access chamber is provided for a considerable distance in order to facilitate measurement of the flow and maintenance operations.

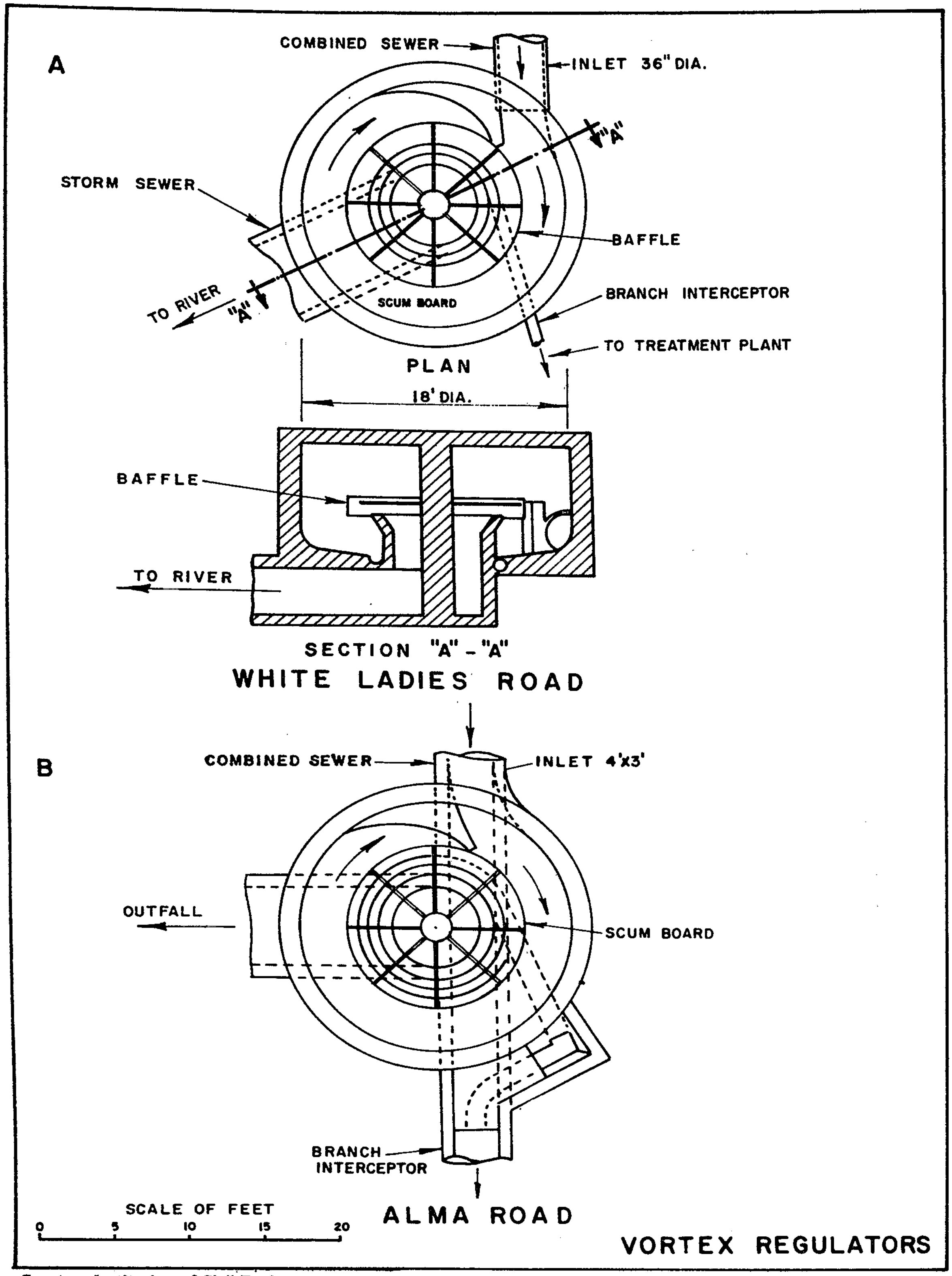
FIGURE 28



POSSIBLE APPLICATION
STILLING POND REGULATOR

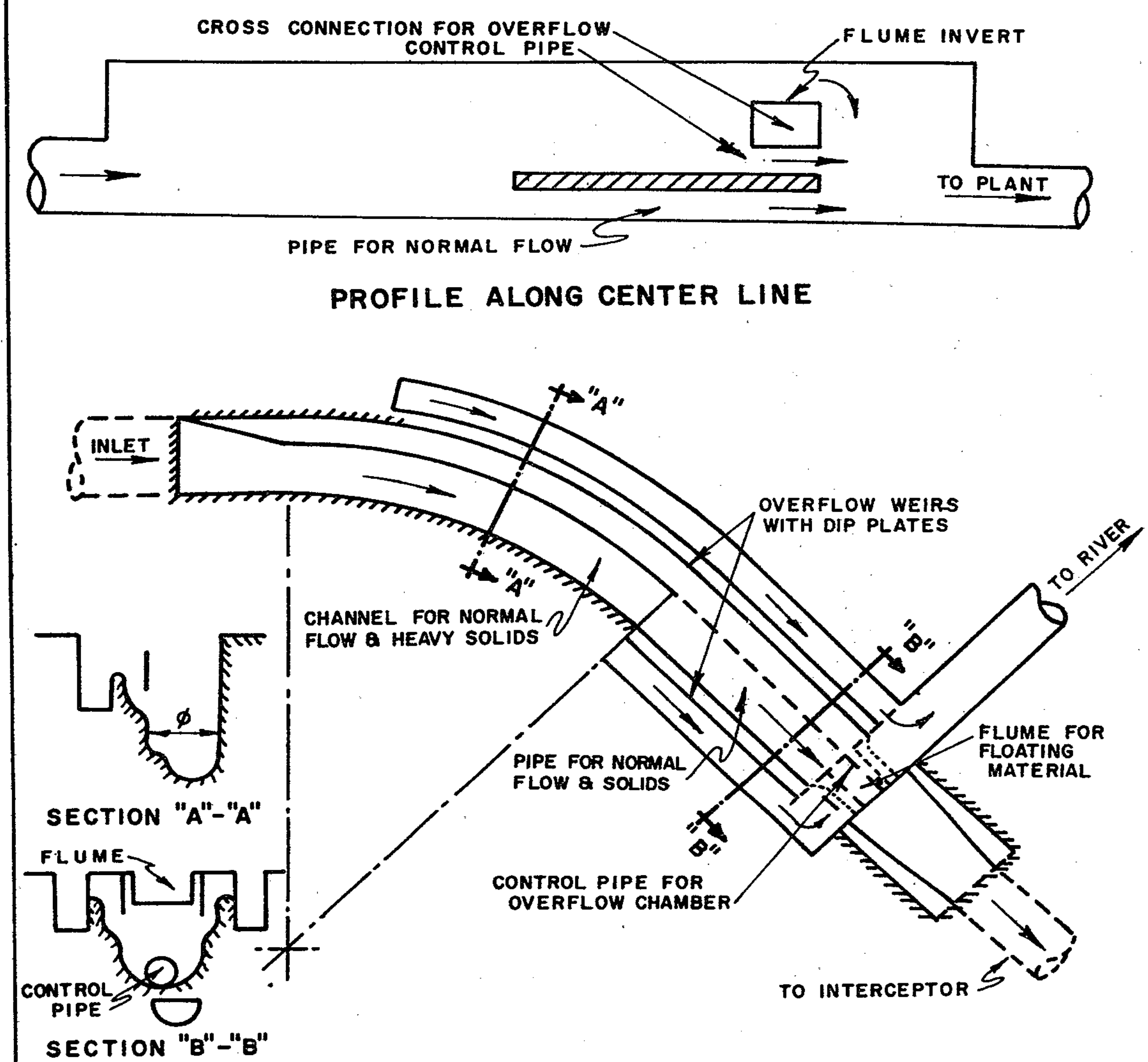
Courtesy Institution of Civil Engineers

FIGURE 29



Courtesy Institution of Civil Engineers

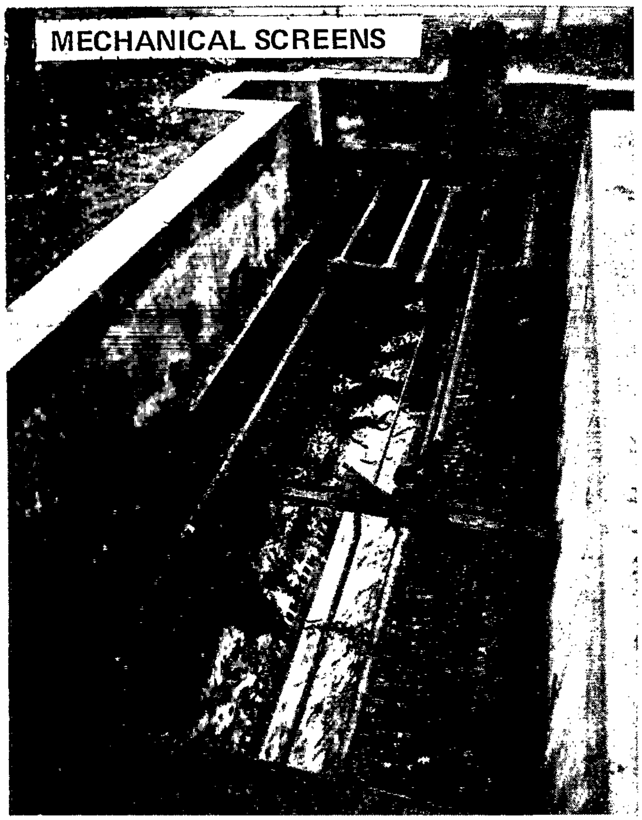
FIGURE 30



SPIRAL FLOW (HELICAL) REGULATOR

Courtesy Institution of Civil Engineers

FIGURE 31



Courtesy The Longwood Engineering Co. Ltd.

Manchester: The City of Manchester is rebuilding portions of its combined sewer system to eliminate overflows and to increase capacity. The new regulator facilities are basically of the long weir type with large stilling basins; a scum board is used to minimize overflow of floating debris. Storm water in excess of the sewage treatment plant capacity is taken to the treatment plant where the flow is screened and then run through long grit chambers prior to entry into storm water holding tanks. The stilling basin serves to reduce the number of overflows and to return non-floating solids to the foul sewer. Penstock controls are used to control flows.

Bristol: The City of Bristol is rebuilding much of its storm water combined sewer system, using high side-spill weir overflows and taking six times DWF to the treatment facility.

During the investigation of possible design for regulators to be used on a major relief sewer to protect the business area of the city, the concept of using a circular vortex regulator was evolved in order to obtain adequate weir length without the expense of constructing a long side-spill weir structure. Laboratory studies of the vortex configuration were carried out and eventually two regulators were constructed in 1964.

The facility which was inspected by the project personnel had a diameter of approximately 16 feet. Retention time is approximately 11 seconds; tests indicate that 70 percent of the solids are diverted to the interceptor.

A scum board is used to retain floating solids. Clogging of the outlet has occurred only three times in six years–caused each time by bricks from deteriorated sewers.

The City of Bristol is continuing its work, utilizing the vortex principle with an experimental primary settling tank for a flow rate of 3,000 gpm. Results to date are very satisfactory.

Summary of European Experience

Although hydraulic conditions in Europe and England vary from American conditions, there are several practices which should be considered for adoption or adaptation in the United States and Canada:

1. Limit the number of overflow points.
2. Improve the quality of overflow by screening or applying secondary flow motions.
3. Consider utilization of stilling ponds, high side-spill weirs, and circular vortex regulators–all with controlled outlet controls.

SECTION 9

ROLE OF PRODUCTS, PROCESSES, AND FUTURE REGULATOR PROGRESS IN IMPROVED CONTROL OF OVERFLOWS

The investigation of problems relating to combined sewer overflows, carried out under the 1967 Investigation disclosed the numbers, locations, and types of regulator devices in use in the United States. These devices may be categorized, basically, as static and dynamic regulators.

Devices in the static class, such as weirs and orifices, have been fabricated locally by either small foundries or machine shops or installed or built in place by the sewer system jurisdiction or contractors serving them. Other so-called static devices, such as manually operated gates and siphons, have been supplied by companies in the national field. Dynamic regulator devices, including semi-automatic and automatic units, have been built and supplied by manufacturers for the national market and are usually listed in catalogs and technical brochures. Instrumentation facilities for application to the regulator field have been manufactured by companies experienced in the electronic-electrical recording-controlling-automation field.

Potential developments and future progress will depend in great measure on the desires and capabilities of experienced manufacturers to research and create improved processes, products and materials for primary applications to combined sewer service and for other related functions.

The interrelationship between the equipment manufacturers and the development of improved regulator practices for the improved control of overflows is very important. It was decided that evaluations of available devices and facilities and the prospect for future developments must be determined directly with manufacturers. The purpose of such contacts between producers and users of regulator devices and systems was to ascertain the need for, and means of, developing new regulator practices to eliminate unnecessary overflows; to provide better guidelines for the application and adaptation of existing and proposed regulator facilities; and to catalyze the development and use of new and improved technologies and materials.

Developing a Relationship With Manufacturers

This type of coordinated effort can be accomplished in two ways: by individual contacts with all such manufacturers; or by collective group discussions with interested and concerned manufacturers and suppliers.

The second procedure was adopted on the basis that better exchange of information would result from such group contacts and that a broadening and cross-fertilization of interests between all such manufacturers and suppliers would result from this procedure. To expedite this decision, a one-day exploratory conference on regulator problems was convened by the American Public Works Association, with a representative of FWQA participating. Approximately 50 manufacturers of various types of regulator equipment and appurtenant facilities were invited to attend the session. Eighteen manufacturers sent representatives and approximately ten more expressed interest in the project and asked to be advised of further developments and to receive information on the findings and conclusions of the exploratory meeting.

Creation of the Manufacturers' Advisory Panel

During the exploratory conference, the manufacturers' representatives recommended the creation of a smaller working panel to serve as the liaison between the manufacturing field and the FWQA-APWA research project. This subgroup was created and designated as the Manufacturers' Advisory Panel. Members of the panel are listed in Section 11 of this report, in acknowledgement of their invaluable services and the importance of the information which they supplied to the project.

At the first organizational meeting, the panel decided that its operations could be expedited and the performance of its functions improved, by designating subcommittees to carry out specific phases of its responsibilities. The following subcommittees were created:

1. A subcommittee on the most effective materials for regulator facilities;
2. A subcommittee on improved operation and maintenance practices;
3. A subcommittee on instrumentation and control; and
4. A subcommittee on the "total systems" concept of sewer management and control.

Pertinent excerpts from preliminary reports of panel subcommittees are included in Section 14 of this report.

Survey of Existing Products and Processes and Stimulation of Future Developments in Regulator Practices

Over and above the functions assigned to the Manufacturers' Advisory Panel, an attempt was made to contact all known manufacturers of products and processes directly or indirectly applicable to the regulator field. A communication was addressed to all such companies requesting them to supply the following information:

- A full catalog listing of all equipment now offered, such as: regulators, gates, valves, standard actuating devices, direct controls, instrumentation, automatic-automation systems, sensing devices, remote control and telemetry facilities, and any other related products or processes.
- Other technical literature on regulator equipment, materials and methods, such as brochures, engineering reports, technical papers, cost data, and application data.
- Forecasts covering important trends and developments in improved regulator methods, materials and mechanisms, all within the limits of proper protection of any and all proprietary and patent rights to their products and processes.

Catalog material was received from a number of manufacturers, partially serving the purpose of inventorying available hardware and auxiliary equipment related to the regulator field. A limited number of replies gave some indication of future trends and developments and showed limited manufacturers interest in the improvement and enhancement of regulator practices by means of new products and technologies and better application of existing facilities and equipment. In a number of cases, manufacturers who do not now market products in the regulator field, but whose equipment could have such applicability, expressed minimal interest in the utilization of their products and processes for regulator-control purposes.

In addition to the catalogs and technical bulletins received from manufacturers, other sources of such information were utilized to partially augment these basic data. In keeping with the broader definition of regulation to encompass the control of both the quality and quantity of overflow waste waters (the "Two Q" concept outlined in Section 2 of this report), a search was made for catalog and bulletin data which might have a direct bearing on this two-phase principle of overflow regulation, either directly or in a secondary manner. Table No. 28 contains collated data on products and processes.

TABLE NO. 28
TECHNICAL CATALOGS AND BULLETINS RELATING TO PRODUCTS AND PROCESSES OF PRIMARY AND SECONDARY APPLICABILITY TO THE REGULATION AND CONTROL OF OVERFLOWS FROM COMBINED SEWER SYSTEMS

Allis Chalmers Manufacturing Corp.—Butterfly valves; fabricated valves; water control gates

Armco Steel Corp.—Sluice gates; flap gates

Autocon Industries, Inc.—Supervisory control equipment; remote control; telemetry; panels

Badger Meter Mfg. Co., Instrument Division—Flow tubes; Parshall flumes; transmitters/receivers

Bailey Meter Co.—Pneumatic and electric level transmitters; computer control systems; orifices; flow nozzles

BIF—Application data on electronic control systems; telemetry; weirs; orifices; valves

Bird Machine Co.—Aeration process

Bowles Fluidic Corp.—Technical bulletins/data on fluidic/technology and water management; FWQA report on fluidic interceptor control

Bristol Co.—Liquid level measurement and control equipment; telemetering; pneumatic and electric transmitters and controls

Brown & Brown Inc.—Automatic sewage regulators; tide gates; engineering data

Chicago Pump, FMC Corp.—Barminutors; Comminutors; screening machines; grit removal

Cla-Val Co.—Valves

Clow—Comminutors

Coldwell-Wilcox Co.—Hydraulic cylinder-operated sluice gates; flap gates; tide gates; backwater gates; fabricated diverter gates; gate operators

Crane, Cochrane Division—Microstrainers; ozonators for storm water overflows; waste water treatment equipment

Delta Scientific Corp.—Analytical equipment for monitoring and control of waste water

DeZurik Corp.—Eccentric valves

Dorr Oliver—Grit removal equipment; waste water treatment equipment

Firestone Coated Fabrics Co.—Fabricated plastics; Fabritanks; Fabridams

Fischer & Porter Co.—Time pulse receivers; chlorinators; meters

Flomatcher Co.—Sewage pump control systems; fluid start-stop sequencers; pneumatic control systems

Foxboro Co.—Liquid level measurement and control equipment; telemetering; receiver-recorders; transmitters; pneumatic and electronic controls; analog computing stations

General Electric Co.—Integrated circuitry; remote station operators; digital coding systems; supervisory systems for automatic variable-speed pumps

Glenfield & Kennedy, Ltd.—Microstraining equipment

Golden Anderson Valve Specialty Co.—Solenoid-operated valve systems

Healy-Ruff Co.—Telemetry equipment; pressure-operated controls; float operated controls

Henry Pratt Co.—Butterfly valves; controls

KDI Poly-Technic, Inc.—Water quality monitors

Leopold & Stevens, Inc.—Flow meters; telemetering systems

Link—Belt, FMC—Screens; grit removal equipment

Minneapolis Honeywell Regulator Co.—Flow and liquid level meters; telemetry; industrial controls; graphic panels

National Sonics Corp.—Water-solids interface sensors

Neptune Meter Co., Neptune MicroFloc, Inc.—Microfloc equipment

Phipps & Bird, Inc.—Sewage sampling equipment

Rex Chainbelt, Inc.—Trash racks; water screens; grit collectors

Rockwell Mfg. Co., Republic Div.—Pneumatic transmitters; pneumatic relays; pneumatic controllers, positioners; electronic transmitters; final drives

Rodney Hunt Co.—Sluice gates; gate hoisting equipment; fabricated slide gates; fabricated timber gates; flap valves; tide gates

Rohrer Associates Inc.—Underground storage facilities for storm water,

Waco, Products Div.—Stop gates; slide gates; bar screens; weir plates, aluminum products

Wallace & Tiernan Co.—Chlorinators; residual chlorine analyzers; controls

Western Machinery Co.—Grit removal equipment

Yeomans-Clow—Pneumatic pump-ejectors; aeration equipment; clarifiers

Zurn Industries, Inc.—Microstrainers; waste water treatment equipment

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The Potential Market For Regulators and Appurtenant Devices

The contacts with the manufacturer were made for the purpose of stimulating new research and development efforts. At the exploratory conference, manufacturers expressed concern over the required expenditure of industry's time and money for the development of materials, methods and mechanisms which would have limited use and sales potential. Reference was made to the general lack of action against combined sewer overflows on the part of pollution control regulatory agencies, and to the hesitancy of municipal officials to expend the funds necessary for the improvement of regulator facilities and systems. This concern was based on these above factors, and on the fact that the construction of new combined sewer systems will be of limited significance in sewer practice in the future, hence limiting the market for new regulator stations.

Manufacturers were advised that the market lay not necessarily in the area of new regulator station installations but, rather, in the modernization and upgrading of regulator facilities in existing systems and stations, in order to facilitate the reduction of the frequency and period of duration of overflows. Upgrading of regulator facilities may also be necessary when facilities are constructed to treat overflows.

While the project survey of the policies of state water pollution control agencies gave no great assurance that any intensive drive for the betterment of regulator facilities was imminent at the state level, a subsequent investigation of Federal policies indicated that a tangible market for the improvement of regulator practices could be anticipated. A partial listing was obtained of recent Federal water pollution control enforcement conferences with state agencies, where Federal recommendations had been made on combined sewer problems. Excerpts from this record of enforcement conferences are included here to indicate that there is a new interest in the prevention of pollution caused by ineffective regulator devices. This interest indicates a reasonably important market for new regulator devices, and the application of automatic-automation-instrumentation practices which will result from research and development efforts by manufacturers.

SUMMARY OF SPECIFIC RECOMMENDATIONS CONCERNING STORM WATER OVERFLOWS IN RECENT FEDERAL-STATE ENFORCEMENT CONFERENCES

The following are excerpts from enforcement conferences where recommendations were made on the combined sewer problem.

Pollution of Boston Harbor and Its Tributaries
April 30, 1969

1. A report, by a consulting engineering firm, calls for the most practical and economical solution for abatement of the pollution effects from tributary streams and combined sewer overflows in Boston Harbor which will be completed by the winter of 1970-71. The report is to be followed by an implementation schedule which will incorporate the approved recommendations.

Pollution of Lake Erie and Its Tributaries
(Michigan, Indiana, Ohio, Pennsylvania, New York)
Second Session, August, 1965

1. All new sewerage facilities are to be designed to prevent the necessity of bypassing untreated wastes.
2. Combined sewers are to be prohibited in all newly developed urban areas and eliminated in existing areas wherever feasible. Existing combined systems are to be patrolled and flow-regulating structures adjusted to convey the maximum practicable amount of combined flows to and through treatment plants.

While the dates for completion of various stages of the other requirements for municipal treatment, etc., have extended, it is to be noted that the above requirement of patrolling combined sewer systems was to start immediately.

Pollution of the Inter-State Waters
Of the Hudson River and Its Tributaries
(New York, New Jersey)
September, 1965

1. The pollution problem caused by discharges from combined sewer overflows is to be reviewed, and a program for action is to be developed for consideration by the Federal government, the states, and the Interstate Sanitation Commission, by December 31, 1968.
2. Programs shall be established for surveillance of existing combined sewer systems and flow regulatory structures to convey the maximum practicable amount of combined flows to and through treatment plants.

Pollution of Lake Michigan and Its Tributary Basin
(Wisconsin, Illinois, Indiana, Michigan)
January-March, 1968

1. Unified collection systems serving contiguous urban areas are to be encouraged.
2. Adjustable overflow regulating devices are to be installed on existing combined sewer systems, so designed and operated as to utilize to the fullest extent possible the capacity of interceptor sewers for conveying combined flow to treatment facilities.

–The treatment facilities shall be modified where necessary to minimize bypassing. This action is to be taken as soon as possible and not later than December 1970; pollution from combined sewers is to be controlled by July, 1977.

Pollution of the Interstate and Intrastate Waters
of the Upper Mississippi River and Its Tributaries
(Wisconsin, Minnesota)
February–March, 1967

1. Present combined sewers should be continuously monitored and operated so as to convey the maximum possible amount of combined flows to and through the waste treatment plant. Methods to be used to control waste from combined sewers and a time schedule for their accomplishment should be reported to the conferees within two years.

Pollution of Interstate Waters of the
Potomac River and Its Tributaries
Washington Metropolitan Area
(District of Columbia, Maryland, Virginia)
April-May, 1969

1. Detailed analyses of alternate methods of meeting future water quality requirements and sewerage needs in the Metropolitan Area shall include fail-safe sewer systems to prevent raw sewage discharges; possibilities for load transfers to other sewage treatment plants, etc.
2. The conferees, at six-month intervals, shall review plans for elimination of pollution from combined sewer overflows and establish a timetable for the control of such pollution.
3. The State of Maryland shall take action to control sewage overflows from sources in Maryland. Alexandria, Virginia, shall complete plans by December 31, 1971, for elimination of pollution from combined sewer overflows.

Functional Gaps in Regulator Practices

One of the major goals of the research study, in terms of contacts with manufacturers, was to create a recognition of the functional gaps which now exist between present products and practices, and those which hold promise to provide new sophisticated improvements in regulator control facilities. The challenge is to fill these gaps with new products, processes and procedures.

As has been stated, the problem of regulator-overflow improvements must be solved by a two-pronged approach to quality and quantity control of waste waters discharged from combined sewer systems to receiving waters, either directly or following some form of treatment, or quasi-treatment processing.

Two things are apparent from a listing of "gaps" in combined sewer system operation and control. *Reduction in the quantity of overflow wastes from combined sewers must be combined with the improvement of the quality of overflow wastes which reach receiving waters. The "Two Q" definition of regulator functions and overflow control must be accepted in all future work in this field.*

Study of foreign and current North American trends has served to emphasize the challenges that lie ahead. These include, but are not limited to, the following procedures:

A. Control of Overflow Quality

1. Use of screens, present or new types, to protect regulator devices from clogging, deterioration or other physical damage, and to intercept waterborne waste substances which might otherwise add to the pollutional impact of overflows;
2. Utilization of skimming-baffling devices to improve the quality of overflow waters;
3. Utilization of fluid secondary-motion configuration devices to concentrate solids in sewer flows and to thus enable the withdrawal of the solids to the interceptor sewers and treatment works;
4. Utilization of fluidics-principle devices for better and more sensitive regulation of intercepted and wasted flows, and for the possible improvement of the quality of waste waters allowed to overflow to receiving waters;
5. Use of retention facilities to intercept combined sewer overflows and return them to the treatment plant during normal flow periods; and
6. Treatment facilities such as microstraining, dissolved air-flotation, and high-rate filtration.

B. Control of Overflow Quantities

1. Application of new siphonic principles for better regulation of overflows from combined sewers, and for prevention of backflow into collector and interceptor sewers by tidal and high river-stage waters;
2. Application of inflatable fabric dams to provide effective and sensitive control of overflows by storing combined flows upstream in sewer systems;
3. Adaptation of valves, pumps and other available equipment to the specific purpose of combined sewer regulation and overflow control;
4. Maximizing application of all feasible methods of in-system or off-system retention of surplus flows to reduce or eliminate discharges of overflows to receiving waters; and
5. Monitoring of overflow incidents and periods of duration, for the purpose of evaluating the feasibility of quantity control of overflows.

C. Total Systems Management of Combined Sewer Systems

1. Application of more effective and sophisticated instrumentation and automatic-automation facilities for the purpose of achieving "total systems" management of combined sewer networks;
2. Development of new hardware and auxiliary equipment to implement systems management of combined sewers and to utilize the full potential carrying and retention capacities of all parts of a total sewer system;
3. Integration of urban area precipitation and runoff rates by means of rain gauge monitoring circuitry which will alert control centers and automated overflow-regulator stations to anticipated excess flow conditions;
4. Total systems analysis of combined sewer networks for the purpose of ascertaining the potential benefits of more sophisticated overflow control;
5. Utilization of the knowledge and skills of local utilities in the communication field, in exploring the feasibility and workability of total systems management techniques; and
6. Consolidation of overflow points into fewer locations which can then be equipped with more effective regulator facilities and geared into a total systems control and management program by means of automatic-automation-instrumentation procedures.

The necessary improvements in equipment and systems is dependent on the manufacturing industry.

This cooperation must be nurtured and guided by means of a continuing liaison between suppliers and users of the kind of equipment and apparatus upon which improved regulator-overflow practices must depend.

Some of the goals set forth above are being met, in whole or in part, in combined sewer practices in demonstration projects in the United States and Canada, and in actual field installations in other countries. Current developments in regulator and control facilities and methodologies offer tangible proof that the scientific knowledge of the 1960's will be better utilized for the control of the quantity and quality of overflows from combined sewer systems in the 1970's. Of special significance is the application of the "total systems" management concept in demonstration projects stimulated by FWQA grants to various governmental jurisdictions. The possibility of "making two blades of grass grow where one grew before"—utilizing not only the *transporting* capacity of sewer systems but their *retention* capacity—by means of "total systems" control is worthy of serious consideration by the governmental field and the industries which serve it.

References to actual in-system applications of combined sewer management in this report of the study project, and in the Manual of Practice which is an integral portion of the project, add pertinence and practicality to the use of improved quality and quantity control of overflows to alleviate the water pollution problems besetting the water resources of the American continent.

SECTION 10

THE "SYSTEMS CONCEPT" OF COMBINED SEWER REGULATION: AN OVERVIEW

Combined sewer systems have been designed and constructed on the principle that overflows at frequent locations could be used most effectively to provide prompt and local relief of collector sewers and interceptor lines. This proliferation of overflows and regulators also served to reduce the size of interceptors required in various sections of the total sewer system.

This principle may have been pertinent and permissible when the amount of combined sewer overflow and the actual location of the discharge were not considered significant in the control of water pollution. However, if pollution control is to be achieved, there must be a reduction in volume of overflows, in terms of frequency and duration, and in the pollutional strength of the waste water discharged to receiving waters. Improved regulator practices and facilities can play a major role in achieving this goal. In addition, treatment facilities for combined sewer overflows can be more effectively operated if the flow to the facilities is controlled by a well designed and operated regulator.

The major imperfection of combined sewer overflow regulation stems from the proliferation of individual facilities, designed to perform the elementary function of relieving the sewer system without any consideration to the effect of each individual discharge point upon the total sewer system, as well as on the waters into which the overflows spill. This each-unit-of-a-sewer-system-for-itself concept fails to integrate the various facilities into a master management plan. Specifically, it is based on the principle that, in substance, each regulator-overflow installation is a separate entity not related to the rest of the total system. If this principle prevails, little can be done to alleviate the frequency and duration of the total system's overflows. Even with better control obtained at each overflow point, for example, by converting static regulator devices which are insensitive to in-sewer conditions to dynamic systems which react to collector sewer and interceptor levels and capacities; such regulators will tend to maintain desired hydraulic conditions in the restricted area where the unit is installed, but no major benefits are likely to occur in the overall system.

The defects of single-unit control are: (1) multiplicity of overflow points; (2) inability to establish a priority sequence of locations to minimize environmental harm and hazard; (3) failure to achieve the full hydraulic capabilities of each section of a total sewer system; and (4) lack of opportunity to utilize the whole sewer system in direct relation to the patterns of storm and runoff in various areas of a community, particularly those with large areas and variable topographic characteristics.

This unintegrated condition can be likened to an automobile traffic control system which relieves congestion at a specific intersection and blinds itself to the fact that in so doing it affects the flow of traffic in all other parts of the system.

The value of improving each regulator device to the highest level of effectiveness, to sense and do something about local conditions at a local point must not be minimized; however, maximum benefits of regulator control and combined sewer management cannot be achieved until the perspective is broadened into the full function of a combined sewer system control program. This latter procedure involves the "systems concept."

The systems concept in its simplest form envisions the management or control of all elements or facilities which are parts of the sewer system to:

1. Make maximum utilization of interceptor sewer capacity to carry combined sewage to the waste water treatment plant;
2. Make maximum utilization of in-system storage;
3. Give priority in the interceptor sewer to those flows which have a higher pollutional load and which, if they overflow, would result in adverse conditions in receiving waters; and
4. Integrated use of combined sewer overflow storage or treatment facilities.

Effects of systems control on the waste water treatment plant must be considered and modification in facilities and procedures provided.

The systems concept envisions that means are available to control the operation of elements of the system and that there is available adequate information as to flow volumes and pollution characteristics to allow decisions to be made.

In the newly recognized "traffic routing" system of combined sewer operation, applicable for large, interconnected systems, the capability of an overall systems management program is applied to the task of shunting flows from surcharged conduits to those with surplus flow and storage capacities and could, thereby, eliminate or at least reduce the need for overflows from the total system. Large-sized combined sewer networks have large storage potential.

Communication is the key to a systems approach. Lack of such communication between individual regulator installations is the weakness of the each-regulator-for-itself procedure. The effective use of modern communication methods is the basis for "tying together" all the individual units into a master system.

The fact that water seeks its own level offers possibilities for intercommunication between individual control-overflow points by means of transferred hydraulic levels. This means of integrating operation procedures, however, is not sufficiently dynamic to provide sensitive control. The same hydraulic conditions which might be depended upon to actuate unified regulator operations, of themselves, may cause the type of local hydraulic overloads in sewer systems which individual regulation stations were intended to prevent

Over simplification of the systems concept of combined sewer system management and overflow control must be avoided. First of all, fixed or static regulator devices will be of limited value in any sophisticated, integrated system. Thus, systems control dictates conversion from static to dynamic facilities in a majority of regulator installations. For this reason, the feasibility of converting multiple chamber locations into a single, sophisticated regulator-overflow station is a key part of a total systems management plan.

The adoption of dynamic regulators, or the adaptation of existing devices into facilities having adequate regulating capabilities, is only the first step in weaving a system of regulators into a total master plan. The problem requirement is to develop facilities and techniques that will efficiently route, limit, divert, transfer, and store waste waters within the sewer system according to a planned scheme of action. This will involve elements for measurement or registering hydraulic conditions at a wide range of locations; for status determination in terms of the rest of the system; for gathering information or data at a systems control station; for using these data to provide the basis for decision-making; for execution of the control plan; for verification that the instructions have been executed, by feedback; and for correction and evaluation of the results of the master control system. The fact that conditions in a sewer system are constantly changing makes prompt control and correction essential.

Measurement and status determination can be accomplished by various types of sensors which utilize electrical or electronic signals to represent such conditions as flow, head, differences in pressure, gate position, and level in receiving waters. Data gathering can be achieved by equipment which conditions or codes signals over prearranged communication channels. Correlation of data is the role of indicators, recorders, loggers, alarm systems, and computers. Decision-making becomes the function of supervisory personnel or of computer programs prepared by such persons. Execution of decisions is assigned to field crews or to remote control automation facilities capable of receiving instructions and carrying them out. Verification can be accomplished through communications with field crews or playback of automated data by way of communication channels. Verification can be accompanied by any corrections required to achieve the desired regulator control.

Examples of Total System Management

The total systems concept is in use in several jurisdictions with combined sewer systems, as the result of demonstration grants from the Federal Water Quality Administration.

Three systems are a matter of record: (1) The Minneapolis-Saint Paul Sanitary District; (2) the Municipality of Metropolitan Seattle; and (3) the City of Detroit.

The Municipality of Metropolitan Seattle, Washington

A total systems concept plan has been described in reports and technical papers prepared by Metropolitan Engineers, Consulting Engineers. The following information on studies of the feasibility of such a system for Metropolitan Seattle are excerpted from these documents.

The Municipality of Metropolitan Seattle ("Metro") has awarded a contract to the Philco-Ford Company for over $1,200,000 for furnishing and installing a Computer Augmented Treatment and Disposal System ("CATAD System"). The primary objective of the CATAD System is to permit optimum utilization of available storage within existing combined sewers in regulating storm water flows to minimize the frequency and magnitude of sewage overflows into Puget Sound. Successful implementation of the CATAD System will serve the immediate and urgent need for abatement of the pollution of Puget Sound by sewage overflows and postpone the multi-million dollar separation of combined sewers which can thereby be accomplished by an orderly construction program as funds become available. Further, it is expected that the degree of separation required will be substantially lessened by the CATAD System, thus saving many millions of dollars.

To minimize the volume and duration of these overflows, motor-operated gate regulator stations are being built wherever major trunk sewers cross the main interceptor sewer. FWQA demonstration grant funds have partially contributed to construction of some of the regulator stations and all of the CATAD System controls. Ten regulator stations are now in operation and nine more are planned or are under construction.

The primary function of the Metro system is the interception of sewage from the collector sewers of the various cities and sewer districts in the Metro service area and conveying the sewage to a treatment plant.

A significant portion of the Seattle Metropolitan area, including the downtown area and the major industrial area along the lower Duwamish River, is presently served by combined sanitary and storm sewers. All of these combined sewers are tributary to the West Point System. Economic considerations dictated that neither the interception system nor the treatment plant be designed to handle storm flows in addition to ultimate sanitary flows. Thus, during some storms, it may be necessary to overflow untreated combined sewage into the Duwamish River and into Puget Sound.

Existing Local Station Controls

Each regulator-outfall station has been provided with local automatic controls which use operating conditions at the station as control references. Diversion of flows from trunk lines into the interceptor sewer is controlled by a regulator gate which is modulated to maintain a preset maximum level in the interceptor sewer. When the interceptor level is above the control set point, sewage is stored in the trunk sewer up to a preset maximum level. When this level is exceeded, the outfall gate is opened in steps to maintain the level at the overflow set point. The maximum tidal range in Puget Sound is about 16 feet and many of the outfalls are below high tide levels. Therefore outfall gate controls have been provided with tidal override features which automatically maintain the trunk level control set point 6 inches above the tide level. The existing controls are of the pneumatic type, water levels being sensed through bubbler devices.

Objectives of Controls

The principal objectives of the CATAD System controls are as follows:

1. To provide optimum trunk sewer lines;
2. To permit utilization of potential storage capability of collector and interceptor sewers in separated areas under storm conditions and to make available the maximum capacity of the interceptor for combined storm and sanitary flows in unseparated areas; and
3. When overflows are necessary, to control such discharges at selected locations so as to obtain minimum harmful effects on marine life or public beaches.

Control Procedures

The regulation of storage in the sewage collection system will be accomplished by controlling the operation of regulator stations and of sewage pumping stations.

Since the primary objective of the CATAD System controls is to reduce the number of occurrences of sewage overflows, it was considered essential that a high degree of reliability be built into the design. Therefore, an overflow occurrence directly attributable to any failure of the remote control equipment including the communications channel could not be tolerated and the criterion was established that upon failure of the remote control equipment, the station would be restored to local automatic controls in an orderly procedure.

Storage control at regulator stations is accomplished through direct control of the position of the regulator gates which control the volume of sewage being discharged into the interceptor sewers and consequently the volume of sewage being stored in the trunk sewers. The regulator gate will be returned to local control only on loss of the remote signal.

The storage of sewage in the trunk lines with overflow provisions is limited to a preset maximum level by a local outfall gate controller. If sewage is stored above the set point level the outfall gate will open, resulting in an overflow. In establishing the set point level for the outfall gate controller, the most unfavorable tidal condition has been considered since the local station controller does not include logic for determining either the direction of tidal movement or the maximum level of the next high tide. Consequently, the trunk level set point has been set low enough so that peak flows can be stored for the maximum duration of the high tide condition, which imposes a severe limitation on the use of potential storage in trunk lines.

In order to overcome this limitation when operating under remote control, it is necessary for the CATAD System to include remote controls for the outfall gates. Two procedures were investigated for these controls, as follows:

1. Direct control through the gate motor controller, and
2. Indirect control by varying the outfall gate controller set point.

Direct control of the outfall gate position from the central terminal would result in potential backup of sewage in the trunk if telemetry to the station failed while a storage operation was in progress. This problem cannot be resolved by restoring the station to local controls since this procedure would result in an unnecessary overflow if the level of sewage in the trunk was above the local set point.

Indirect control of the outfall gate through control of the set point provided a more satisfactory solution.

As in the first alternative, loss of the telemetry signal could result in a potential sewage backup if the set point had been moved above the normal level for local control or in a potential overflow if the set point was abruptly lowered from the abnormal high level on the loss of signal. To prevent either occurrence, electronic circuitry was installed at each outfall gate controller which will cause the outfall gate set point to be restored to the normal level for local control over a selected period of time. The time interval will be sufficient to allow sewage stored in the trunk sewer to be discharged into the interceptor through the regulator gate.

Remote control of the set point is accomplished by transmission of a contact command signal to the remote terminal which opens or closes a contact in a circuit from a variable-rate pulse generator to a stepping motor. The stepping motor drives a potentiometer which produces a proportional voltage output signal. The potentiometer signal is converted to a digital quantity through an analog to digital converter and transmitted back to the central terminal. When the desired set point has been reached a contact command signal is transmitted to the remote terminal which opens the contact.

A loss of signal from the remote control equipment will initiate a local control restoring sequence. The restoring circuit equalizes the remote controlled set point with a constant signal from a manual set point device at a prescribed rate through a closed-loop balancing circuit.

Pumping Station Control

Sewage pumping stations in Metro's system contain from three to six variable speed pumps. Existing pneumatic controls at these stations use a pressure signal which senses the influent sump level as a control reference. In response to changes in the influent level, the controller varies the pump operating speed and at designated levels changes the pump operating mode. The operating mode determines the number of operating pumps or, where the station contains pumps of more than one size, determines the specific combination of pumps.

The alternatives for remote control of the pump stations were similar in principle to those investigated for control of the outfall gates. These alternatives were as follows;

1. Direct control, overriding local controls, and
2. Indirect control, overriding the pressure signal from the influent level sensor with a computer directed control signal. The direct control procedure would have required substantial modifications and extensions to the existing local controls which, in the case of the larger stations, were already quite complex. Direct control also introduced major problems of designing and installing the necessary circuitry for effecting an orderly transfer from remote to local control upon failure of the remote equipment.

As in the case of the regulator stations, indirect control provided the most satisfactory procedure. No modifications to existing local controls were necessary and relatively simple methods were available for controlling the set point and for restoring the station to local control. These methods and the control circuitry used for implementation are similar to those used for restoration of the outfall gate set point. The computer-directed control reference is varied by positioning a stepping motor connected to a potentiometer which provides a proportional current signal. The current signal is converted to a pneumatic signal through a current to a pressure transducer as the input to the local control equipment.

Loss of remote signal will initiate a sequence for restoring control to the influent level pneumatic signal which is equalized with the influent level signal through an electronic balancing circuit. Equalization takes place over a sufficiently long time interval to permit the local controller to settle into the control mode which is appropriate to the inflow rate without overshooting.

CATAD Equipment

The CATAD System includes the following principal items of equipment:

1. A computer central processor with input and output terminal equipment;
2. Peripheral input and output devices;
3. A digital transmission system; and
4. An operator's console.

The computer central processor is a Xerox Data Systems XD5 Sigma 2 Computer which is a high-speed unit with an access time of 920 nanoseconds to each 16-bit word of core memory and a maximum channel input-output transfer rate of 400,000 8-bit bytes per second. The initial system will provide 32,768 words of core memory expandable to 65,536 words which will be supplemented by a fixed head disk memory with a capacity of 1,474,560 16-bit words and an average access time of 17 milliseconds.

In addition to its data gathering and control functions, the computer will be time-shared by background data processing operations. For this purpose the system includes such peripheral input and output devices as a line printer, card punch and reader, and a paper tape punch and reader, in addition to the customary programmer's console.

Operator's Console

An operator's console and wall map display at the central terminal will serve as the interface between the operator and the control system. The console will incorporate light panels for displaying the operating status and alarm conditions at any remote terminal, and push-button arrays for selecting point locations for the execution of control functions and for data entry. A major feature of the console will be a bank of seven cathode ray tubes for display of quantitative operating data from selected groupings of pump and regulator stations which are located within a common area and are related from an operating standpoint. The operating data to be displayed will include both observed data, such as water levels, and computed data, such as sewage flow rates and storage volumes.

The wall map will supplement the operator's console by associating each cathode ray tube display and each alarm with its geographic location. Four lights will be situated adjacent to the location of each station to indicate one or all of the following conditions:

1. The station is one of the group being displayed on the cathode ray tubes, or a supervisory control command is being executed at the station.
2. The station is operating under remote control from the central terminal or is under local control.
3. An overflow is taking place at a regulator station or a high influent level is occuring at a pump station.
4. Alarm condition is present at the station (light blinks until the situation is corrected).

Telemetering

All data from regulator-outfall and sewage pumping stations will be telemetered to a central location in Metro's offices over leased telephone lines. At the central terminal these data will be entered in a process control computer which will also direct the data gathering. Control signals from the central terminal will be transmitted as contact operate commands.

Monitoring

A two-phase monitoring program has been implemented to evaluate the effect and eventually to provide input data for control of the CATAD System. Half of the monitoring program examines the receiving water quality; the other half checks on overflow strength and volumes.

The Duwamish River is monitored automatically by five robot instruments that telemeter dissolved oxygen, temperature, pH, conductivity, turbidity and solar radiation information hourly to a central recording station. This information is supplemented by manually collected receiving water samples at some 55 locations in the immediate study area (nearly 300 points in the entire Seattle area). Bacteriological and additional chemical tests are run on the manually-collected samples.

A second study centers on the overflow utfalls themselves. Refrigerated automatic samplers have been installed at nine overflow sites and will be installed at four more when the adjacent gate control structures are completed in 1970. These automatic samplers also are supplemented by a manual sampling program which adds bacteriological analyses to the chemical tests run on automatically collected overflow samplers.

The monitoring program: (1) provides information on amounts and variation of loading to receiving water caused by combined seweage overflows, (2) establishes relationships between overflows and rainfall characteristics, (3) provides information to determine the benefits of converting from locally controlled regulators to total system control, (4) locates critical overflow sites or other pollutants—should be programmed to be the last overflow point under total system management, (5) assists in locating sources of undersirable industrial wastes within the city, and (6) allows evaluation of the effects of Seattle's combined sewer separation program and other sewer construction activities within the collection system.

System Operation

It is planned that the central terminal initially will be attended by an operator only during the normal 40-hour work week. While this operator is on duty, the system initially will be operated in a supervisory control mode. During the remaining hours, control will be returned to the local stations, but data gathering and alarm monitoring from the central terminal will be continued.

When a mathematical model of the system has been developed and adequately reconciled with observed operating characteristics, the system will be put under program control by the computer.

Minneapolis-Saint Paul Sanitary District

A system of computer control of its combined sewers has been developed for this important District, to "maximize capture of urban runoff by the combined sewer system." Its purpose is to eliminate "past methodologies (which) assume the 'worst case', establishing the limiting threshold at the peak design conditions, necessarily requiring a low threshold limit to avoid damage due to flooding during extreme runoff. This method allowed overflows to occur during light, frequent runoff even though the system was not being used to fullest capacity or advantage."

It is evident from this statement by a representative of the Sanitary District that the new computer-controlled system will make fuller use of the in-sewer system capacity and markedly reduce the pollutional overflow waste waters discharged into the upper Mississippi River.

The following excerpts have been taken from reports covering the new system.

Project Objectives

The project objectives, as outlined in the Minneapolis-Saint Paul Sanitary District (MSSD) grant application to the Federal Water Quality Administration, were as follows:

"The proposed project will demonstrate a new technique of instantaneous observation and control of interceptor system performance, based on adequate information, to drastically reduce losses of combined wastes. Information gathered will provide a basis for further reduction of losses by using trunk sewers for storage and the facilities constructed will allow such a measure to be attempted. Post-construction evaluation will provide information which will allow the method to be adapted to other large combined sewer systems of differing configuration and climatology.

Since the majority of losses of wastes occurs during the recreational season, considerable benefit to the Mississippi River, where it passes through the populated area, will accrue."

Regulator Modifications

Modification of regulators and installation of the data acquisition and control system (DACS) were the largest of the tasks required for the physical installation. Regulators were typically modified to meet the needs. Existing floats on gates were removed and replaced by hydraulic cylinder operators. Inflatable dams were installed in the trunk sewer outlet to the river. Level sensing bubbler tubes with transducers and gate position slidewires were installed to provide sewer level and regulator status information. The control and telemetry equipment was installed in underground vaults.

Figure 32, Artist's Drawing, Inflatable Control Gate System, indicates the typical arrangement that is used in Minneapolis-St. Paul. Figure 33, Upstream View of Inflatable Fabric Dam, shows a dam in use.

Leased Telephone Lines

The leased line communications system utilized eight pairs, each connected in party-line fashion to a number of individual remote stations. Connection in this fashion minimizes line rental costs and substantially reduces equipment costs and maintenance problems. A slight sacrifice in access time and system redundancy and reliability occurs. Access time for any data point is less than two seconds. The system uses random access and by proper selection of sampling frequency, adequate system response is obtained.

Data Acquisition and Control System

The data acquisition and control system provides both manual remote, as well as automatic, control of the system by the central computer. The interface equipment uses multiplexed parallel tones to connect the manual controls and the computer to the leased communications lines. Table No. 29 shows the number of measurements and control functions provided by the system. In addition to the out-plant functions shown, equipment was provided and interfaced to the treatment plant process to log approximately 250 points of plant process data.

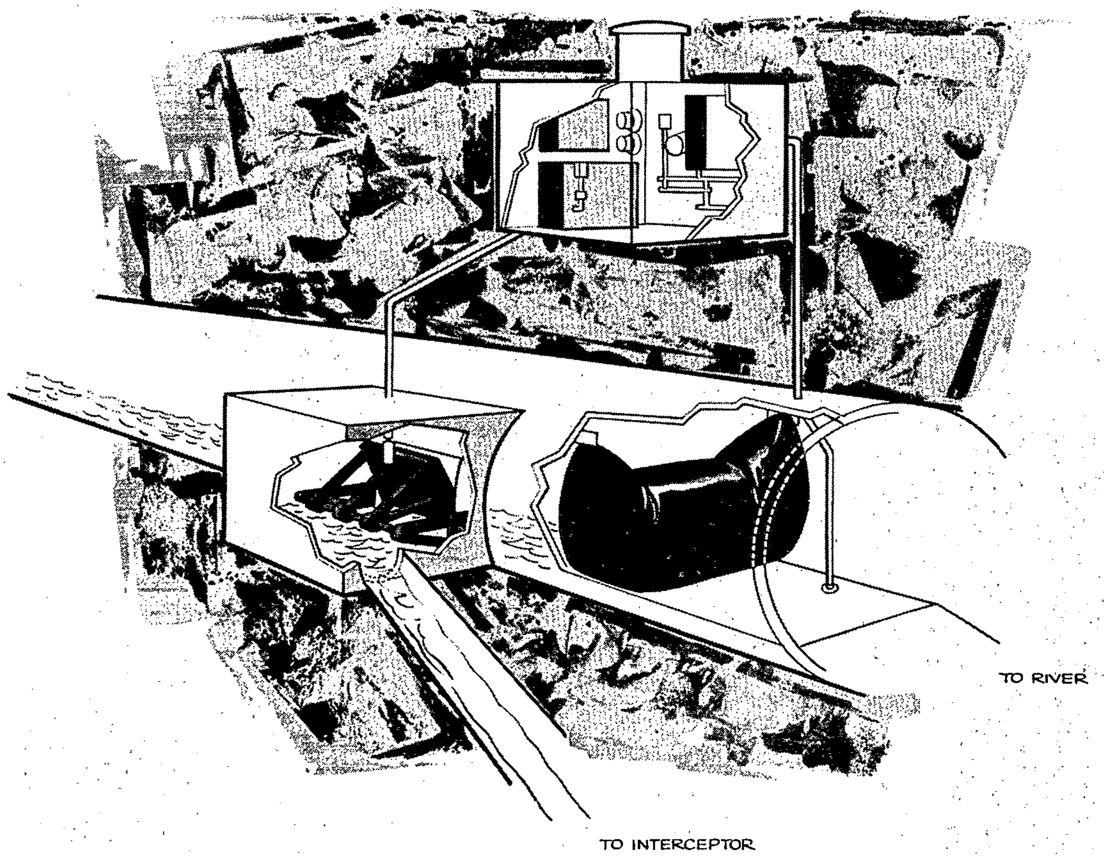
Table No. 29

NUMBER OF MEASUREMENT AND CONTROL FUNCTIONS–MINNEAPOLIS-ST. PAUL SANITARY DISTRICT

FUNCTION	NUMBER OF LOCATIONS	NUMBER OF POINTS
Level Measurement – Interceptor Sewers	12	12
Level Measurement – Trunk Sewers	15	16
Level Measurement – Outlets to Interceptors	14	14
Gate Positions and Controls	17	34
Rain Gages	8	8
River Quality Monitors	5	30
Alarms	19	19
	(a)	133

(a) Total number of locations of telemetry equipment is 37 due to overlapping functions at certain stations.

Artist's Drawing, Inflatable Control Gate System



Courtesy Firestone Coated Fabrics Co.

River Quality Monitors

Five river quality monitor stations were installed, one in a permanent location and four in semi-portable trailers. The units measure chlorides, conductivity, dissolved oxygen, oxidation reduction potential, pH, and temperature. The units are installed in the 21-mile stretch of river in the urban area. They are intended to be used to measure the effect of combined sewer overflows on the river.

Sampling and Analytical Program

An extensive sampling and analytical program was undertaken and operated for various periods during two years of the project. Approximately 25,000 hourly grab samples of waste water were obtained and analyzed, using automated sampling and automated chemistry techniques. Determinations of chemical oxygen demand, kjeldahl nitrogen, ammonia nitrogen, dissolved phosphate, and chloride ion concentration were made.

Data Reduction and Analysis

These data, and data obtained by manual sampling of the river, and from automatic composited plant influent samples have all been stored using electronic data processing techniques. The purpose of the sampling and analytical program and the placing of these data in ADP form were:

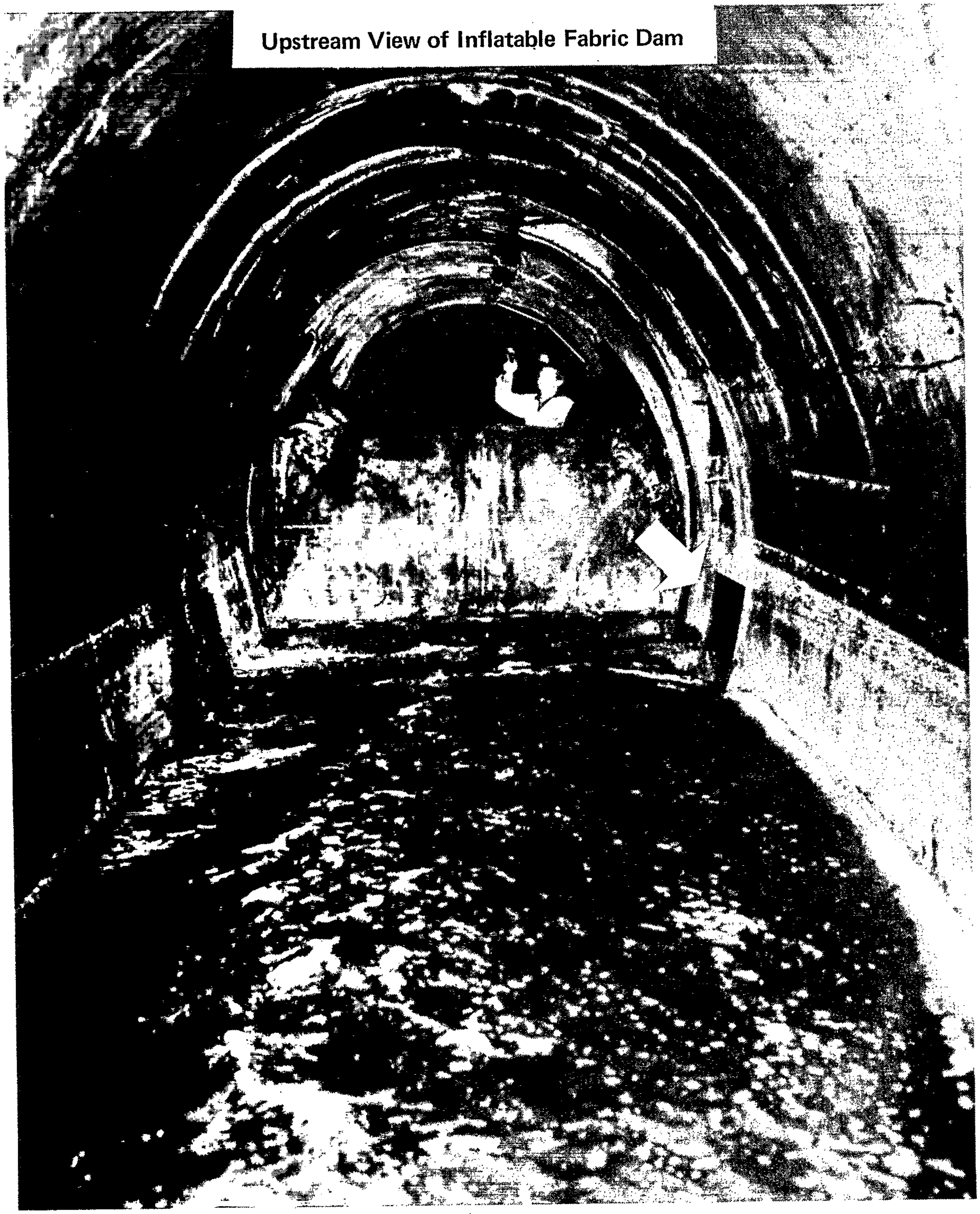
1. To facilitate an attempt to produce approximate chemical mass balances across the entire system;
2. To evaluate the pollutional losses from the combined sewer system to the river before and after modifications;
3. To possibly define the character and quantity of urban runoff in comparison with waste water; and
4. To provide a basis for priorities of point of discharges at regulators, based on pollutional load at controlled locations.

Mathematical Model

The original purpose of preparing a mathemetical model of storm runoff, regulator performance and interceptor routing was to provide a guide to the operator and assist him in making changes in gate settings during runoff events. In addition, as

FIGURE 33

Upstream View of Inflatable Fabric Dam



Courtesy Firestone Coated Fabrics Co.

secondary objectives, the model preparation also was intended to be useful as a research tool and as a planning and design tool.

The mathematical model, using rain guage data as input, generates a runoff hydrograph at each regulator, calculates the quantity of flow diverted by the regulators, and routes the diverted flow through the interceptor sewer system. The entire operation requires about 10 minutes to do all calculations and to communicate output information to the operator.

Detroit Metropolitan Water Services

Faced with the problem of preventing pollution in the Detroit and Rouge Rivers and in Lake Erie, Detroit has evaluated what it characterizes as a "dubiously effective sewer separation program" at a cost of $2 billion, in comparison with a sewer monitoring and remote control system for controlling the pollution from overflows during numerous small storms at a cost of $2 million.

The total system would involve rain gauges which will be telemeter-connected to a control center; sewer level sensor systems; overflow detection facilities; a central computer; master data logging equipment; and a central control console for remote activation of pumping stations and selected regulating gates. The instrumentation system will enable the operators to anticipate storm flows; intercept "first-flush" flows; selectively retain storm flows; and selectively regulate overflows.

The following excerpts have been taken from a report on the Detroit system made by personnel of the Detroit Metropolitan Water Services.

The Detroit Metropolitan Water Services has been monitoring water pressures and remotely operating water pumping stations and valves throughout the metropolitan area for eight years. Utilizing this experience, DMWS studied the possibilities of installing a sewer monitoring system with remote control of sanitary sewage and storm water pumping stations and regulating gates. The following factors relate to the installation of a monitoring and remote control system.

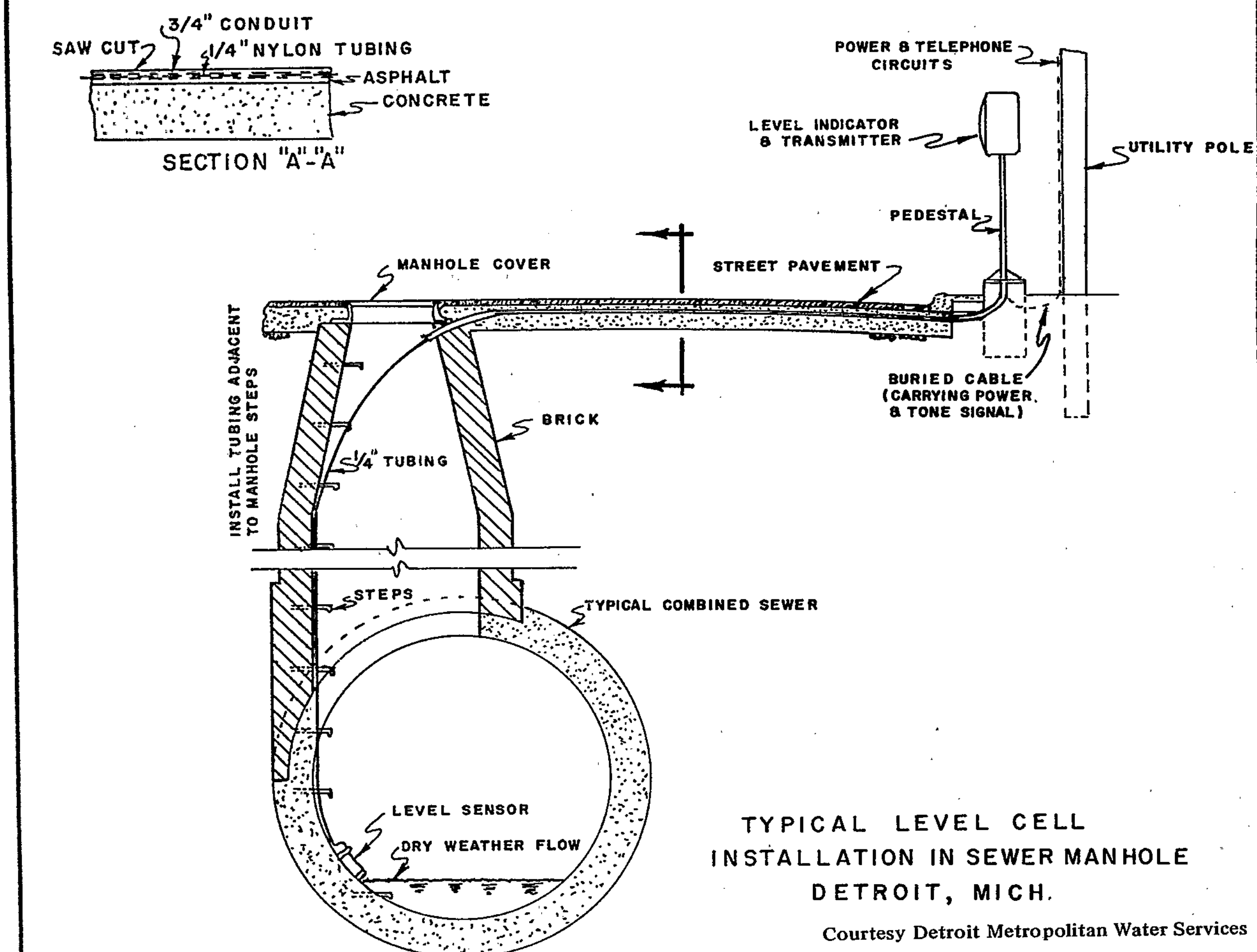
1. There are large areas served by pumping stations whose tributary lines could be used as storage areas during small storms.
2. The grades of the sewers, either rectangular or cylindrical types, are relatively flat, which would permit substantial storage under level conditions near the outfalls.
3. Interceptors along the Detroit and Rouge Rivers are fed through float-controlled regulators equipped with sluice gates which appear to be adaptable to conversion to remote-controlled, power actuated regulators.
4. Interceptors along the Detroit and Rouge Rivers are fed through float-controlled regulators equipped with sluice gates which appear to be adaptable to conversion to remote-controlled, power actuated regulators.
5. Most of the 71 outfall points are equipped with backwater gates and/or dams which serve as automatic retention devices.
6. Interconnections exist throughout the system which could be used for flow routing if remote controlled gates are added.
7. From knowledge of the particular industrial plants connected to certain sewers, there apparently would be a wide variation in the quality of dry-weather effluent.
8. In order to utilize the potential of the system, it is necessary to have instantaneous synchronized information about the behavior of the system, including rainfall, sewer and interceptor levels, and the status of pumps, valves and backwater gates, as well as the ability to remotely operate the pumps and valves.
9. To later determine the improvements achieved through monitoring and remote control, it is first necessary to establish a base by monitoring the system as it would naturally behave.

Potential Benefits

With central system monitoring and remote control, the following benefits appeared possible:

1. The sewer system could be operated to contain completely a small spot storm.
2. Runoff could be anticipated, sewers could be emptied and in readiness, and grossly contaminated "first flushes" in areas adjacent to the interceptor selectively could be captured, especially during large storms.
3. All flow near the end of a large storm could be held in the system for subsequent treatment.
4. Regulators could be adjusted to get the most efficient use of the interceptor and to favor the most grossly contaminated inlets.
5. Backwater from floods in the Rouge River Valley could be selectively controlled.
6. Pumps could be operated to minimize basement flooding in the east side areas which have no gravity relief outlets.
7. The flow to the waste water plant from various segments of the city could be better balanced.

FIGURE 34



Special Equipment

The recent Detroit installation includes the following equipment:

(a) 14 telemetering rain gauges;

(b) 89 telemetering sewer level sensors, 41 telemetering interceptor level sensors and 4 telemetering river level sensors;

(c) 30 telemetering proximity sensors on backwater gates;

(d) 38 telemetering probe-type dam overflow sensors;

(e) 3 event recorders for storm water pumping stations discharging direct to river;

(f) 1 central digital computer with drum and disc memory;

(g) 3 data loggers with 30-inch platens;

(h) 1 teletypewriter for input, output and alarm;

(i) 1 central operator console;

(j) 8 sets of equipment for the remote control and monitoring of pumping stations; and

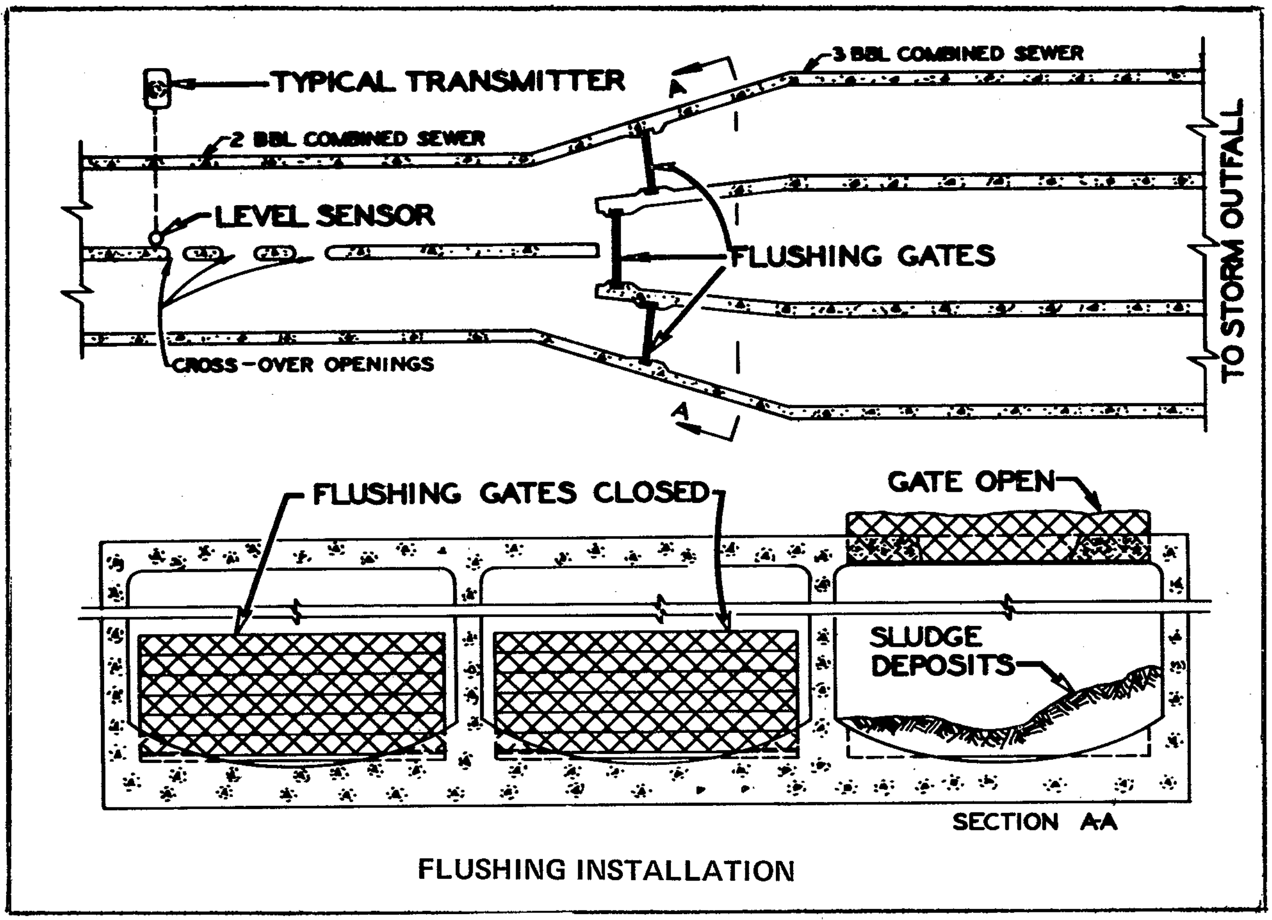
(k) 5 sets of equipment for the remote control and monitoring of sluice and flushing gates.

Anticipating Small Storms

In order to safely practice storm water storage in the sewer barrels, it is necessary to determine the correlation between the various storm intensities and the recorded downstream storm flow. From precipitation and flow data, the sewer hydrographs of the maximum amount of storm water that can be stored in the various combined systems are being developed for each area.

The present level sensors on 25 of the larger outfalls in Detroit permit calculating the runoff from 86 percent of the area of the city. Measurement of the flow from the remainder of the smaller outfalls has been deferred because of the capital cost for equipment. However, some very reasonable estimates of the overflow can be secured since elapsed time of spilling is known, plus average runoff per square mile from other comparable areas. Figure 34, Typical Level Cell Installation in Sewer Manhole—Detroit.

FIGURE 35



FLUSHING INSTALLATION

Courtesy Detroit Metropolitan Water Services

Small Storm Water Storage

The storage of flows from small storms within the barrels of sewers is dependent upon the following factors:

1. Size of box or parallel,
2. Slope of the conduit,
3. Imperviousness of tributary area,
4. Time elapsed since previous rain,
5. Available height in sewer before gates open,
6. Intensity of length of storm,
7. The level of the receiving water, and
8. Available capacity in the interceptor.

Available storage at the various outfalls either upstream of pumps or backwater gates, must be calculated and tabulated for use by the system control operators.

Any storage of runoff in larger trunk line sewers results in reduced velocity. Velocities below 2 feet per second usually cause graded sedimentation, with coarse deposits occurring upstream where the velocities are still relatively high and finer deposits downstream where the velocities approach zero. This is another problem which must be considered in the operation of a system with in-system storage.

Figure 35, Flushing Arrangement, Detroit, incicates the physical location of a system of gates which has been installed in a three-barreled interceptor sewer. Dry-weather flow will be passed through only one barrel at a time in order to flush deposited solids to the treatment facility.

SECTION 11

SUMMATION OF THE STATE OF THE ART OF COMBINED SEWER MANAGEMENT

The combined sewer systems which now serve all or parts of more than 1,300 municipal jurisdictions in the United States, and the larger Canadian communities are not the product of today's sewage works needs and practices. Their use in local areas in the older sections of the continent labels this combined method of collection of both sanitary sewage and storm drainage runoff waters as a sanitation solution which predates the intensified water pollution control efforts of the sixth and seventh decade of the 1900's.

The need for new methods and new techniques in the management of these combined sewer systems is brought into sharp focus by advancements in the treatment of sanitary sewage and industrial waste. As long as the periodic and repetitive overflows of admixtures of sewage and other wastes with storm runoffs continue to pollute rivers, lakes and coastal waters, the maximum value of urban liquid wastes treatment cannot be achieved. This fact makes it mandatory that new concepts and methods of combined sewer management be evolved to prevent spoiling the water and land resources which treatment works are intended to protect.

This need led in 1966 and 1967, to a study of the "Problems of Combined Sewer Facilities and Overflows" sponsored by FWQA, and carried out by the APWA. From the study came findings which stressed the generally unsatisfactory application and condition of many overflow regulators, as well as the inadequate methods used by some local jurisdictions in operating and maintaining these devices and their appurtenant facilities. A recommendation was made in 1967 that an in-depth investigation of design, application, operation, performance and maintenance of regulators was needed, to serve as the basis for a new approach to combined sewer management. The project upon which this current report is based was the outcome of that recommendation.

The vast numbers of overflow points, with and without regulator devices to "split" total storm period flows into portions to be transported to treatment plants and surplus volumes to be wasted into nearby receiving waters are the product of an era when the main thrust was to prevent local sewer flooding and interceptor system surcharging and to be less concerned with the pollutional effect of such spills on these receiving waters.

The great numbers of overflow-regulator locations pose the challenges which pollution control authorities, governmental sewer system owners and the design engineering profession now face. An important factor in corrective programs is the fact that practices in the design, choice of overflow locations, applications of types of available regulator devices, and operation and maintenance practices were, and continue to be inexact and inadequate. Those who will innovate better combined sewer and regulator management techniques now have the opportunity to reduce the pollution effects of unnecessary overflows at far lower cost than equivalent improvements in receiving waters could be accomplished by partial separation of combined sewer systems and/or the treatment of overflow wastes by partial purification means. The fact that better combined sewer management methods will be aimed at utilizing the relatively large internal capacities of combined sewer networks for the retention of significant amounts of storm runoff flows adds incentive to the methods set forth in this report.

The further fact that this project has spotlighted the new concept that regulator installations can and must be charged with the dual responsibility of controlling the quality as well as the quantity of overflow wastes, is a challenge that offers new goals in performance and economics for regulator facilities and systems.

These new techniques cannot be achieved without more advanced knowledge than was available to previous designers and administrators of combined sewer systems and regulator installations. Regulator control must be based on new and specific guidelines of design, facility choices and operational practices.

For this reason the project involved the preparation of two documents: This report contains the actual study methods used, the findings of the in-depth research work, and the specific recommendations which reflect the findings and the means by which combined sewer practices can be achieved. The second volume, a Manual of Practice, provides guidelines for the actual accomplishment of better system management methods.

The research project took on greater depth and dimension under the guidance of advisory groups which represented the many facets of the government, engineering and industrial life involved in the combined sewer problem. To provide the understanding and concern of local government operations, a broad-based Advisory Committee was created, composed of representatives of jurisdictions which contributed funds to assist in financing the studies. A more specialized Steering Committee was created to guide the details of the research program and to help interpret and evaluate the findings. Representatives of the American Society of Civil Engineers and the Water Pollution Control Federation were included in this steering group for greater depth. A Consulting Panel was retained to add the knowledge and experience of planners and designers of sewer systems. A Manufacturers Advisory Panel was set up to enlist the advice and guidance of the industrial organization which serves the sewer system field.

These advisory bodies had a greater purpose than the mere charting of research goals and procedures. Behind their service in this connection was the hope that by creating a team effort, the findings and recommendations emanating from the research and investigative work would be converted into tangible accomplishments.

The 1967 Investigation of overflow problems resulted in "price tags" of an extrapolated nature which estimated the cost of such corrective actions as separation of public sewer systems; separation of facilities in private structures and on private properties; and/or the construction of treatment facilities to handle overflow wastes.

The current project has turned its attention to the ability of improved sewer system management and combined sewer regulator practices to minimize or correct overflow problems. Efforts to arrive at rational cost estimates for construction of new regulator improvement programs, and for maintenance practices, were not fruitful because of the paucity of such information in the governmental field. There is need for such fiscal data to serve as the basis for comparisons of costs and benefits of regulator modernization and "total systems" management practices with the multi-billion-dollar price tags of the corrective procedures to which the 1967 investigation addressed itself.

The Impact of Combined Sewer Overflow Control on National Water Resources

Regardless of how effectively a combined sewer system is managed and its admixed sanitary and storm water flows controlled by means of the most sophisticated total systems techniques, some overflows will occur. The system concept is designed to reduce these overflows to the irreducible minimum. It can do this if the parts of the system are coordinated into a planned master control network. The impact of these waste discharges on receiving waters will be markedly reduced by the type of practices described, and defined in the three specific system examples previously outlined. The greatest reduction of the pollutional effect will result from the ability of a monitored and controlled system to retain flows during precipitation and runoff incidents of less than maximum amounts. However, unless provision is made for the further retention of maximum storm runoff and the return of the stored waste water back to the interceptor system and thence to the treatment plant during periodsfrom of non-peak flows, or unless some form of initial treatment is provided for overflow waste discharges from combined sewers such overflows will impose pollutional loads on receiving waters. If discharges of combined sanitary sewage and storm water flows are limited to periods of high runoff, there is the possibility that the spills will benefit from the high dilution afforded by such high runoff volumes.

This point is stressed here to avoid any impression that even the most efficient systems management program can be expected to eliminate all overflow incidents.

Regulator practice improvement can accomplish a partial, perhaps a significant correction of the pollution effects of overflows. The regulator problems and palliatives outlined in this report must be placed in focus with the total problem, and evaluated to determine what they can accomplish in partially solving the water pollution control problem now facing the American continent.

This will take a full understanding of the potentialities of the total systems management concept as well as the improvements which better individual regulator units can accomplish. Instrumentation, telemetry and centralized control of total systems management should be adapted to the combined sewer field if the full potentials of overflow control are to be achieved. Dependable cost data must be evolved to make it possible to make comparable economic evaluation on such new techniques.

The complexity of such new technologies emphasizes the need for experienced and knowledgeable personnel for every phase of combined sewer practices—from conception, to consummation to operation and maintenance. The era of "buried and forgotten" is gone in combined sewer service. The problems caused by combined sewer overflows must be brought to light and solved by effective and economical means.

SECTION 12

ACKNOWLEDGEMENTS

The American Public Works Association is deeply indebted to the following persons and their organizations for the services they rendered to the APWA Research Foundation in carrying out this study for the 25 local governmental jurisdictions and the Federal Water Quality Administration who co-sponsored the study. Without their cooperation and assistance the study would not have been possible. The cooperation of the American Society of Civil Engineering (ASCE) and the Water Pollution Control Federation (WPCF) is acknowledged for their participation on the project Steering Committee.

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SECTION 13

GLOSSARY OF PERTINENT TERMS

(as applied to this report on the regulator study project)

Collector Sewer—A pipe or conduit which collects sewage, other waste water, and storm water runoff from their points of origin and conveys these flows by means of other collecting sewers to points of discharge, or by means of interceptor sewers to points of treatment.

Combined Sewer—A sewer which carries sanitary sewage with its component commercial and industrial wastes at all times, and which during storm or thaw periods serves as the collector and transporter of storm water from streets or other points of origin, thus serving a "combined" purpose. Combined sewers make provision for the overflow of excessive amounts of flow, over and above the volumes to be carried by interceptor sewers and handled by treatment or pumping facilities, from the combined sewer system at predetermined points where some form of regulator devices are located.

Dynamic Regulator—A semi-automatic or automatic regulator device which may or may not have moveable parts that are sensitive to hydraulic conditions at their points of installation and are capable of adjusting themselves to variations in such conditions, or of being adjusted by remote control to meet hydraulic conditions at points of installation or at other points in the total combined sewer system.

Helical Motion—The inducement of secondary motion, over and above the normal pattern of hydraulic flow, in a stream of flowing sewage by configurations in the structure of the sewer conduit itself, thus producing a physical separation of a portion of the suspended, floating or settleable solids contained in the flow at predetermined points, from which the more concentrated liquors can be discharged to an interceptor sewer and the more dilute liquids can be wasted to overflow points.

Interceptor Sewer—A sewer that receives dry-weather flow from a number of transverse sewers or outlets, and frequently additional predetermined quantities of storm water admixed with sanitary flows, and conducts such waste waters to a point for treatment or disposal point between the collector sewer and the interceptor sewer.

Jurisdiction—Any unit of local government, including a county, city, town or village, or multi-county agency or a duly constituted district or authority, which has responsibility for one or more phases of sewer system service in the area served.

Overflow Facility—A weir, orifice or other device or structure which permits the discharge from a combined sewer system of that portion of sewage and storm water flow which is in excess of the amounts allowed to enter the interceptor sewer and which must, therefore, be discharged to receiving waters or to some form of retention or treatment facility.

Regulator—A device or apparatus for controlling the quantity and quality of admixtures of sewage and storm water admitted from a combined sewer collector sewer into an interceptor sewer or pumping or treatment facility, thereby determining the amount and quality of the flows discharged through an overflow device to receiving waters, or to retention or treatment facilities.

Static Regulator—A regulator device which has no moving parts, or has moveable parts which are insensitive to hydraulic conditions at the point of installation and which are not capable of adjusting themselves to meet varying flow or level conditions in the regulator-overflow structure.

Storm Water—Waste water flow in a combined sewer system, resulting from the runoff of precipitation from any part of the urban area or from the thawing or draining of previous precipitation.

Tide Gate (Backwater Gate; Flap Gate)—A gate generally with a flap suspended from a free-swinging horizontal hinge, normally placed at the end of a conduit discharging into a body of water having a fluctuating surface elevation. During high water stages in the receiving waters the gate is closed because of external hydraulic pressure, but it opens when the internal head is sufficient to overcome the external pressure, the weight of the flap, and the friction of the hinge.

"Total Systems" Concept—Total systems includes any and all control and treatment needed to fully control combined sewer overflows. All regulator-overflow operations in an entire combined sewer system must be coordinated by means of some type of central information and control point which integrates climatological data and sewage flow and the operation of individual control stations or overflow points into conditions existing in the entire sewer network. This coordination serves to reduce the frequency and duration of overflow incidents by utilizing the retention and transporting capacities of the entire system. The "total systems" management

plan is adaptable to automatic-automation instrumentation control of a complete sewer system by means of predetermined operational and maintenance procedures.

The "Two-Q" Principle—Assignment of two distinct and related functions to a regulator device: The control of overflow quantities, and the improvement of the quality of the overflow waste waters by some means which will result in the entrainment or concentration of pollutional solids and their diversion into the interceptor system, and the consequent improvement of the liquids which are to be discharged into receiving waters or overflow retention or treatment facilities.

Vortex Separator—A device which, by structural configuration, kinetically induces a rotary motion to the flow of waste waters in a combined sewer, resulting in secondary motion phenomena which cause a concentration of solid pollutional materials at a predetermined point from which it can be diverted into the interceptor sewer, thereby producing a less concentrated waste liquor for discharge or overflow into receiving waters.

Wet-Weather to Dry-Weather Flow Ratio (WWF:DWF) —The numerical ratio between the wet-weather flow of sanitary sewage and storm water runoff in a combined sewer system and the average dry-weather flow of sanitary sewage and other extraneous waste waters. The ratio is dictated by the design capacity of the interceptor sewer and treatment plant to handle predetermined amounts of the admixtures of sewage and storm water. For example, a WWF:DWF ratio of 3 to 1 represents the ability of the interceptor to carry three times the average dry-weather flow during periods of storm runoff.

SECTION 14

APPENDIX 1
REPORT OF THE SUBCOMMITTEE ON MOST EFFECTIVE MATERIALS TO MEET SPECIFIC REGULATOR CONDITIONS AND FUNCTIONS

Durability

Sewage regulator equipment should be designed for a minimum useful service life of 20 to 30 years. This period approximates the time that a properly designed treatment plant will operate without extensive redesign and refurbishing of its major equipment.

Service Conditions

Although the environment in a sewer can have a fairly wide chemical range, extreme conditions are usually short-lived; and it is not normally necessary or desirable to design for them. Fresh sewage is slightly alkaline; but as it becomes septic, it becomes acid. Dry spells coupled with over-capacity sewers, will result in acid semi-septic or septic sewage which is more inimical to treatment, than fresh sewage. Small amounts of hydrogen sulfide, ammonia, carbon dioxide and sometimes methane will be present in the sewer atmosphere. Temperature variations are not extreme, but the humidity can be very high. Condensation conditions necessitate the use of corrosion resistant materials for equipment. Regulator facilities in coastal cities usually overflow into salt water basins and must have tide gates constructed of a material that will stand up in salt water.

Metals

The best of the bronzes for corrosion resistance and strength seems to be silicon bronze. This is a very high copper, zinc-free bronze. Manganese bronze castings and extrusions wear well. For this reason they are used for valve seats and operator stem nuts.

Among the stainless steels, the 18-8 (chromium-nickel content percent, respectively) series wears best. Types 303, 304, and 305 are used for valve stems, studs, nuts and bolts. Type 316 stainless steel is especially good in sea water and less costly than Monel metal, which also gives excellent service in salt water. Heavy body castings are usually grey iron complying with ASTM A-126 Class B. However, in highly corrosive applications, Ni-Resist Type lA, or equal, can be used successfully. This is a trade name of International Nickel Company for an iron casting with the folowing alloys: 14% nickel, 6% copper, 2½% chromium.

Cast iron is customarily coated with a hot tar enamel, in accordance with AWWA Specification C203-62. Bronze, stainless steel and Monel are not usually coated.

Elastomers and Gasket Materials

The most commonly used elastomer is Neoprene. Neoprene is a copolymer of butadiene and acrylic nitrile. It has good resistance to hydrocarbons and ozone and resists air-hardening. Nitrile and a blend of nitrile and polyvinyl chloride also have good resistance to sewer atmospheres. Natural rubber deteriorates in sewer applications and is not recommended. Gaskets and packing should be made of asbestos, teflon coated asbestos or tallow lubricated flax.

Electrical Equipment

Certain municipalities allow electric lines to be run in sewers. Motors must be explosion-proof and water proof. All wires must be run in solid corrosion-resistant conduits. No exposed wires are allowed because of the possibility of rats chewing off insulation and causing an explosion.

Plastics

Although plastics and plastic-coated metals have not been used to any appreciable extent in sewer regulator systems, they offer considerable promise for the future. Coatings such as epoxy, vinyl, nylon, and cellulosic applied by the fluidized bed process all endure well in sewers. They are quite abrasion resistant, which is necessary because grit has not been removed from the sewer flow. These coatings applied to steel or aluminum offer maximum corrosion resistance, coupled with good strength characteristics.

APPENDIX 2
REPORT OF SUBCOMMITTEE ON SEWER REGULATION SYSTEMS

A typical sewer regulator, as viewed from a control system standpoint, is shown in the block diagram. Typical in-loop functions noted in this diagram are the error sensor, control logic, and main flow actuator-modulator. Typical out-of-loop functions are the command and monitoring instrumentation equipment. The error sensing equipment is often considered part of the instrumentation equipment. The result of the in-loop functions is the modulation of flow into the normal channel in accordance with a preset, or remotely commanded, flow requirement. The out-of-loop functions serve to relay commands to the regulator from a remote command location, and to monitor the operation of the error sensor, control logic, or actuator-flow modulator; and to either generate time records of these functions for later review, or to relay the performance of these functions to a remote command location for real-time monitoring at that location.

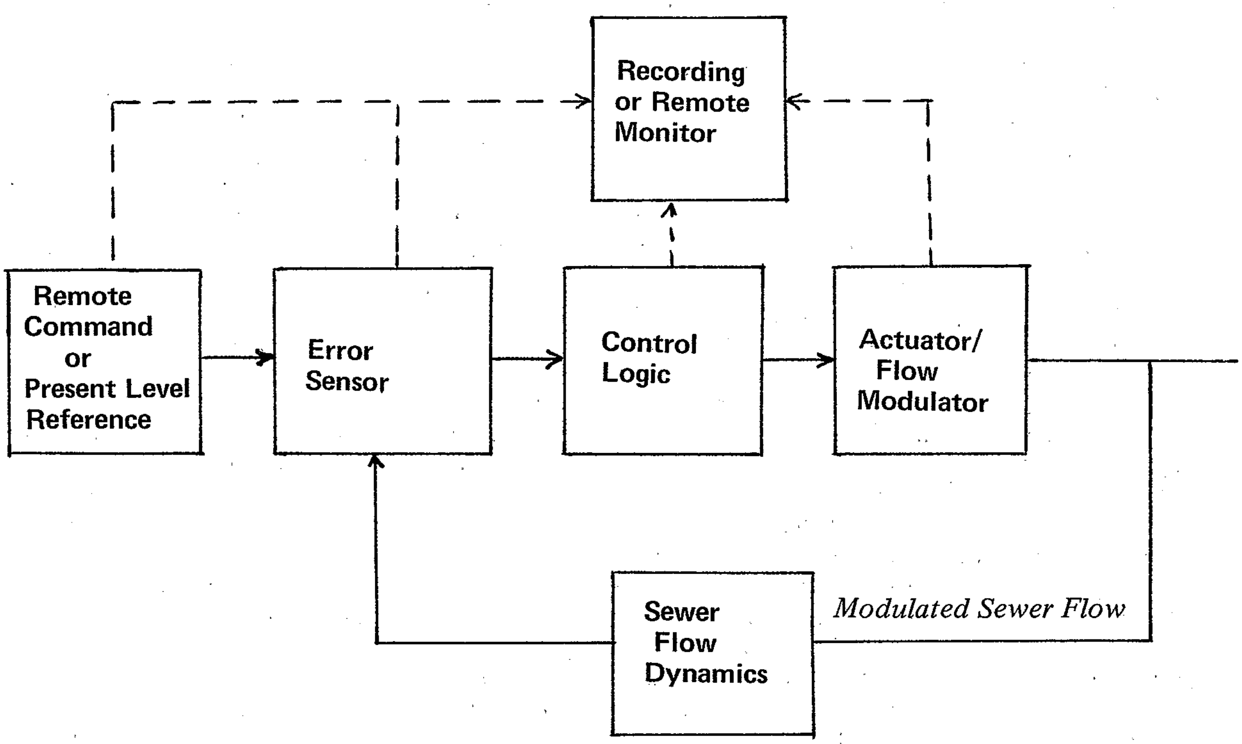
Each principal block is discussed below.

Error Sensor

The error sensor provides the remainder of the regulator loop with intelligence as to whether the flow output is in conformance with the desired value. This intelligence is in the form of an error signal whose sense and magnitude are interpreted by the control logic block in determining the degree of main flow modulation necessary to satisfy the flow demands desired in the normal channel. In most current installations, the error signal represents the difference between the actual water level in the normal channel and a preset reference level. In a few modern sewer systems, where flows are remotely commanded, the command control input directly establishes the reference level.

In some sewer installations, flow into the normal channel is sensed, or measured directly, instead of being derived through the sensing of another variable, such as the water level. Again, an error signal is

SCHEMATIC BLOCK DIAGRAM—SEWER REGULATOR



generated when the actual flow differs from the preset, or commanded reference flow. As the requirements for sewer regulation systems have become more sophisticated, variables other than water level or flow are being sensed. For example, in addition to flow magnitude it is sometimes desirable to modulate the flow into the main channel as a function of sewage quality, such as, concentration of pollutants, acidity, alkalinity and temperature.

The error sensor may use a wide variety of communication means to transmit error information to the control logic equipment. These can include many forms of electrical energy such as DC or AC voltage, current, pulse width and pulse frequency; as well as mechanical motion, gas or liquid pressure or flow, acoustics, or various combinations of these. These instruments can be energized directly by the flow stream from appropriate auxiliary energy sources, such as electric service or water power, or locally installed pumps, compressors or generators.

Several of the most used types of error sensors are described in greater detail below.

Flow Meters

Partially Filled Sewers: The Parshall flume is the most commonly used metering device. It lends itself to this type of service since it is self-cleaning and relatively maintenance-free, inexpensive and durable. Sizes 36 inches and under (throat width), are frequently fabricated from fiberglass reinforced plastic. Larger sizes can be formed easily in concrete to adequate tolerances.

There is one major consideration that must be given to this device. Generally, in new installations sewer grades are such as to provide free flow conditions. However, where these flumes are installed in existing sewers there is usually not sufficient grade to provide the free-flow conditions, thus producing submerged flow conditions and erroneous flow measurements.

The secondary instrumentation for this device is usually a transmitter and flow recorder, the most popular of which is the in-stream type, since it eliminates most of the maintenance and cleaning problems. The secondary instrumentation can be equipped with electrical and pneumatic transmitters for control functions, the scope of which is limited only by the imagination of the design engineer.

Sewers Flowing Full: The Venturi tube has long been used as a primary device for sewage flow measurement. Its major limitation is that it requires continuous purge water and periodic cleaning. However, under normal maintenance, the venturi tube and secondary instrumentation will give long dependable service.

Secondary instrumentation is usually a main meter or D/P sensor, transmitting to a recorder. Here again the instrumentation can be equipped with electrical and pneumatic transmitters for control purposes.

Level Sensors

Quite frequently flow measurement is important in the overall control of combined sewer regulation. However, level measurement is a basic control parameter.

Bubbler Systems consist of a tube extending to the bottom area of the sewer, through which air flows at a fixed supply pressure. As the level increases, the back pressure increases accordingly. This pressure is then converted to a usable signal for overall system control.

Capacitance is measured by means of a coated probe immersed in the fluid to form one plate of the capacitor. The second plate is formed by the fluid level around the outside of the probe. The changing level causes a corresponding change in capacitance which is converted to a usable signal for control.

Floats are mechanical devices that float on the surface of the water and move with level changes. This motion is converted to a usable signal for control.

Analytical Sensors

Various sensors are available for analyzing pH, conductivity, dissolved oxygen, oxygen-reduction potential, and dissolved chlorides and other sewage components which would provide readout for the amount of pollution that would be bypassed to receiving waters in the event of high storm flow. These can be provided with usable signals for control.

Control Logic

It is the function of the control logic equipment to ascertain the degree, or extent to which the actuation-flow modulation equipment should be operated in order to produce the desired flow into the normal channel. Its operation in many respects resembles that of a computer, in that the basic proportions, thresholds, limits, operating points, operating modes, specialized mathematical or time-dependent functions, and other factors are programmed while real-time data are fed in from the error sensor equipment. The control logic equipment then computes an input to the actuator-flow modulator directing it when, in which direction, and how far to operate.

As its likeness to a computer suggests, the control logic function can be implemented in a wide variety of ways, using many forms of mathematical logic.

Two commonly used types of logic for control systems are analog and digital. Analog logic is characterized by smooth, continuous outputs, generally in proportion to the inputs. Digital logic is characterized by discontinuous, or on-off outputs, in response to changes in the state of input conditions or to the exceeding of certain magnitudes by input conditions.

In addition to the basic logic arrangement of the controller, certain time-dependent characteristics may be required in order that the system operate properly. For example, a "lead" or anticipation function may be useful to prevent or minimize excessive oscillation or "hunting" of a sewer regulator during rapidly varying, or surging flow occurring as a result of violent thunderstorms. In another situation, it may be desirable to add a smoothing, or delaying characteristic to the control action in order to prevent excess operating wear on the actuator-flow modulator when small fluctuations in water level produce a "noisy" error signal input from the error sensing equipment.

Sewer control logic equipment may require two or more modes of operating logic, depending on the general weather conditions or water usage by the area being serviced. For example during storm periods, dry-weather flow peaks, or emergency situations such as water main breaks, a high-speed mode of analog operation of the sewer regulator may be required. In periods of low, or slowly changing flow, a simpler digital operation mode may prove useful to prolong the operating life of the regulator.

As in the case of the sensor, the detailed mechanization of the control logic can be accomplished in a multitude of ways, available to the system designer to best match the local situation. Available approaches include electronic, electromechanical, pure mechanical, hydraulic, pneumatic, fluidic, or various hybrids of two or more of these. The control logic unit may also require one or more transducers, depending on the mechanical choice, to properly interpret information being received from the error sensor, or to properly have its outputs interpreted by the actuator-flow modulator. It is obviously desirable to select a type of mechanism that uses the minimum number of such interface devices, to reduce costs and to achieve the maximum operating reliability. A good example of this is shown by the simple mechanical float-operated regulators in current use. In this case, the error sensor, the float, drives the controller, the linkage which operates the actuator-flow modulator, and the gate. In larger installations, the operating forces for flow modulating are beyond the practical capabilities of float linkages, and a source of externally supplied energy is required. Again, to minimize interface equipment, all-electric, or all-hydraulic mechanism could be selected. Further details of control logic mechanization follow:

Electronic Equipment

A very broad base of electronic technology, engendered by recent aerospace advances, is available to mechanize any desired degree of sewer regulator-logic complexity. The initial cost of electronic control equipment is fairly reasonable; its basic operating reliability is fair, however service, other than through the manufacturer, may be difficult to obtain since municipal maintenance crews usually are not trained for electronic repair work. Its capability to operate when needed most may be jeopardized by power failures often accompanying storms, unless emergency standby power is available. An electronic control logic unit requires a relatively expensive interface arrangement, usually involving either electrical switchgear, or electro-hydraulic valving. Both of these devices have involved maintenance and reliability problems in the sewer environment. This type of equipment can be procured from many electronics or computer manufacturers, usually on a special order basis. An off-the-shelf product status undoubtedly will occur if demand warrants.

Mechanical Equipment

Mechanical systems have been successful in smaller regulator installations. They are relatively simple and inexpensive. They are susceptible to environmental corrosion and fouling by sewage debris, particularly if the mechanism is submerged. Municipal experience has shown that frequent (once a week in some cases) inspection and servicing, are required to keep such systems operating.

Hydraulic Equipment

Hydraulic systems are finding acceptance in a number of jurisdictions. A basic version of hydraulic control logic consists of a 3-or 4-way spool valve, using potable water as a source of pressurized hydraulic fluid. The valve outputs are connected to large hydraulic cylinders, which operate the flow modulation structure. The spool valve can be operated either by a small hydraulic valve on the error sensor, or positioned directly by the sensor. This system is comparatively expensive to install, however, it is fairly reliable when frequently inspected and maintained. The regulation performance is quite good. Adequate design precautions are required to prevent cross-connection of sewage into the water system in the event of a loss of water pressure.

Electro-mechanical Equipment

A typical electro-mechanical version of a control logic unit is a switch-gear installation containing a power relay train and starting circuitry for a large electric motor drive. This type of equipment is generally used for a digital system. It is moderately expensive to install, and is subject to corrosion problems in the sewer environment. Elaborate protection must be installed to protect against spark-triggered explosions, a danger which has led many jurisdictions to ban the use of electrical equipment in sewers.

Pneumatic Equipment

The pneumatic approach to a sewer regulator control logic unit is generally similar to that of a high-pressure hydraulic unit, and has the same advantages and disadvantages.

Fluidic Equipment

The fluidic approach is currently in the experimental stage. It has been investigated under a FWQA research contract. Basic characteristics of fluidic devices are no moving mechanical parts and ability to be used to implement a wide variety of system approaches. The working fluid can be the sewage stream itself, and no outside source of control energy need be supplied. Fluidic control logic units may be constructed with any corrosion resistant material including concrete, and the interface devices are simple, low cost, and flexible in construction.

Instrumentation Equipment

This equipment may be provided when it is desirable to secure data on the total system and to control the collection of sewage in various parts thereof. Communication equipment is required at sampling stations to provide data to a central location.

Complete Sewer Regulator Systems

The foregoing has dealt with equipment conforming to individual functions. In surveying the available equipment that conforms to these functions, it has been found that very few manufacturers supply equipment for more than one of the indicated functions. This situation sometimes requires that the sewer system designer piece together a complete system from a large assortment of components and, in the process, consider all the interface requirements that arise in integrating many dissimilar elements into an operating system.

APPENDIX 3

REPORT OF THE SUBCOMMITTEE ON THE SYSTEMS CONCEPT OF COMBINED SEWER SYSTEM REGULATION AND CONTROL

The role of regulators and control facilities in use today makes it imperative that they be designed, equipped, and maintained on the basis of a total systems concept. This is necessary just to meet the standards of combined sewer control already in existence today, and to prepare for those of the future. They can no longer be simple "either–or" devices, left all alone to function or not, as the case may be, in any storm, flood, or other emergency. Each regulator and its associated control is not an isolated entity, affecting only its immediate environment. Rather, it is a part, however small, of a total water-flow pattern and, as such, can be compared to the individual link in a chain, the proper functioning of each being required to obtain the desired result from the total system.

There are many factors and parameters that influence the total combined sewer system; these must be considered by those involved in planning design, construction and operation. They can be catergorized as follows:

1. Function and type of unit—overflow, bypass, fixed, variable, temporary, permanent;
2. Flow handled—minimum, maximum and variation, high or low pressure;
3. Area served—minimum, maximum and variation due to inter-regional operation;
4. Quality of wastes—normal, abnormal, organic, chemical; upstream and downstream;
5. Treatment of wastes—normal, minimum desired, future requirements;
6. Instrumentation and control—gravity, manual, electric, automatic, automated;
7. Communications—normal, emergency, manual, electronic, automated;
8. Authority responsibility—public, private, individual, group, legal entity; and
9. Responsibility—public, private, individual, group, legal entity.

The effectiveness and subsequent sucess of each regulator, each group, each system, and finally each total watershed regulatory system, will depend on the amount of forethought, planning, design and, ultimately, the implementation of the aforementioned factors. Where shortsightedness is combined with limited funds, the system finally put into service will be inadequate to perform the task expected of it, let alone meet the required regional and sectional environmental and performance standards.

A further detailed analysis of each main factor must cover the following criteria:

1. Function and type:
   a. Is there a current method for using any or all of the existing or proposed regulators in series?–in parallel?
   b. How does operational failure of a regulator affect other regulators in its flow pattern, both upstream and downstream?
2. Flow:
   a. What is the sanitary flow variation—hourly through yearly; minimum through maximum?
   b. What is the storm water flow variation—hourly through yearly; minimum through maximum?
   c. On what basis does overflow from combined flow (untreated) occur?
   d. Will gravity handling be sufficient?
   e. If gravity flow is not sufficient, what total pumping system will be required?
   f. Can the current or proposed system sense upstream and downstream flow variation?
3. Area:
   a. What is the specific area affecting each individual regulator?
   b. What is the specific area affecting each series of regulators?
   c. Into what receiving waters does the effluent from sanitary flow treatment discharge?
   d. Into what receiving waters does the effluent from combined flow treatment discharge?
   e. Into what receiving waters does the overflow from combined flow (untreated) discharge?
   f. What failure of any group of regulators can the total system tolerate and still maintain 50 percent or higher effectiveness?
4. Treatment:
   a. What degree of sanitary flow treatment is currently maintained?
   b. What degree of sanitary flow treatment do regulatory agencies now require?

c. What degree of combined flow treatment is currently maintained?

d. What degree of combined flow treatment do regulatory agencies now require?

e. What degree of storm flow treatment is currently provided?

f. What degree of combined storm flow treatment will regulatory agencies require?

g. What degree of combined flow treatment can be provided while still in the retention area awaiting regular treatment?

5. Instrumentation and control:

a. How is control of flow and quality of sanitary flow obtained?

b. How is control of flow and quality of combined flow obtained?

c. How is control of flow and quality of storm flow obtained?

d. How is control of flow and quality measured?

e. How are variations of flow and quality measured?

f. How are failures of regulatory devices detected?

g. If control is by gravity, what limitations apply as to flexibility?

h. If control is manual, what limitations apply on flexibility?

i. If control is automatic, what system is used and what is its reliability.

j. If control is automatic, can it be automated; and to what extent?

6. Communications:

a. What system is used to communicate data on the treatment process?

b. What system is used to communicate data on the operation of regulators?

c. What system is used to communicate failure or malfunction of individual regulators?

d. What is the reliability of the communication system during storms?

e. What backup system is available in case of power failures?

f. What is the extent of the communication network as compared to the total regional watershed area?

7. Authority:

a. In whom is the regulatory authority vested—individual or agency?

b. In what agency is the regulatory authority vested—private or public?

c. How is the regulatory authority vested—legal: assumed?

d. How widespread is the authority in the watershed area?

e. Who has master control authority in the watershed area?

f. Who has authority to recommend changes, additions and expansions?

8. Responsibility:

a. To whom is the individual or agency having authority accountable?

b. How is this responsibility assigned or designated?

c. If involved with more than one private or public body, how is cooperation obtained and maintained?

d. Who or what entity has responsibility to initiate or approve changes, additions or expansions?

e. Who or what entity has responsibility to finance the total system?

Many more problems arise when the scope of the regulatory system is expanded beyond the individual or localized area. These intensify and multiply as the regulatory system expands from the unit to the area; to the municipality; to multiple—community; to sanitary district; to intrastate regional watershed area; to national levels; and finally to international watersheds. The more significant problems include, but are not limited to:

1. From the individual municipality standpoint, what effect on its total combined flow problem does the following have:

a. Intensity and duration of the individual storm?

b. Intensity and duration of a series of storms over a day, several days, weeks or months?

c. Failure of one or several regulatory devices?

d. Upstream conditions, if located on stream or river?

e. Tidal conditions, if located on ocean or estuary?

f. Sudden thaw conditions, if located in heavy snow areas?

g. Effect of its overflow on downstream communities?

h. Effect of its overflow on the total watershed?

i. Effect of its overflow on its own potable raw water supply?

j. Effect of its overflow on downstream potable raw water supply?

2. From the multiple-community or area sanitary district standpoint, what effects do the following factors have:

a. What is the primary responsibility of the district, by law?

b. What are the secondary responsibilities of the district, by law?

c. What is the moral responsibility of the district, based on public opinion and accentuated by local news media?

d. In case of failure of primary regulatory functions, what determines the choice of area to be flooded, polluted, or otherwise affected?

e. What relationship exists between the sanitary district and the potable water authority, if they are separate entities?

f. Can one legally restrain the other if they are separate entities?

g. What is most important to overall health of the total area?

3. From the newly established regional watershed pollution control district standpoint, additional requirements are:

a. Establishment of priorities of need for regulating devices and systems during storms.

b. Maintenance of potable raw water supplies in the total watershed.

c. Alternative sources of potable raw water supplies in case of pollution.

d. Maintenance of total watershed conservation and recreation capabilities at highest level appropos to storm emergencies.

e. Maintenance of total agricultural endeavor in the watershed area, with minimum interference due to flooding and/or pollution.

f. Maintenance of total industrial endeavors in the watershed area, with minimum interference due to flooding or contamination of potable and/or process water.

g. Maintenance of total residential facilities in watershed area, with minimum interference and inconvenience due to flooding, sewer backup, potable water supply contamination, or other conditions.

h. Maintenance of marine facilities and endeavors, such as fisheries, oyster and clam beds and shipping, with minimum interference due to flooding, pollution and actual destruction of facilities in estuaries, harbors, and tidal areas.

4. In regional watershed pollution control districts which cross state boundaries, the environmental factors include:

a. How is the regional district comprised and made up politically?

b. Which state or states, if any, are most influential?

c. Which state or states have most urgent needs during storms?

d. Where and how is recourse action located and accomplished when states object or disagree with actions of the regional district?

e. What are the arbitration procedures and in what agency are they vested?

f. What agency has ultimate authority over district actions?

In view of the extreme complexity of the total systems described above, and the human as well as the purely mechanical factors, the most important parameter of all involves communication. This must, of necessity, involve the following aspects:

a. It must be vertical, horizontal and diagonal.

b. It must be accurate, especially as regards objective data.

c. It must be timely, or fast enough so that decisions made therefrom can be implemented in time to be effective.

d. It must be aimed primarily at preventive rather than corrective analysis, diagnosis and action.

e. It should have as its ultimate goal the maintenance of the current level of control, as a minimum.

f. It should have as its final ultimate goal the establishment of a regulator control system that will actually enhance the total environmental and ecological state of existence for all living things.

To accomplish this desired level of communication, there is no satisfactory substitute for a completely automated system of environmental and ecological data sensing, transmission, collection, analysis, evaluation, action based thereon, and feed-back to indicate results as soon as possible. The basic advantages of automation include but are not limited to:

1. Capability to communicate almost instantly throughout the system.

2. Awareness of systemic water quality at any given time.

3. Awareness of systemic water quantity at any

given time.

4. Awareness of localized water quality at any given time.

5. Awareness of localized water quantity at any given time.

7. Awareness of the effect of any specific external environmental change.

8. Awareness of the effect of a combination of external environmental changes occurring simultaneously or sequentially.

9. Awareness of the effect of any specific regulatory control procedure.

10. Awareness of the effect of any combination of regulatory control procedures.

11. Awareness of the effect of any specific treatment process during a crisis.

12. Awareness of the effect of any combination of treatment processes during crisis.

Failure to consider all of the foregoing factors, as a minimum, will result in a regulatory system that is inadequate or incapable of responding to the current combined sewer overflow requirements and problems. Such a system would be completely helpless to meet new water quality standards and make impotent any attempt to meet the even more stringent requirements of the future.

APPENDIX 4

REPORT ON DIVERSION SCREENING

Diversion screening comprises screening equipment wherein the trash removed by the screening rake is discharged into the interceptor sewer to the plant for centralized removal or handling.

Diversion screening is recommended to avoid clogging of regulators and to remove floatable trash from the overflow to the receiving waters thus improving the quality of the storm water overflow.

Generally, bar rack screen openings of 1-inch are satisfactory. However, for outfalls into the ocean or lakes drum screens are available having ¼ inch circular openings which will remove ten to twenty times the trash removed by a 1-inch screen opening including cigarette filter tips which otherwise float and cause unsightly litter on beaches or shore banks.

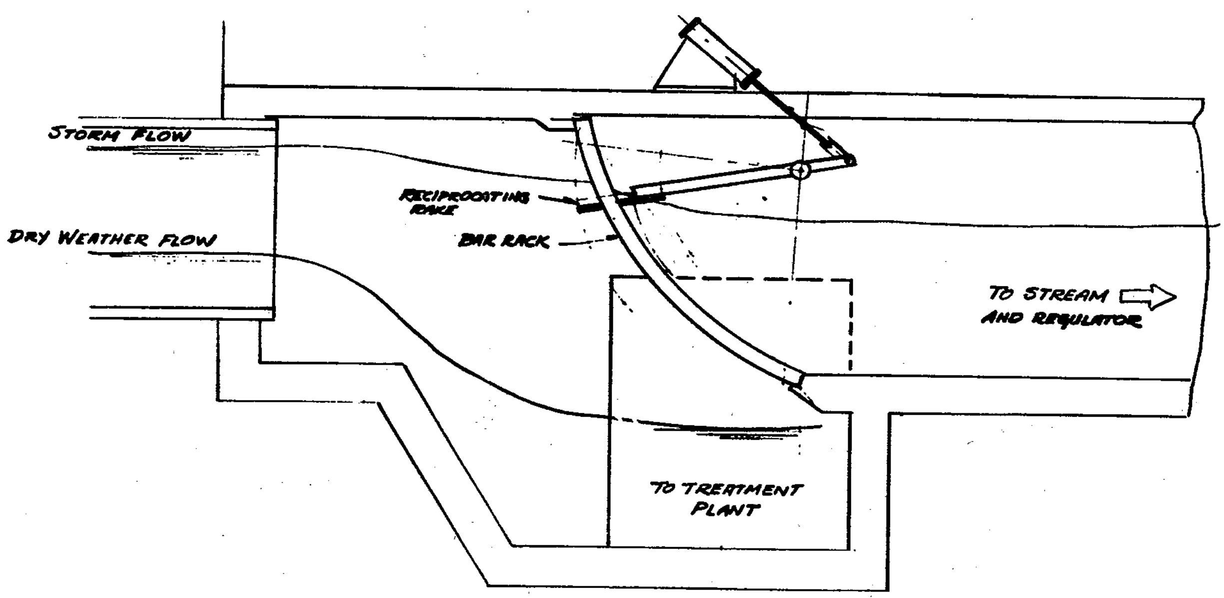
The bar racks shown in Figs. 1, 2, and 3 have 3/4 inch or 1 inch openings with reciprocating rakes that can be driven by water or oil-operated hydraulic pressure systems used for some regulators, or electric motors, totally enclosed for explosion-proof and water-proof application.

The rakes are actuated by water levels that indicate overflow conditions for flow-through regulators and outfalls where layouts are generally as shown in Figs. 35, 36, and 37.

Otherwise where dry-weather flow is directed through a regulator to the interceptor sewer, such as through a Fluidic Y-Branch Diverter, screening rakes operate continuously. The revolving drum screen for fine, 1/4-inch screening can be applied to discharge screenings directly into the interceptor sewer from a discharge chute or by means of a conveyor driven by a screen drive take-off.

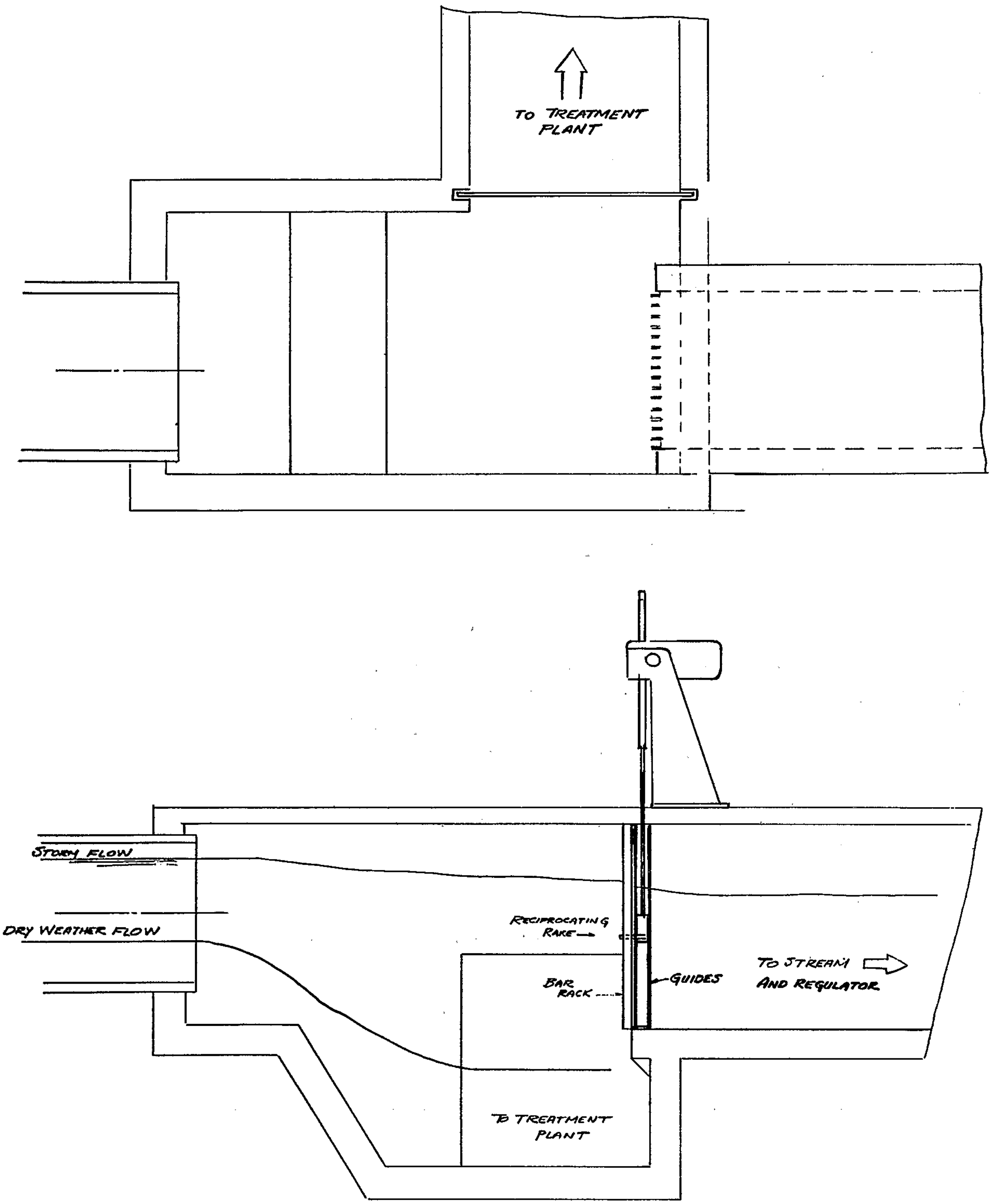
FIGURE 36

Arrangement, Storm Sewer Interceptor Screen—Reciprocating Rack



Courtesy FMC Corp.

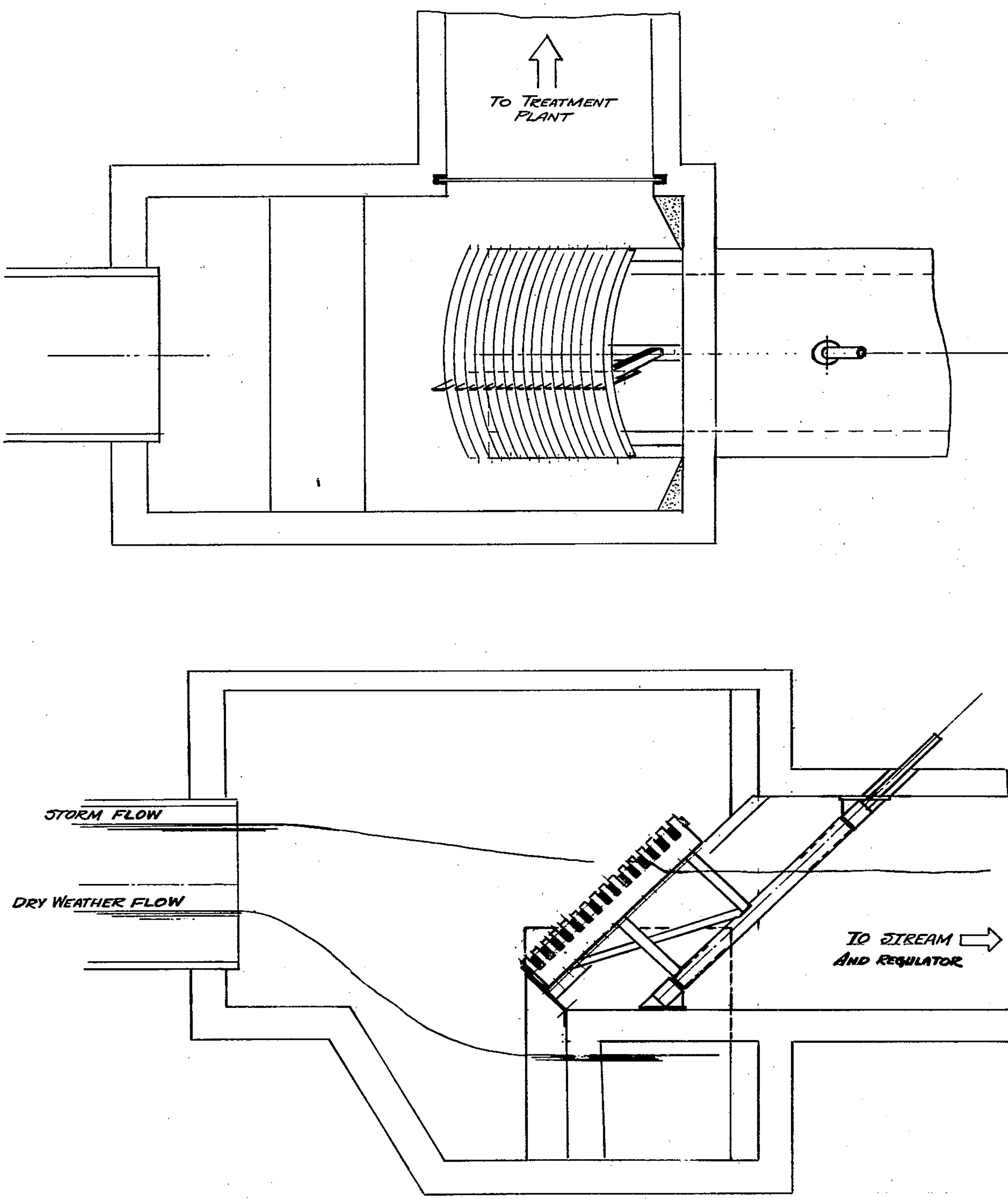
Arrangement, Storm Sewer Interceptor Screen—Bar Rack



Courtesy FMC Corp.

FIGURE 38

Arrangement, Storm Sewer Interceptor Screen—Curved Bar Screen



Courtesy FMC Corp.

BIBLIOGRAPHIC: American Public Works Association, Research Foundation. Combined Sewer Regulator Overflow Facilities FWQA Publication No. 11022DMU07/70

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This report and accompanying manual were submitted in fulfillment of Contract 14-12-456 between the Federal Water Quality Administration, twenty-five local jurisdictions and the APWA Research Foundation.

KEY WORDS

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Operation
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