ASSESSMENT OF SEWER SEALANTS

by

Richard H. Sullivan

William B. Thompson

American Public Works Association
Chicago, Illinois 60637

Grant No. R806567

Project Officer

Richard P. Traver

Storm and Combined Sewer Section
Wastewater Research Division
Municipal Environmental Research Laboratory (Cincinnati)
Edison, New Jersey 08837

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

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FOREWORD

The U. S. Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes performance attributes for a sewer sealant. In addition, tests for use by the manufacturer and user are provided to allow insight to be gained as to what application and use characteristics a new sewer sealant might exhibit. It is hoped that several products will be made available from the private sector which will be usable for infiltration control. Hopefully, such new products will be capable of being applied without the need for major retrofitting of the estimated 800 sewer sealant units now owned by sewer service contractors and local governmental agencies.

An investigation was also conducted to determine possible methods to improve systems to seal house service lines. Cost effective technology is needed in this area.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

ABSTRACT

The control of infiltration into sanitary sewers is a major element of local governmental agencies' pollution control program. In 1978 the major product used for small diameter sewers was withdrawn from production. A study was conducted to develop performance attributes of a sewer sealant which could be used with existing sewer sealing equipment.

A series of laboratory, soil box, and field evaluation studies were also devised to assist in the testing of new products.

Manufacturers in the United States and throughout the world were contacted to determine if there were additional chemical formulations which could be used or if there was interest in developing a product.

Present methods for sealing building sewers were also investigated and suggestions for new methods developed.

This report is in partial fulfillment of the U. S. Environmental Protection Agency Grant No. R806567. Work was completed in August, 1980.

ACKNOWLEDGMENTS

The American Public Works Association (APWA) conducted this study with the assistance of the National Association of Sewer Service Companies (NASSCO).

Project Director for APWA was:

Richard H. Sullivan
Associate Executive Director

Director for NASSCO was:

William B. Thompson
Executive Director

Consultant - Testing:

Reuben H. Karol (Ph.D)
Consulting Engineer

Members of the project steering committee were:

A. B. Colthorp
Penetryn System, Inc.
Knoxville, Tennessee

James Conklin
NASSCO
Winter Park, Florida
(Chairman, Safety Committee)

Kenneth Guthrie
Cues, Inc.
Orlando, Florida

Lonnie McCain
Cherne Industries, Inc.
Edina, Minnesota

James Monaghan
Gelco Grouting Service
Salem, Oregon

R. L. Nolte
Metro Sewer District
St. Louis, Missouri

Elton Smith
Department of Sanitary Sewers
Tampa, Florida

William B. Thompson
NASSCO
Winter Park, Florida

Richard P. Traver, USEPA
Municipal Env'l Research Lab
Edison, New Jersey

James Witt
Naylor Industries
Baton Rouge, Louisiana
(Chairman, Equipment Committee)

ACKNOWLEDGMENTS (continued)

For their assistance to the study, we would also like to thank -

Richard M. Berry
Penetryn System, Inc.
Knoxville, Tennessee

Will Jacques
Avanti International
Houston, Texas
(Chairman, Testing Committee)

James W. Johnson
3M, Chemical Resources
St. Paul, Minnesota

Patsy Sherman
3M Chemical Resources
St. Paul, Minnesota

William J. Clark
Geochemical Corporation
Ridgewood, New Jersey

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SECTION I

OVERVIEW AND RECOMMENDATIONS

In recent years the need to reduce infiltration from sanitary sewer systems has become recognized as one of the means available to reduce the hydraulic loading of wastewater treatment facilities. Without infiltration, treatment plants may serve additional customers without expansion or allow construction of smaller facilities. In addition untreated overflow of infiltrated flow and sewage are also minimized.

Sealing of defective joints in sewers has been a recognized method to reduce or eliminate infiltration for many years. Where the pipe is structurally sound and equipment can be inserted into the pipe, sealant materials can be injected into a joint and a seal achieved.

Although many types of chemicals have been used for grouting, the major material used in this country and throughout the world was an acrylamide monomer manufactured by American Cyanamid. In 1978, production of this product was discontinued. By 1979 a similar product was available from Japan. The price has almost tripled.

In recent years a urethane foam grout sealant was developed by the 3M Company. Though the product is used in small diameter sewers, its major use has been in sewers where physical access by workers can be obtained.

Concern was expressed by the USEPA, local government, and sewer service contractors over the high cost and dependence upon a single foreign manufacturer. A study was therefore undertaken to determine if there were alternative products available; to develop performance specifications for a sewer sealant; to assist manufacturers considering entering the market; to develop a series of tests to evaluate new products; and to evaluate methods available or which appeared possible for sealing building sewers. Building sewers have not generally been rehabilitated because of the high cost of current technology.

The American Public Works Association (APWA) in conjunction with the National Association of Sewer Service Companies (NASSCO) established an advisory committee of local governmental and Federal and industry officials. The committee reviewed products and made recommendations throughout this study.

During the course of the study, several manufacturers announced new products of their intention to do so in the near future. A list of all currently available products is contained in Section VIII.

In an effort to broaden the search, letter contact was made to major United States chemical companies and nations with domestic chemical industries. This search proved futile. As a result of the letter inquiry no new chemical products were suggested for use as a sewer sealant.

A one-day meeting was held to brief representatives of chemical companies as to what was needed and the environment in which a sealant system must function. Several companies were present, and some have indicated that they are developing and testing products to be introduced to the market.

A set of sewer sealant performance attributes was developed as explained in Section II. In conjunction with the limitations of existing equipment used for sewer sealing described in Section IV manufacturers now have an overview of what characteristics a product should have to be considered for sewer sealing.

Section III sets forth a series of tests by the manufacturer and tests which might be conducted by a user to evaluate a product. To speed the evaluation and possible acceptance of new products, a framework for field evaluation of new products also was developed.

Section IV provides an overview of the existing equipment and its delivery capabilities and limitations.

Existing and proposed methods of sealing building sewers are described in Section V. Existing methods are very costly and generally not cost effective. Difficulties of access to the small pipe used makes sealing of this portion of the sewer system very difficult.

RECOMMENDATIONS

1. The study has made it clear that several manufacturers have developed chemical sealing systems which may be used in sanitary sewers. Acceptance by consulting engineers, local government, and sewer service companies of such new sealants would be stimulated if a controlled field demonstration were conducted. The availability of an unbiased, third party report on the performance of the sewer sealant products is desirable to allow consideration by local governmental agencies, sewer service companies, and consulting engineers and would allow a broader understanding of conditions specific to the use of each sealant tested.

   It is recommended that USEPA sponsor a field demonstration program for at least four of the sealants deemed to have the characteristics most likely to provide a superior product with minimum retrofit of existing equipment, or a probable low cost product compared to others available, if such a product has also developed usable application equipment. The field demonstrations should be conducted in various climates under various soil and groundwater conditions, types of pipe materials, and size of pipe. The evaluation should include observations and testing over at least a one year period.

2. The importance of economically and effectively eliminating infiltration from building sewers has become apparent in recent years. (2,4) Present methods, depending upon access from a surface excavation, are costly. There has been relatively little private research and development effort reported.

It is recommended that USEPA sponsor a symposium to be attended by other Federal agencies, consultants, local government, sewer service contractors, and industry to review the findings and suggestions of this report and such other work as may be available, and suggest to USEPA what technologies are available from other areas to provide a sealant system for the building sewer and the direction that USEPA's Research and Development effort should take.

SECTION II

PERFORMANCE SPECIFICATIONS - SEWER SEALANT

—To assist users of sewer grouting materials and manufacturers who are considering the development of new products, a performance specification has been developed. The performance attributes of a sealant have been detailed. These attributes may or may not be applicable to a particular chemical system due to the chemistry of the particular system used.

Experience with sealing sewers over a 20-year period has indicated many desirable features of a system depending upon how the sealant is to accomplish its primary task of not allowing infiltration into the pipe. In addition, there are several requirements which must be met due to the normal processes of shipping, handling and work safety.

At the beginning of this study two methods were in use for sealing a sewer joint: 1) form a new gasket in the joint, and 2) build up an impermeable band of material around the outside of the joint. The nature and quantity of material is generally different for the two methods.

A third method, bonding the pipes together (3), was tried several years ago. However, due to trench conditions, loadings and placement problems, the concept does not appear workable.

Two major constraints adopted by this study were: 1) the sealant must be capable of being applied internally with remote controlled equipment in small diameter pipes, 15 cm (6 in.) to 76 cm (2.5 ft); and 2) the application of the sealant should be accomplished with existing equipment in use by local governmental agencies and sewer service companies or with only minor retrofit costs. Existing equipment for the purpose of this study has been defined as that sewer sealing equipment presently in use by the public and private sectors to internally seal small diameter sewers. Minor retrofit cost has been defined as the cost which, when capitalized over the remaining life of the equipment and if used with a particular product, would be cost effective. Thus the cost would vary with the ultimate cost of the installed joint and would be influenced by both the cost of the material and the cost of application.

Table 1 lists the steps in the life of a chemical sealant from manufacture to conditions which may be found at the site of placement. These steps provide a quick screening of the major conditions which dictate the necessary specifications for a sealant.

TABLE 1

STEPS IN LIFE OF CHEMICAL SEALANT

BY	STEP
Manufacturer	1. Formulate components and package
Manufacturer	2. Warehouse storage
Common carrier	3. Transport to distributor
Distributor	4. Warehouse storage
Common Carrier	5. Transport to applicator
Applicator	6. Warehouse storage*
Applicator	7. Transport to field
Applicator	8. Field storage*
Applicator	9. Transport to job site
Applicator	10. Mix batch*
Applicator	11. Pump to application
Applicator	12. Mix with catalyst/activator
Applicator	13. Force into/through joint a. sand c. water e. voids b. grease c. bedding
Applicator	14. Remove excess grout from pipe barrel*
Applicator	15. Clean equipment
Applicator	16. Subject grout to a. freeze-thaw* d. chemicals* b. submergence e. flexure c. wet-dry* f. pressure head

*may not always be required

BOTTOM OF IMAGE ARE OUTSIDE DIMENSION

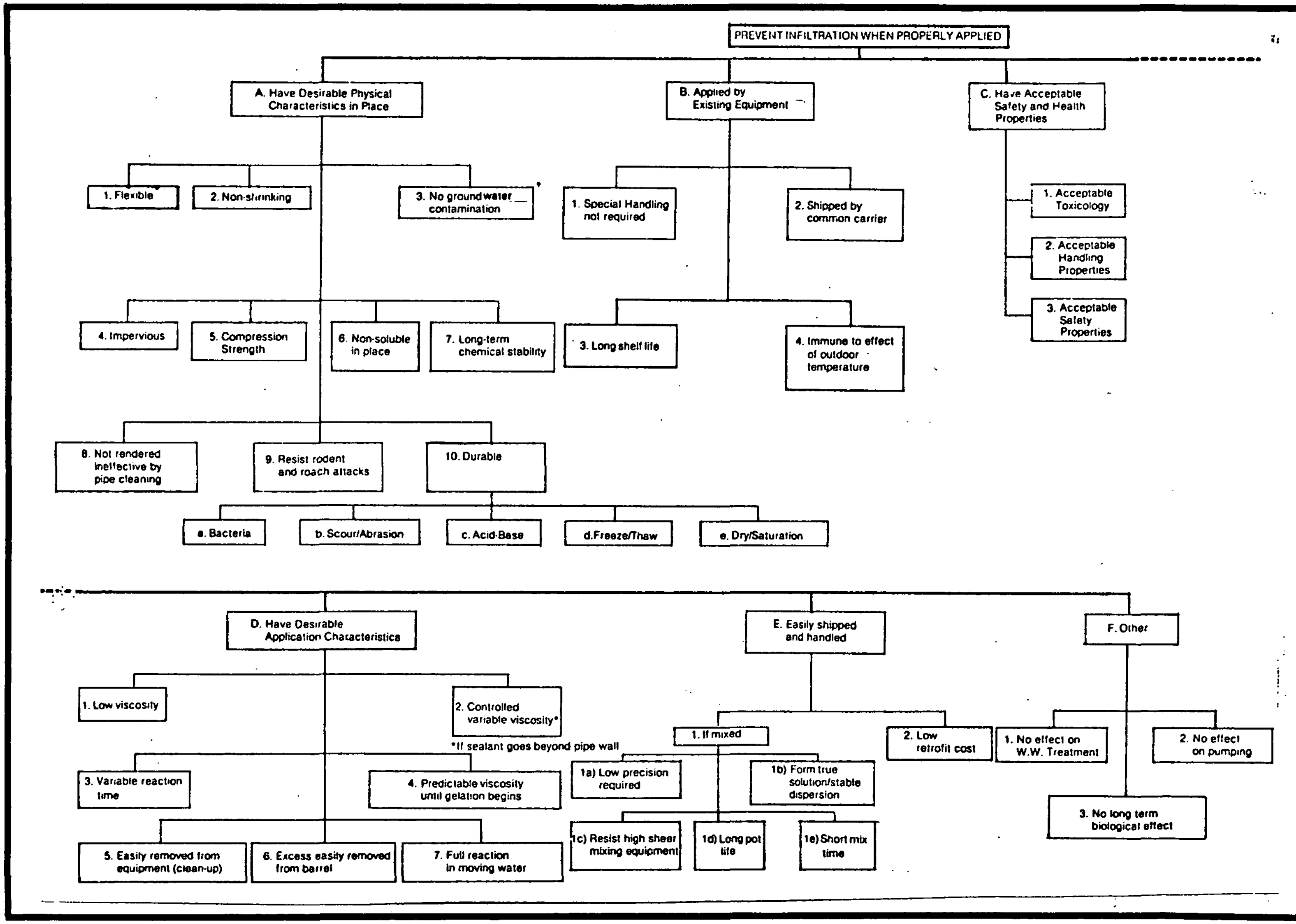


Figure 1 Attributes of Specifications for Chemical Sewer Sealant Systems

The performance specifications are intended to develop a "picture" of the desirable characteristics and the physical conditions and restraints by which the sealant's performance will be evaluated.

A variety of materials with regard to performance and manufacture is desirable to allow competition, meet the needs of specific application problems, and decrease dependence upon only one or two sources. Described is what is necessary, rather than how to obtain the desired objective. This is particularly important as systems based upon several families of chemicals may be found to be usable.

Although any given chemical sealant may not meet all of the performance specifications and physical standards, it may still be a viable material. The applicator would "trade off" advantages, total cost, or superior performance for deficiencies. Thus the specifications developed are for general guidance and in most instances are not absolute.

Both functional and physical characteristics of sewer sealants must be considered. Figure 1 is a chart which arrays the various attributes required of a sealant. Those in the "A" and "B" groups are thought to be of primary importance to the grouting application and rely upon the inherent characteristics of the material. Other groups are dependent upon the manufacturers or the application system developed to use the product.

Table 2 lists the limits for the various factors shown in Figure 1.

TABLE 2

ATTRIBUTES OF SEWER SEALANT CHARACTERISTICS

(amplifies information outlined in Figure 1)

A. Have Desirable Physical Characteristics in Place

1. Flexible: deflect pipe 1° to 5° without cracking or losing seal through temperature range of -7° to 38° C (20° to 100° F.)

2. Non-shrinking: no adverse shrinkage that could cause loss of seal.

3. No groundwater contamination.

4. Impervious: not allow infiltration of groundwater or roots through the material.

5. Compression strength: withstand a 2.1 kg/sq cm (30 psi) hydraulic pressure without damage to or loss of seal in place.

6. Non-soluble in place: will not dissolve in ambient groundwater or sewage flow over the life of the material.

Table 2 continued

7. Long-term chemical stability: no loss of desirable characteristics due to long term chemical change in place.

8. Not rendered ineffective by pipe cleaning: in place the materials or seal will not be rendered ineffective by sewer cleaning equipment.

9. Resist rodent and roach attacks: material will not be affected by roaches and rodents.

10. Durable:
    a. bacteria: non-biodegradable.
    b. scour/abrasion: 1.5 m/sec (5 ft/sec) of flow in pipe with grit load.
    c. acid/base: not rendered ineffective by acid/base in normal concentrations.
    d. freeze/thaw: not rendered ineffective by repeated freeze-thaw cycles.
    e. dry/saturation: not rendered ineffective by repeated cycles of dry and saturated environment.
    f. organic solvents: not rendered ineffective by repeated exposure to organic solvents.

11. Long life: material in place, should have a useful life of 20 years.

B. Applied by Existing Equipment

If mixed:

1. Low precision required: no special equipment or precise measurements required for mixing of components and/or additives.

2. Form true solution/stable dispersion: once mixed, the materials shall not settle out or separate from solution for a minimum of 24 hours.

3. Resist high sheer mixing equipment: material will be unaffected when mixed with blades or paddles.

4. Long pot life: minimum 5 days.

5. Short mix time: maximum 15 minutes.

C. Have Acceptable Safety and Health Properties

1. Acceptable toxicology: material should not be harmful or cumulatively toxic in amounts likely to be transmitted by finger-to-mouth contact or by smoking. Skin contact absorption should not be toxic or cumulatively toxic. Components

Table 2 continued

of spills or unreacted components drained from equipment should not cause damaging effects to wastewater treatment plants or receiving waters when washed into sanitary or storm sewers at a dilution of 1,000/1. Unreacted components in small amounts, diluted by groundwater 1000/1 should not form an identifiable pollutant with a life of more than 48 hours. Manufacturers Material Safety Data Sheets (MSDS) OSHA Form-20 and Standard Ratings for Toxic Substances (LD 50) reports should be available.

2. Acceptable handling properties: skin contact, as well as dust or fumes, should not cause burns, blisters, peeling, dermatitis, or allergic reaction. Accidental eye contact should not cause permanent eye damage. Concentrated and unreacted components should have a solvent for cleaning the materials from skin and/or equipment. The solvent should have acceptable toxicology, handling, and safety properties.

3. Acceptable safety properties: the materials should not be so corrosive as to require special packaging and plumbing. The material, as well as dust or vapor, should not be dangerously combustible. Flash point should be above working temperature 40° C (100° F), and preferably above a possible storage temperature of 60° C (140° F). The sealant components should not be hypergolic, i.e., (ignite spontaneously) with common materials, e.g., rags, oil, gasoline.

D. Have Desirable Application Characteristics

1. Low viscosity at point of application: materials which perform by grouting of the soil generally must have a viscosity of 1 to 30 cps over temperature range of from -1° to 50° C (30° F to 120° F). Materials must be capable of being pumped 150 m (500 ft) in hoses of 1.2 to 1.9 cm (0.5 to 0.75 in.)

2. Controlled variable viscosity: with additives, increase the viscosity from 1 to 10 times.

3. Controlled variable reaction time: from 5 seconds to 15 minutes.

4. Predictable viscosity until gelation begins: once mixed and during placement the viscosity remains essentially constant until gelation begins.

Table 2 continued

5. Easily removed from equipment: clean equipment in 30 minutes or less without special equipment or toxic, flammable solvents.

6. Excess easily removed from pipe barrel: excess material removed with the packer.

7. Full reaction in moving water: unconfined groundwater flowing at 2.5 cm (1 in.) per second.

E. Easily Shipped and Handled

1. Special handling not required: meet DOT regulations.

2. Shipped by common carrier: meet DOT regulations.

3. Long shelf life: Minimum of 6 months; 1 year desired.

4. Immune to effect of temperature over normal range: unaffected in temperature ranges of -1° to 50°C (30° F to 120° F).

5. No danger if mixed with other chemicals, etc.: will not cause explosion, fire, or poisonous gases or fumes if accidentally mixed with other chemicals that might commonly be found at a sewer line rehabilitation site.

6. Labeling:

   a. labeling should be easy to read.
   b. contain instructions for handling damaged materials.
   c. contain instructions for cleanup of spillage and disposal of excess materials and packaging.

F. Other

1. No effect on wastewater treatment plant: excess material or material's components will have no negative effects on the performance of wastewater treatment plant operations.

2. No effect on pumping: excess materials will not clog or damage pumps used for the transportation of sewage.

3. No long-term biological effects: will not break down, leach, or release any toxic materials.

Additional background information concerning safety criteria and existing equipment should be considered by the manufacturers of grouts.

Table 2 continued

Safety

Sewer sealants are handled and applied by construction-type workers using truck-mounted equipment. Operations are performed in the field (away from warehouse or yard) under all weather conditions. Sewer sealant materials are carried on the truck in concentrated form (powder or liquid) and the components may be dissolved/diluted/mixed/blended, as required, at the work site. The components, in liquid form, are then pumped through 155 to 215 m (500 to 700 ft) of hose to the point of application in the sewer where final mixing/catalyzation/ reaction of the components takes place and affects seal.

Worker Exposure - Regardless of preferred procedures for handling, mixing, and applying chemical sealants, workers can (and will) occasionally be exposed to the sealant components.

For example:

- Containers (bags, drums, pails) will receive rough handling in the field. There will be breakage and spills from time to time.
- Equipment and plumbing (tanks, pumps, hoses, fittings) will be disassembled for repair/replacement.
- Diluting/mixing, blending of the concentrated components may cause airborne dust, mist, or vapor. There may be spills and residuals.
- Manual access sealing of large pipes and manholes will expose workers to the components at the point of application.

Safety Equipment

Workers will have and use approved respirators, gloves, goggles, aprons, and such for protection when mixing and handling the chemicals. Use of such personnel protection gear cannot be assured at all times.

Wash Facilities

Workers will not generally have shower, hand wash, or eye wash facilities available at the job site.

Table 2 continued

Desired Safety and Health Properties

It would be ideal to have a chemical sealant system which was non-combustible, non-corrosive, non-toxic, non-irritating, non-allergic, etc. In all probability, however, it would also be non-effective.

Moderate and tolerable levels of undesirable properties may exist. The important thing is to rule out materials having highly dangerous and cumulatively toxic properties.

SECTION III

TESTING OF POTENTIAL SEWER SEALANTS

To evaluate the potential usefulness of a material proposed for use as a sewer sealant, at least four levels of testing appear needed. These are: 1) basic tests by manufacturer and bench tests to determine essential characteristics of the material as related to the desired performance attributes; 2) soil box tests to evaluate the application characteristics of the material and its potential ability to seal the sewer under various conditions; 3) controlled field applications to determine long-term stability and application factors; and 4) examination of sealed joints after a period of service.

Many testing requirements for new chemical formulations have been imposed by the Federal government. Such tests are not discussed in this report. Rather, tests which will allow a user to evaluate a product for particular applications are outlined. Inasmuch as the tests were not developed for a specific sealant, they must be evaluated for applicability to a specific product considered. Manufacturer tests have not been developed in detail by the project inasmuch as material specific tests should be provided and these may vary widely, based upon product base materials.

This chapter sets forth a series of simple specific measurements or bench tests. These may be made of candidate materials for sewer grouting work by the manufacturer and individuals interested in using these materials for sewer sealing.

It is important to keep in mind that sewer joint sealing is only a segment of the overall pressure grouting field in its broadest sense. Pressure grouting might be defined as the introduction of material into remote areas to obtain a changed condition. Over the years pressure grouters have probably worked with almost every material which may be made to flow. Under ordinary conditions pressure grouters are working through pumps, pipes, and hoses, and injecting liquified materials into below-ground structures. In addition to sewer lines, pressure grouting techniques are commonly applied in mines, tunnels, dams, shafts, and foundation soils primarily to control the movement of water.

The tests described herein enumerate the characteristics of an "ideal sewer sealant." Several materials in common use today for sewer sealing do not pass all of these tests at their maximum or most ideal levels. There is no "pass or fail" for a sealing material. It is entirely possible, and perhaps even to be expected, that some new sealant would earn itself a very comfortable place in some of the market for which it was not originally intended but was ideally suited. Acceptance by the end-user is, after all, the ultimate test.

MANUFACTURER TESTS

The manufacturer should provide detailed test results and product composition information. Depending upon the method by which the product effects a seal, the following types of tests should be reported. By 1981, it is expected that ASTM Committee D-18 on Soil and Rock for Engineering purposes will promulgate various standards, some of which may be appropriate for sewer sealants.

It is important that grouts be stable. The use of a suitable unconfined compressive strength test before and after the various tests will indicate if stability is being maintained.

Unconfined Compressive Strength

For sealants to be used in cohesive soils, ASTM D-21.66 can be used with low strength chemical grouts. A standard filler of #5 silica sand can be used. This sand has a D_{50} of 0.39 mm. Figure 2 is a plot of the percent of the sand mixture by size. A minimum sample appears to be a 5 cm (2 in.) - diameter/cylinder, 10 cm (4 in.) long. ASTM D 1056 might be adapted for use with flexible cellular materials such as urethane foam grouts.

Toxicology

Identify all known toxic components of the grouting materials together with their individual and combined toxicity, flammability, and/or other hazards prior to, during and after placement. From these statements extrapolate the potential for:

1. Groundwater contamination.
2. Personnel hazards.
3. General environmental hazards.

If chemicals not supplied by the manufacturer are needed, similar information should be provided. USEPA toxic material register numbers or status of listing should be provided.

Product Reaction Characteristics Variability

Mix and react the product in all of the configurations which may be recommended for field use including admixtures or additives which might be employed to change the characteristics of the product. Report and comment on the minimum, average, and maximum product reaction times (gel times) and report the

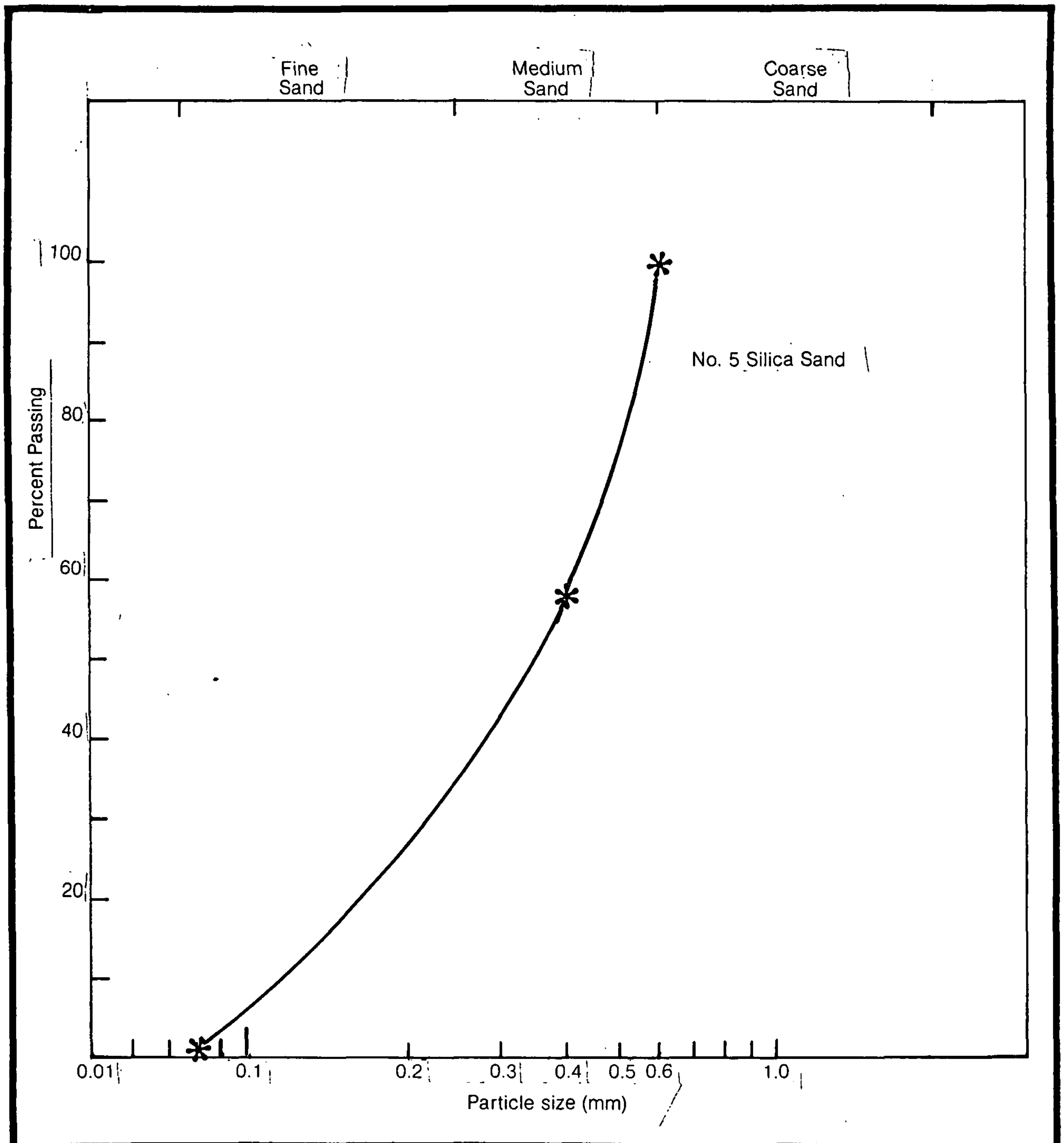


Figure 2 Gradation of Sand for Test Cylinders

results, including physical appearance or performance characteristics over the gel time range. Report all physical properties of the cured material.

Predictable Viscosity	React five samples of the product at a minimum of each of the minimum, average, and maximum gel times. Measure, by any appropriate standard viscosity measurement technique, the viscosity of the product (and particularly changes in the viscosity of the product) between the time of product mixing and product gelation. Draw the viscosity curve for the product from the time of product mixing to product set for gelation.
Adhesion	If the seal depends primarily upon adhesion, tests results should be provided to demonstrate the ability of the product to adhere to the various pipe materials under conditions of cleanliness which can be expected within a sewer.
Solubility and Chemical Reaction	Solubility tests should be made on the cured material for reaction in or with alcohol, ketones, hydrocarbons, and metal salts. Response of the cured material to solutions up to 10 percent strength of sulfuric acid and caustic sodium hydroxide should be determined. Compression tests should be made after these tests.
Biodegradation	Report on the constituents of the cured grout material both separately and in combination and extrapolate from the information the possibilities of decomposition of the cured grout from: 1. Bacterial activity. 2. Consumption by rodents and/or insects.
Flammability	Flash point information in accordance with DOT regulations for shipping.
Acid/Base Reactions	Components. Comment on the effects of and the range of acid- or base-mix waters. Comment on the effects of the cured grout sample (the mixed product) in place or during placement as to toleration of acids/base contact with in-place solutions prior to final product reaction. Prepare cured samples of grout with standard buffer solutions of pH 5 and pH 9. Compare physical properties of the cured grout made with pH 5 and pH 9 buffer solutions with those of cured grout prepared with distilled water (control).

Final Product.

Prepare 27 cured samples. Precisely weigh and measure each sample and record these measurements along with the physical appearance of each sample. Then immerse three of the samples in separate containers of pH levels of 4, 7, 10. Let all samples stand for 24 hours at ambient temperature. Remove the samples. Measure and weigh each and report their physical appearances and conditions.

Compression tests should be made after these tests.

Permeability Report on the permeability of the product under varying pressure heads of up to 2.1 kg/sq cm (30 psi).

BENCH LEVEL TESTING

The following tests are also suggested for initial product testing by the manufacturer. Product users and applicators may wish to use bench level testing to confirm reported test results by conducting their own analyses.

Note: For all tests except flexibility and permeability samples to be 5 cm (2 in)-diameter cylinders, 10 cm (4 in.) long. As an alternate, samples 5 x 2.5 x 2.5 cm (2 x 1 x 1 in) may be used. Samples to be mixed with proportions specified by manufacturer. Samples should be cast with and without the #5 silica sand and the test results reported separately.

Flexibility Cast a sample of grout material 30.5 x 2.5 x 2.5 cm (12 x 1 x 1 in.)

Take an object with a smooth curved surface and a radius of 10 cm (4 in). Place one end of the sample against the curved surface and gently secure the end against any movement. Grasp the opposite (unsupported) end of the sample and deflect it around the mandrel toward a maximum of 180^0 at a rate of not less than 1^0 per minute.

Record:

1. Degree of deflection at formation of first noticeable surface crack.
2. Degree of deflection when material ceases to conform fully to the mandrel surface curvature.
3. Degree of deflection when crack formation in the material extends one-half the way through sample.
4. Degree of deflection when material fails

completely, as evidenced primarily by extension of the crack more than 90 percent through the sample.

Shrinkage	Prepare a minimum of five cured samples. Weigh each sample carefully and record the weight. Place all samples in 50 percent relative humidity at 38° C (100° F) for 24 hours. Remove the samples and after allowing them to cool to ambient temperature and report their physical appearance. Then weigh and measure each sample and report before and after test results. Repeat test using the standard sand filler. Observe cracking. Immerse dried samples in water at room temperature, 18 to 23° C (65 to 75°F), for 48 hours and observe condition of samples and measure reswelled weight and dimensions. Compare with original weight and dimensions.
Permeability	Cover one end of a 5 cm (2 in.)-diameter cylinder 38 cm (15 in.) long with a small mesh screen. Cast a 2.5 cm (1 in.)-thick sample of cured grout in the bottom (screened) end of the cylinder wall. Add water to the cylinder to a height of 30.5 cm (12 in.) above the cured grout. Collect and measure the amount of water permeating through the cured grout. Although permeability is not desired, rates of 10^{-8} cm/sec would indicate a very impervious material for use as a sewer sealant.
Environmental Cycling	Freeze/Thaw Use 50 cured samples. Precisely measure and record the weight and volume of each sample, then freeze all samples so that each sample reaches a temperature of -18°C (0° F) for 24 hours. Then remove and let stand and allow the samples to thaw gradually to room temperature. Repeat this series for five complete cycles. Select five samples from the group after each cycle and report their physical appearance. Then precisely measure the weight and volume of each sample and report that data in comparison to their original weights and volumes. Wet/Dry Take a minimum of 30 cured samples and precisely measure their weights and volumes. Place the samples in a 50 percent relative humidity environment at approximately 21° C (70° F) for 24 hours.

Remove the samples and immerse them in water at 21° C (70° F) for 24 hours. Repeat the procedure for three complete cycles.

At the end of each cycle interval of 1) 50 percent relative humidity and 2) immersion, remove five of the samples and report their physical appearance; then precisely measure their weights and volumes and report that information as compared to the original weight and volume for each sample.

Organic Solvents

Prepare a minimum of 15 cured samples and precisely measure their weights and volumes. Immerse five samples in separate containers containing a minimum of 165 ml (6 oz) acetone in closed cups. Let all samples stand for 24 hours at about 21° C (70° F). Remove the samples and clean off any liquid obviously clinging to the sample. Dry the samples in a dessicator for 30 minutes and report their physical appearances and precisely measure and report their weights and volumes. Repeat the test with 165 ml (6 oz) of methyl alcohol. Repeat the test with 165 ml (6 oz) of toluene.

Component Storage

Take a minimum of six samples of each component of the chemical grout system to be used in the field. Place each sample in a container which most closely approximates the probable shipping container for each component. React two of the samples to obtain the grout end product and set aside for comparison. Freeze the remaining samples to a sample temperature of -18° C (0° F) for 24 hours. Remove the samples. Let them stand and allow them to thaw to ambient temperature, than heat samples to 49° C (120° F) for 24 hours. Remove the samples, let stand, and allow to cool to ambient temperature.

At each interval of 1) ambient temperature after -18° C (0° F), 2) ambient temperature after 49° C (120° F); react two samples of the product. Record the reaction characteristics as compared to the original controls and report the product appearance prior to each test and after each test.

Pot Life

For materials which must be mixed with other materials prior to placement, prepare a minimum of twelve samples of each grout component in a container which most closely resembles the probable on-job container for each component immediately prior to grout placement. Allow these samples to stand for 24 hours.

	Then take two samples, open their containers, mix the product and take a gel time test. Repeat the test each day for five days. Compare the results of the daily tests for consistency.
Viscosity	Measure the viscosity of the components in their form immediately prior to pumping to the point of application at temperatures of -1^{o} to 40^{o} C (30 to 100^{o} F).

SOIL BOX TESTING

Any sealant material which emerges from bench testing with acceptable characteristics would be further evaluated under simulated use conditions to obtain some knowledge and understanding of the material's more subjective characteristics. Such tests would be performed in a "soil box" and behavior of the material would be reported for the following condition variables as follows:

1. concrete and clay pipe 20 cm (8 in.)
2. hydrostatic pressure 9 m (30 ft)
3. large and small joint leaks
4. laminar water flow outside of pipe
5. fine sand, pea gravel, 5 cm (2 in.) stone, and cohesive soils
6. joint deflection
7. "pumpability"
8. compatability with existing equipment
9. ease of excess material removal from pipe barrel
10. resistance to cleaning equipment
11. resistance to scour and abrasion
12. ease of product handling
13. batch time preparations

Proper conduct of these tests would require construction of at least two well-built soil boxes capable of full closure and pressurization to achieve a 9 m (30 ft) head pressure. Each sealant material would require approximately one week of such soil box testing.

Due to the subjective nature of this phase of testing, actual test work on all sealant material should be performed at the same location and under the same supervision. Careful documentation by written records, audio visual equipment, and photographic equipment would be necessary.

Major items of equipment required for such tests might be listed as follows: soil box quantity - two at $5,000 each; packer or grout ejection system; pump system; hose; mix tanks; agitators; miscellaneous; total cost $25,000. (1980 price estimate)

In addition it would be desirable to employ an outside testing laboratory during this phase of test work. Such a lab could perform independent tests of such variables as unconfined compression, cohesion, extrusion, and other variables as applicable. A final report and synopsis would also be necessary. The total variable cost for such soil box testing might approximate $15,000 per sealant tested.

FIELD APPLICATION

Following these soil box tests, actual field application could be recommended for a sealant showing an acceptable mix of characteristics. Ideally, four locations would be selected from separate areas of the United States and test sections in each area would be tested and sealed for each of two pipe size diameters - 20 cm (8 in.), and 61 cm (24 in.).

The test sections would be critical to the proper evaluation of the material handling characteristics for the following variables: clay pipe, concrete pipe, hot climates, wet conditions, dry conditions, sandy soil, silty soil, clayey soil, northern winter climates, southern summer climates, rock backfill, sealing above the groundwater table, sealing below the groundwater table, salt water in the soil, large leaks, small leaks.

A sealant, such as acrylamide grout which has given satisfactory service over a long period of time, should be used for reference purposes. After application, the joints should be tested as well as visually inspected.

EXCAVATION OF JOINTS

After at least one year in place, representative joints should be excavated for physical inspection. Such inspection should include a visual inspection for cracks and failures as well as evidence of root attack, biodegradation, or solubility problems.

SECTION IV

SEWER PIPE JOINT GROUTING EQUIPMENT

Initially sewer pipe joint grouting equipment were products of specialty contracting firms building and using such equipment within their own organizations. Equipment configurations varied widely depending upon the specific process and needs of the individual contractor. It wasn't until the early sixties that the sewer grouting process had developed sufficiently to attract manufacturers to build equipment for use with the various sealant materials available. Through the years, equipment manufacturers have refined the technology and equipment that is in use today.

During the early sixties commercial equipment was designed and manufactured for the placement of an acrylamide base grouting material (low viscosity) as acceptable alternative grouting materials were not available. When urethane foam grout was introduced in the early 1970's, suitable equipment was likewise developed.

At the present time there are two distinct types of grouting equipment being manufactured: that for placing an acrylamide base material; and that for an urethane grouting compound. It is anticipated, however, that equipment of the future may be designed to accommodate placement of a variety of grouting materials.

PRESENT DAY SEWER GROUTING EQUIPMENT

In an effort to review existing sewer grouting equipment, the following two categories have been established based upon the viscosity of the chemicals as they are pumped to the packer:

Category "A" - Equipment designed for the placement of 1 to 50 centipoise materials (low viscosity delivery system)

Category "B" - Equipment designed for the placement of 1 to 700 centipoise materials (high viscosity delivery system)

These two categories will encompass 95 percent, if not all, of the equipment available for the placement of sewer sealants at the present time. All of the equipment is designed to function effectively in a minimum of sewer line sizes ranging from 15 to 76 cm (6 to 30 in.) diameter. In all cases the "in-line" equipment is manufactured with sufficient tolerances to accommodate the normal deviations of size, alignment and obstructions normally found in a sewer pipe.

From a process point of view, there is little difference between the two equipment systems. Each system utilizes closed circuit t.v. equipment as shown in Figure 3 for visual monitoring of the remote sealing process. A hose and reel combination as shown in Firgure 4 for transporting the sealant material from above ground to the point of placement is included. A packer device shown in Figure 5 is utilized for controlling the injection of sealant into the sewer pipe fault.

The basic process steps may be described as follows:

1. Precleaning of the sewer line from manhole to manhole to remove debris that could interfere with the movement of the television and grouting equipment through the line.

2. Preinspect the sewer line by pulling closed circuit television equipment from manhole to manhole to determine the general condition of the sewer line and if it is groutable as shown in Figure 6.

3. Place the joint sealing packer equipment into the sewer line with the closed circuit television equipment.

4. Move the combined equipment through the line to each joint.

5. Using the closed circuit television equipment, position the center of the packer adjacent to the joint to be tested.

6. Inflate the packer to isolate the joint to be tested from the remainder of the sewer line as shown in Figure 7.

7. Test the joint in accordance with the equipment and medium available. If it holds water or air pressure, move to the next joint and repeat steps 4, 5 and 6 until a joint is reached which will not hold pressure.

8. For joints which fail the pressure test, inject the sealing materials into the joint until a successful seal is achieved.

9. Retest the joint to determine if it will pass a pressure test.

10. Deflate the packer and move to the next joint or remove the equipment from the sewer line, whichever is appropriate.

Differences that do exist between the two defined categories of equipment result from the materials they are designed to handle. As previously

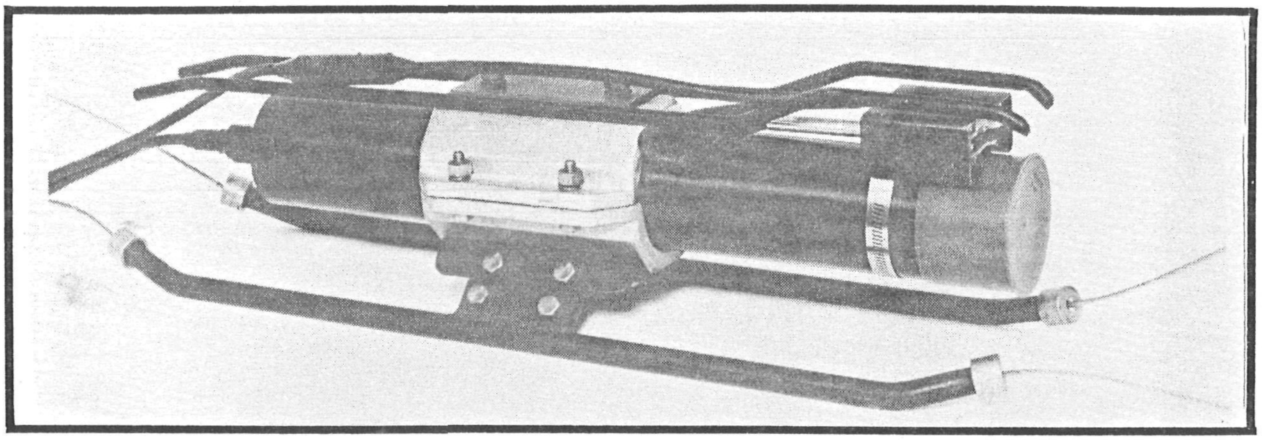


Figure 3 Closed Circuit TV Equipment — Courtesy Cherne, Inc.

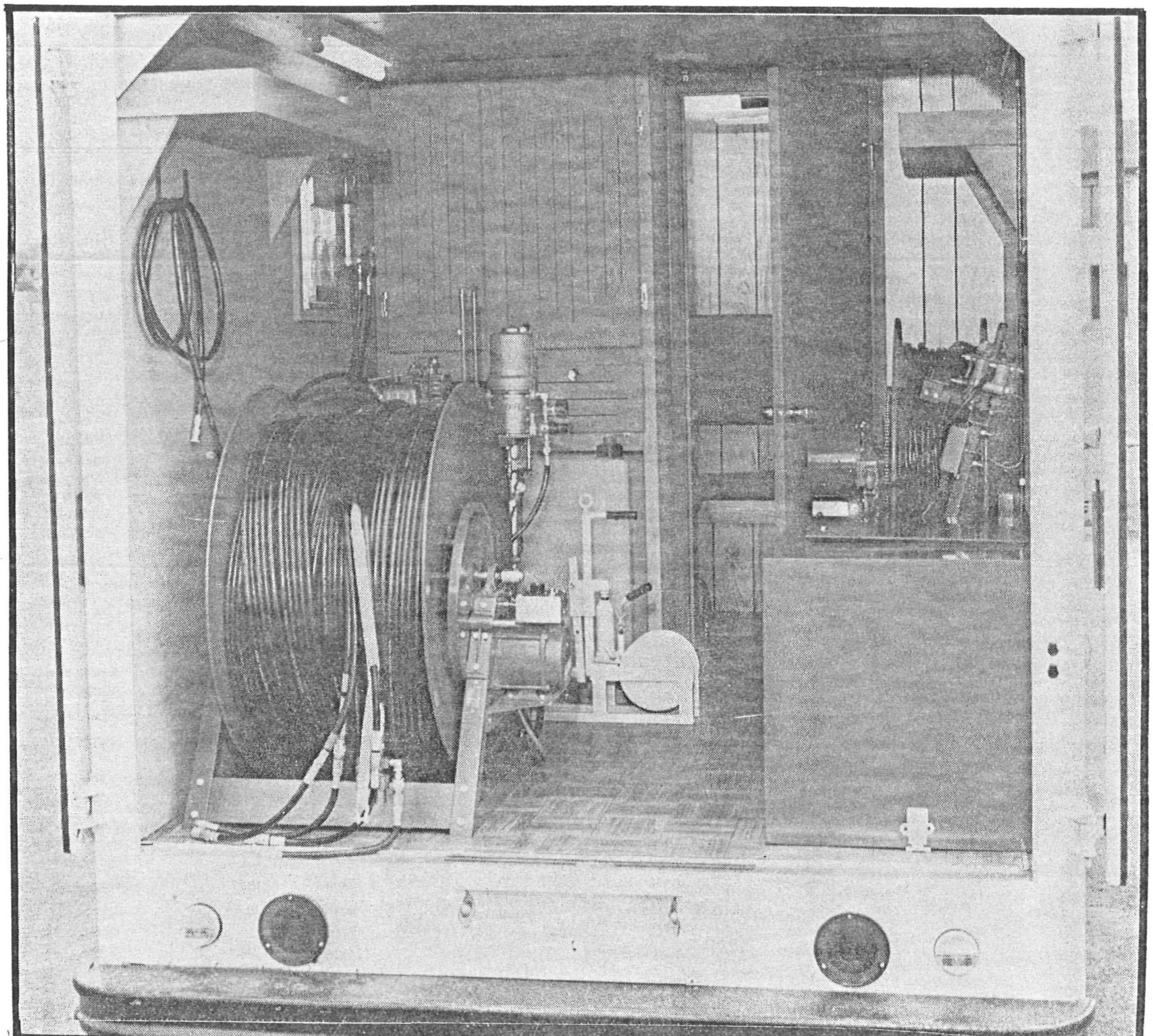
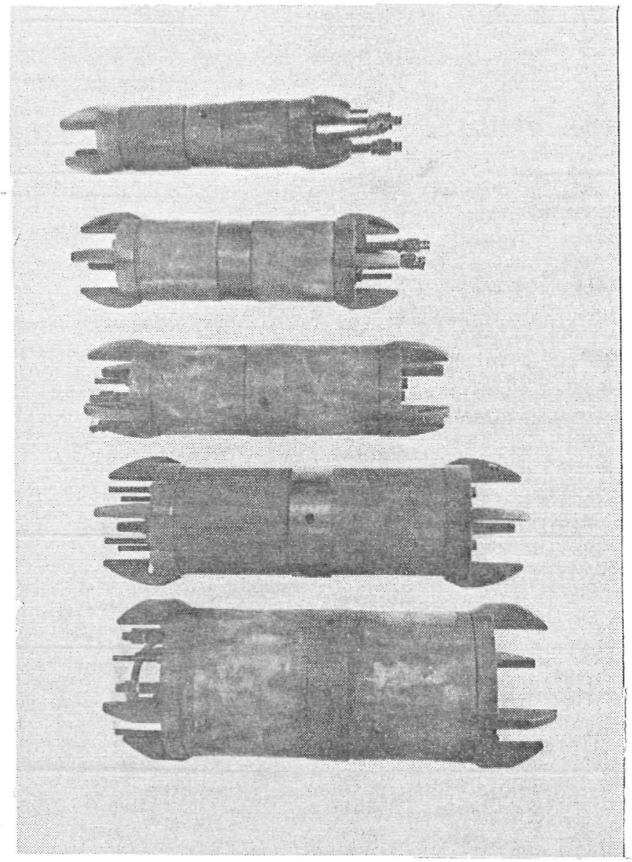
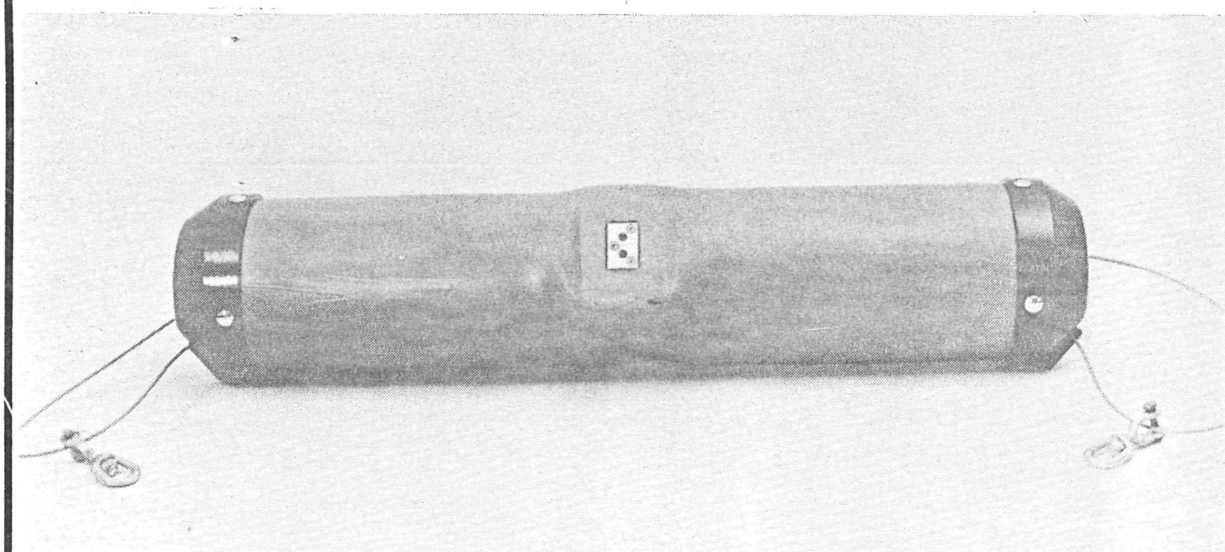


Figure 4 Remote Sealing Equipment — Courtesy Cherne, Inc.



Packer Device (for 10 to 61 cm (4 to 24 in.) diameter) — Courtesy Cues, Inc.



Sleeve Packer (for 10 to 30 cm (4 to 12 in.) diameter) — Courtesy Cherne, Inc.

Figure 5 Packer Devices

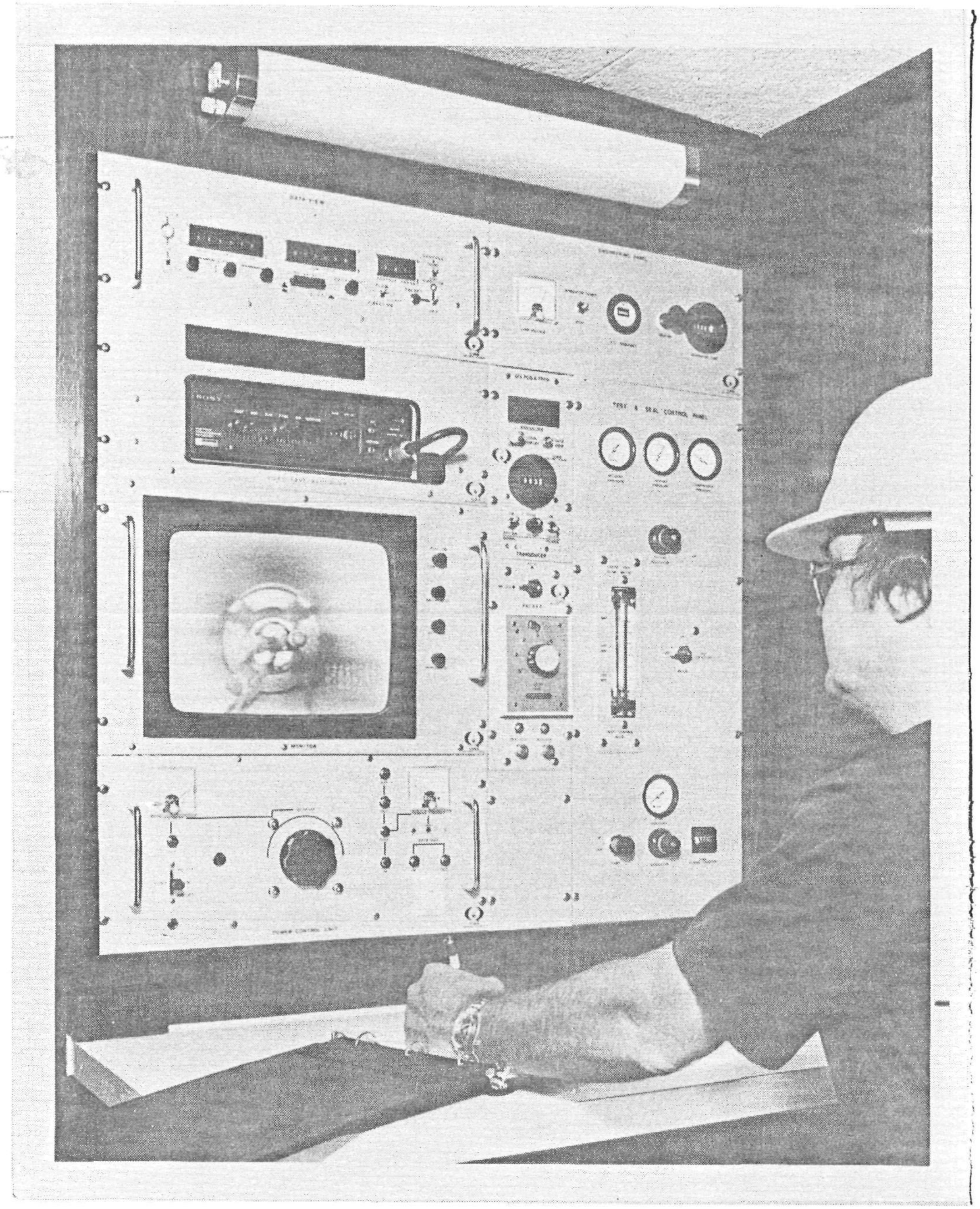


Figure 6 Preinspection of Sewer — Courtesy Cues, Inc.

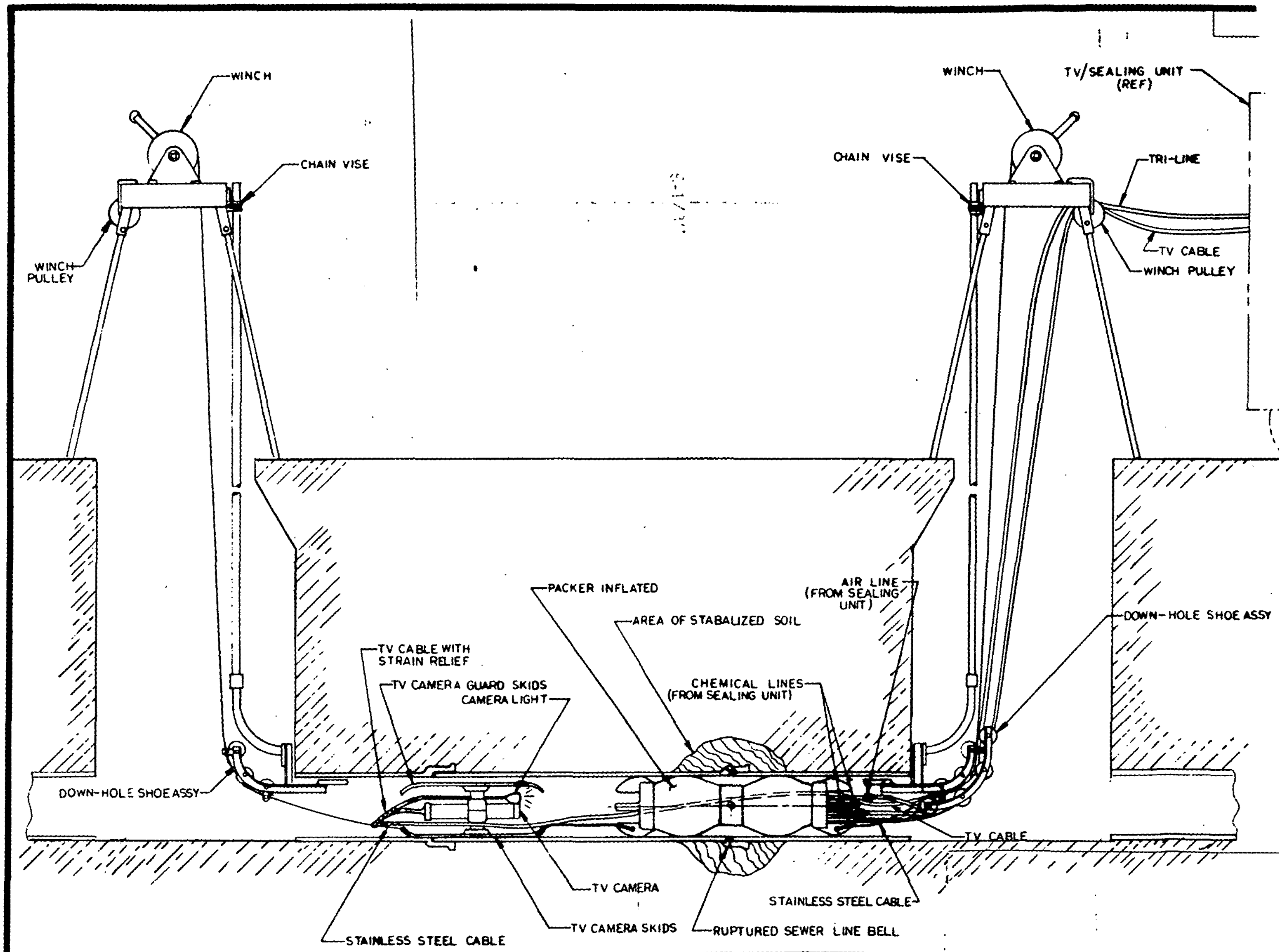


Figure 7 Sewer Joint Sealing — Positioning of Packer — Courtesy Penetryn Systems, Inc.

described, Category "A" equipment generally is designed to pump low viscosity (1 to 50 cps) materials, which, when injected pass through the faulty sewer joint into the surrounding soil to form a watertight barrier. High viscosity (1 to 700 cps) materials pumped by Category "B" equipment when injected, form a new joint gasket and may or may not penetrate into the surrounding soil areas.

Basic characteristics of the two categories of equipment are detailed as follows:

<u>Category "A"</u> (low Viscosity Delivery Systems)

1. Chemical Pumping System: Most of the equipment in this category are equipped with pressure tanks used to pump the sealant from the grouting unit to the point of repair and are commonly referred to as the "air over" system. In practice, the chemical constituents are mixed in two pressure tanks. Once mixed, the tanks are closed and compressed air is introduced on top of the chemical fluid. This air pressure becomes the force that moves the liquid to the point of repair once the line valves have been opened.

   Alternate to the "air over" method is a dual 1 to 1 positive displacement pump system where the chemical constituents are mixed in two non-pressure vessels and are pumped to the point of repair. This method would also allow placement of category "B" materials.

   - With both systems, the chemical fluids are pumped through a dual hose system to the packer where they are mixed at the point of injection.

2. Operating Pressures: The "air over" system operates at a maximum of 8.8 kg/sq cm (125 psi) tank pressure and is thus limited in its pumping capability. The pump systems, by contrast, have the capacity of developing pump pressures in the range of 35.15 to 70.30 kg/sq cm (500 to 1,000 psi) and therefore have the ability of pumping a broader spectrum of materials.

3. Chemical Delivery System: The chemicals are pumped, with either of the two systems described, to a grout control panel where the flow rate of each material may be varied as required and monitored by flow rate gauges. From the control panel the fluids are pumped through 150 m (500 ft) of a 1.2 to 1.9 cm (0.5 to 0.75 in.) diameter dual hose system to the packer in the sewer line. At the point of injection, the two materials are combined for placement. In line check

valves located at the packer are used to avoid combining of the chemicals other than at the point of injection.

Category "B" (High Viscosity Delivery Systems)

1. Chemical Pumping System: All of the equipment in this category are equipped with pumps. None of the systems are of the "air over" type. The dual pump system is of a positive displacement type and pumps in a ratio of 1/1 to 1. With some modification the pump ratios may be changed. Chemical concentrate is either pumped directly from the shipping containers or from non-pressurized storage vessels through a dual hose system to the point of repair in the sewer line.

2. Operating Pressures: Normal pump operating pressures are in the area of 42.18 kg/sq cm (600 psi); however, the pump system has the capacity to pump at pressures in the range of 70.30 kg/sq cm (1,000 psi). Generally, with the type of material being pumped, pressures of a 70.30 kg/sq cm (1,000 psi) are not reached.

3. Chemical Delivery System: Unlike the low viscosity equipment, this system pumps the sealant materials directly from containers, through 150 m (500 ft) of 1.2 to 1.9 cm (0.5 to 0.75 in.) diameter dual hose to the packer in the line where mixing occurs at the point of injection. The ratio of fluid pumped is fixed with only the flow rate being variable based on the operating speed of the pumps. Check valves incorporated in the packer device are used to avoid contamination of the separated materials in the hose line.

It is obvious that there are differences between the two categories of equipment. However, there are similarities as well: in packaging and auxiliary equipment. Both types of equipment are mounted in van trucks or trailers. One hundred and ten (110) VAC power is available from either self-contained power supply units or from 5,000 to 6,500 watt generators mounted within the vehicle. Small air compressors are also standard equipment.

COMPONENT SYSTEMS

Generalized description of three portions of the sealant delivery system are provided for general information. Each is essential to an operating system but may need modification to accept the use of a new product.

Flow Control Systems

About 50 percent of the systems route the chemical through a panel that contains flow meters with flotation device to measure flow rates. The panels are also equipped with flow control valves to activate chemical movement and pressure gauges to monitor back pressure. Other gauges monitor packer inflation pressure and compressor receiver pressure. Most of the remaining systems do not use flow meters. However, they do incorporate pump pressure gauges, pump controls, packer inflation pressure gauges, and compressor receiver gauges.

Reels and Hoses

Virtually all of the systems incorporate a hose reel with rotary passage joints. The reels allow for passage of two to three fluids and one or two air lines. About half of the hoses are triline systems with two chemical and one air line.

Quad line systems have two chemical, and two air lines. The chemical hose sizes range from 1.2 to 1.9 cm (0.5 to 0.75 in.) and the air lines range 0.95 to 1.2 cm (0.375 to 0.5 in.). The hose lengths normally range from 122 to 183 m (400 to 600 ft) with the standard being 150 m (500 ft). Over 50 percent of the hose ends are equipped with quick disconnects. About the same percentage of hose ends are fitted with check valves.

Packers

Some are equipped with two inflatable rubber elements stretched over a cylinder, and fitted into a center casting. The center casting contains two openings to exit the chemical into the void areas after element inflation. Mixing chamber may or may not be incorporated into these packers.

Other packers are equipped with three inflatable elements stretched over mandrels. Chemical exits from the openings between the elements after the end elements are inflated. The center element can be inflated to extrude most of the remaining chemical from the void. Some mixing occurs prior to exit from the portal. Some other packers are used incorporating a long or single sleeve stretched over a cylinder or pipe. The chemical exits from one or two openings passing through the rubber sleeve. Some of these packers are equipped with a mixing chamber.

SECTION V

BUILDING SEWER (HOUSE LATERAL) REPAIR

For many years, the effect of leaking building sewers on the collection system and treatment facilities was considered insignificant. This theory was built around the concept that most of the building sewer would be above the water table and therefore would only be subject to leakage during periods of excessive rainfall or exceedingly high groundwater levels. These sporadic conditions were not viewed as "serious" when compared to other collection system problems.

Therefore, during the early development of internal pipe joint grouting processes, little attention was given to the building sewer. It wasn't until the late 1960's that serious attempts were made to repair building sewers by a means other than by excavation and replacement. Shortly, three primary processes emerged and were used in varying degrees throughout the country. Each of these processes required some excavation and proved to be cumbersome and expensive. Therefore, wide acceptance and use of these processes was never achieved.

Today, however, the recognition of the need to repair building sewers is much greater. Expanded awareness of the impact of building sewers on the collection system and treatment facilities has developed from the current on-going I/I program. Research studies sponsored by the USEPA (4) indicate that a significant percent of the infiltration found in many collection systems is being contributed by the building sewers. In addition, it is now realized that building sewers that are left unattended may become a major source of renewed infiltration, through water migration, after the street sewers have been repaired.

Current technology is not considered to be generally effective or economical in addressing the building sewer infiltration problem. The industry is left usually with only one remedy, the expensive and sometimes impossible task of building sewer excavation and replacement. The need to develop new and more effective processes is well known. The following will provide further understanding of the current processes available for the repair of building sewers. In addition, two new concepts have been developed and are presented. These concepts, though untried, are felt to be sound with each having the potential of being developed into successful and economical processes.

THE BUILDING SEWER

The building sewer is the extension of the waste drain system of a building or other waste producing facility which is extended to the public right of way for conveyance in the collection sewer to the wastewater treatment facility. The building sewer may be as small as 10 to 15 cm (4 to 6 in.) diameter and varies in length from 4.5 m (15 ft) to 30 m (100 ft) or more. The line is usually laid at a minimum self-cleansing grade from the building to the immediate vicinity of the collection or street sewer. At this location there may be an abrupt change in grade in order for the flow to descend to the collection sewer. The building sewer may enter the collection sewer at an angle of 30 to 90 degrees from the axial flow direction and at a verticle angle of 0 to 90 degrees.

The building sewer may have been built with any one of several common products including clay, plastic, concrete, asphalt impregnated paper, or cast iron. Inspection of the construction has generally been described as minimal. The trench for the pipe and the backfill used may act as a french drain and allow more rapid movement of groundwater than would be typical of undisturbed ground.

Few systems provide for access at the property line. Some systems where basement flooding has been prevalent have required a relief overflow point outside of the foundation draining to the surface. Overall, such points for access must be considered as the exception. Access from within the building for sealing equipment is not considered feasible due to the problems of access to the pipe and the type of equipment required as well as the incovenience to the occupants.

EXISTING PROCESSES

As a requirement of this study, current methods for the sealing of building sewers were identified and evaluated. Incremental costs have been developed and are presented for each method.

- Pump full method
- Sewer sausage method®
- Camera-packer method®

Each is discussed in detailed step procedures that must be accomplished for a successful application. Costs associated with each step of the procedure is also given. Note that the cost of excavation has not been given in the tables. Rather, excavation costs have been included in a cost range.The The sewer sausage and camera-packer methods are both patented processes. A fourth method, in-situ lining has been used to a limited extent in some foreign countries and work has been initiated in this country to determine the cost and applicability to conditions of United States practice. Generally, the street sewer must be cleaned for access of equipment. Cost of cleaning has not been included in the price estimate.

Pump Full Method

This concept is one of injecting a chemical sealant through a conventional sealing packer from the street sewer up the building sewer to a point where access has been gained through excavation and plug installed. As the sealant is pumped under pressure, it is forced through the pipe faults into the surrounding soil area where a seal is effected after gelation of the sealant occurs. After the sealing has been accomplished, the excess sealing material is removed from the building sewer and it is returned to service. The steps required to accomplish the work are listed in Table 3 A.

Table 3

(SEALING OF BUILDING SEWERS)

A Pump Full Method

Steps		Labor	Equipment	Materials
			COSTS ($)	
1.	Locate building sewer at property line.	20		
2.	Clean street sewer.	90	45	
3.	Set-up and move camera/packer unit into position in the street sewer	40	20	
4.	Install pipe plug in the downstream end of the building sewer at a point of access.	-	-	
5.	Inflate packer in street sewer and inject sealing materials.	40	20	150
6.	Remove camera/packer from the street sewer and the plug from the building sewer.	40	20	
7.	Remove excess sealing materials from the building sewer.	150	50	
8.	Re-clean the street sewer to remove excess sealing materials.	30	50	
	Subtotal	$410	$205	$150
	TOTAL COSTS			
	a. without excavation			$765
	b. if excavation required		Up to	$1615

Note: Cost estimated as $6.60/kg ($3/lb) material
Average labor cost $20/hr (includes supervision)

Sewer Sausage Method

This method is similar to the pump full method in that it requires access to the building sewer, the use of a camera/packer unit in the street sewer and the injection of a sealant from the street sewer up the building sewer to effect a repair. The primary difference is the use of a tube inserted into the building sewer prior to sealing to reduce the quantity of sealant used and minimize the cleaning requirement after the sealing has been completed. The sealant is pumped under pressure around the tube, up the building sewer and through any pipe faults into the surrounding soil areas where the seals are effected after gelation of the materials occurs. Table 3 B lists the steps and estimated costs to accomplish the sealing of a building sewer.

Table 3

B Sausage Method

Steps		COSTS($) Labor	Equipment	Materials
1.	Locate building sewer at property line.	20		
2.	Clean the street sewer.	90	45	
3.	Set up and move camera/packer unit into position in the street sewer	20	20	
4.	Install tube from the point of excavation down to the street sewer.	60	20	5
5.	Install pipe plug in the downstream end of the building sewer at the point of excavation	-	-	
6.	Inflate packer in the street sewer and inject sealing materials.	40	20	50
7.	Remove camera/packer unit from the street sewer	40	20	
8.	Remove plug and tube from the building sewer.	40		
9.	Remove excess sealing materials from the building sewer.	30	10	
10.	Reclean street sewer to remove any excess sealing materials	30	50	
	Subtotal	$370	$185	$ 55

Steps continued

TOTAL COSTS

a. without excavation		$610
b. if excavation required	Up to	$1510

Note: Cost estimated as $6.60/kg ($3/lb) material
Average labor cost $20/hr (includes supervision)

Camera-Packer Method

Unlike the other methods described this method does not require the placement of equipment in the street sewer. It also differs in concept, as only faults discovered by the television camera would be repaired. This process also requires access to the building sewer. Through the access, a miniature television camera and specialized sealing packer are inserted. Using a tow line, previously floated from the building sewer access to the downstream manhole of the street sewer, the camera packer unit is pulled into the building sewer. The camera/packer unit is then slowly pulled back out, making repairs to faults that are discovered by the television camera. Thus, the deepest leaking joints are sealed first. The repairs are made similarly to the conventional methods used for sealing joints in street sewers. Once the repairs have been completed, the equipment is removed and the building sewer returned to service. The steps and costs are described in Table 3 C.

Table 3

C Camera - Packer Method

		COSTS ($)		
Steps		Labor	Equipment	Materials
1.	Locate building sewer at the property line.	20		
2.	Clean the building sewer	30	10	
3.	Clean the street sewer.	90	45	
4.	Float line from access in the building sewer to the downstream manhole of the street sewer.	20		
5.	Insert special camera/packer unit into the building sewer	40		
6.	Pull camera/packer unit down to the street sewer.	30	15	
7.	Retrieve camera/packer unit, making repairs as detected by the television camera.	110	55	120

Steps continued

	COSTS ($)		
	Labor	Equip-ment	Mater-ials
8. Remove equipment from the building sewer.	40		
9. Flush the building sewer to remove excess sealing materials.	20	5	
10. Remove the tow line from the down-stream manhole of the street sewer.	10		
11. Reclean the street sewer.	30	15	
Subtotal	$440	$145	$120
TOTAL COSTS			
a. without excavation			$705
b. if excavation required			Up to $1615

Note: Cost estimated as $6.60/kg ($3/lb) material
Average labor cost $20/hr (includes supervision)

The costs shown above do not reflect many of the difficulty factors that can be encountered when repairing building sewers. As an example, there are no allowances for difficult site access and excavation dewatering, etc. It is also assumed that the street sewer size would range from 20 to 30 cm (8 to 12 in.). Shown in Table 4 is a range of costs that could be encountered when repairing building sewers with the methods described.

Table 4

Range of Costs for Repair of Building Sewers

Method	Cost Range (1980)
Pump Full Method	$765 - $1615
Sewer Sausage Method	$610 - $1510
Camera Packer Method	$705 - $1615

NEW CONCEPTS

Two concepts for the sealing of building sewers are presented, each concept is different with regards to the development required. One concept utilizes existing sealing materials, but requires the development of mechanical capability. The other concept is based on the use of existing mechanical equipment, but requires the development of suitable sealing material. Both concepts have the singular objective of avoiding the primary disadvantage of existing methods for sealing of building sewers; namely, the necessity of gaining access to the building sewer by excavation either at the property line or at the structure being served. The following describes these two concepts in general terms as specific details would be determined during development.

1. Building Sewer Joint Sealing (Figure 8) - This method is based on using existing sealing materials to seal faulty pipe joints within the building sewer and without the need for surface access to the building sewer. Envisioned with this method is a device of a cylindrical shape (1) that could be pulled through the existing street sewer (6) to the location of the building sewer connection (7) as viewed by a television camera. Once in place, shoes (2) on either end of the device would expand to the wall of the pipe (6) to hold the device in place. The center barrel of the device (1) would be rotated to orient the chute (3) for the self-powered tractor (4) and sealing packer (5) opposite the building sewer opening. The tractor (4) would travel along the chute (3) and into the building sewer (7) pulling the sealing packer (5) with it. Once in the building sewer, the sealing packer (5) would be stopped at predetermined intervals and the pipe tested and sealed if necessary.

2. Building Sewer Exfiltration Sealing (Figure 9) - Based on the use of existing equipment, this concept also does not require excavations to be made for the purpose of providing access into the building sewer. Rather, it would involve the pulling of a standard sealing packer device (1) into the street sewer (3) and locating it so that the center is adjacent to the building sewer opening (4) as viewed by a television camera. Once in place, the end elements (5) of the packer would be inflated to isolate the building sewer (4) from the remainder of the street sewer (3). Then the first component of a staged chemical sealant would be injected through the injection ports (2) and up the building sewer (4). After sufficient time to allow the sealant to migrate through each of the pipe faults into the surrounding soil areas had elapsed, the packer and elements (5) would be deflated and the excess material allowed to flow out of the building sewer (4). The end elements (5) would be reinflated and the second stage of the chemical system would be injected in the same manner as the first stage. The second stage material would be held in place for sufficient time to insure proper chemical curing. After cure the packer end elements (5) would be deflated and the sealing operation would be complete.

An estimate of the developmental cost of either system is beyond the resources of this study. The key elements of a cost effective system appear to be:

1. Use of minimum amount of material.

2. Achieve access to the building sewer from street sewer for a distance of 20 to 60 m (60 to 180 ft).

3. Equipment able to rise almost vertically and make a 90° bend.

4. Equipment able to enter building sewer from any angle from the vertical and from flow direction.

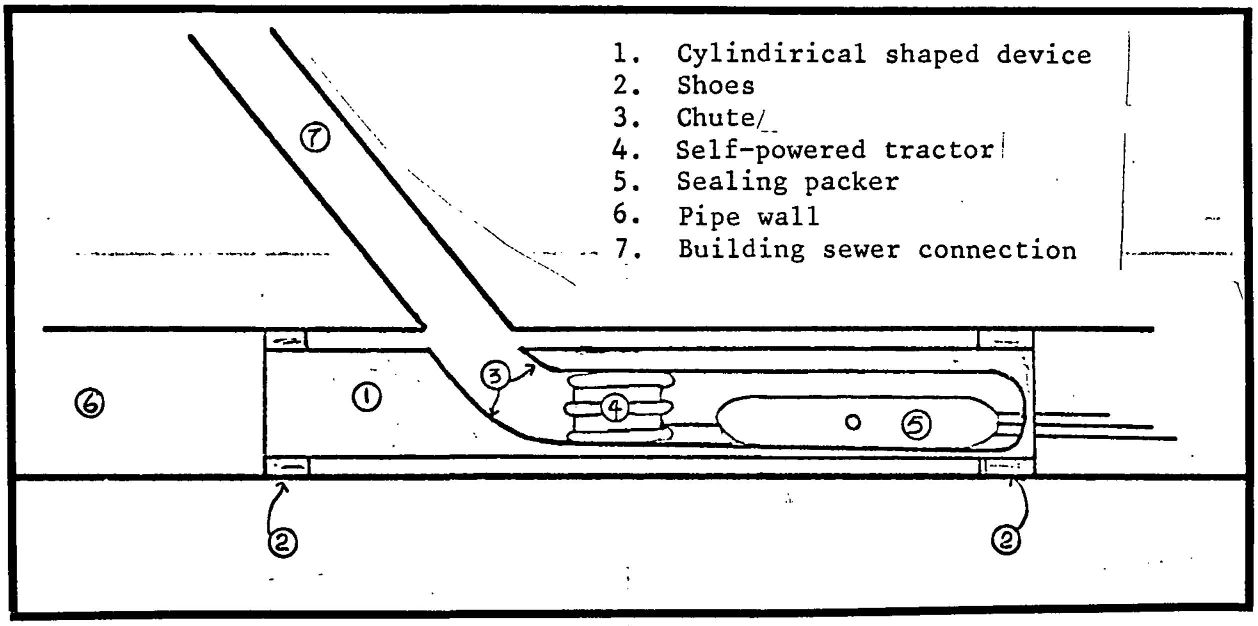


Figure 8 Building Sewer Joint Sealing — Concept

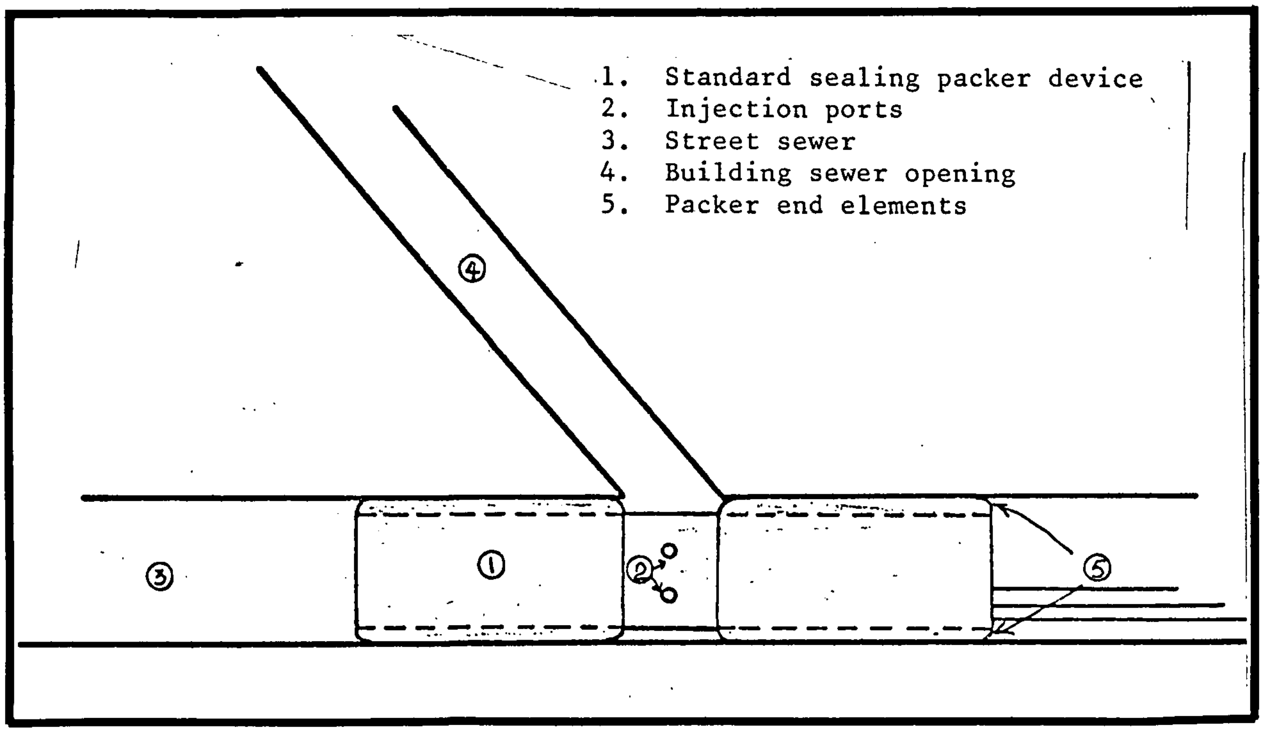


Figure 9 Building Sewer Exfiltration Sealing — Concept

5. Equipment able to go from 20 cm (8 in.) street sewer to 10 to 15 cm (4 to 6 in.) diameter building sewer.

Television cameras have been developed of a diameter small enough to enter a building sewer. However, their length may preclude traversing the abrupt vertical angle in the pipe. Radar technology is available for inspecting water coolant pipes in nuclear reactors, and the use of such equipment might provide a suitable alternate for visual inspection.

The Insituform Method

Limited experience has recently been gained with a building sewer lining method to eliminate infiltration. The Insituform method of lining building sewers not only eliminates infiltration, but provides a degree of renewed structural integrity to the existing pipe. The Insituform method introduces, via inversion, a 3 mm thick polyurethane coated polyester liner which is saturated with a thermal setting, dual catalyzed isothalic resin. This method requires an entry point at the property line. The liner is then inverted through the building sewer and is terminated upon its entry into the the main line. The water used for inversion is then connected to a heat exchange unit which will heat the water in the liner to approximately 71° C (160° F). The thermal setting resin cures and the once pliable liner becomes a structurally sound continuous, i.e., no joints, pipe. The end of the liner is opened by excavation or via a remotely controlled cutting device placed in the main line; the hookup at the property line is completed; the excavation pit backfilled and service to the building sewer is restored.

The Insituform method has been used on main line sewers in Europe for the last 10 years. Now the same principles are being applied to rehabilitation of small diameter building sewers.

The steps and costs are described in Table 5.

Table 5

Insituform Method[1]

Steps		Costs
1.	Locate building sewer at the property line	$ 10
2.	Remove one length of pipe from building sewer	10
3.	Clean the building sewer	30
4.	Televise the building sewer	30
5.	Materials: chemicals, liner material, special equipment	1,250
6.	Cut open liner at main sewer via remote control cutter	150
7.	Labor: TV, cleaning, liner saturation and lining[3]	300
8.	Replace section of building sewer	30
	Total Costs:	
	a. Without excavation	$1,810[2]
	b. If excavation required	$2,710

(1) All costs based on a 10 cm (4 in.) diameter line, 12 m (40 ft) long and located 1.5 to 2.1 m (5 to 7ft) below a grassy surface at the property line. Also, the main line and the building sewer to be lined has no sharp turns nor does it enter the main line via a stack.

(2) This price is based on Insituform's best estimates. Insituform is presently entering into a building sewer lining program and feels this price can be lowered with on-job experience; also daily production volume will lower the price as well. The above price is based on a one line a day production.

(3) Average labor cost $20/hr (includes supervision).

SECTION VI

GLOSSARY OF PERTINENT TERMS

Bench Level Testing - A series of tests which might be conducted by the manufacturer, applicator or owner to screen or evaluate the characteristics of a product prior to additional testing.

Building Sewer - also house lateral, house connection, or house service line. The portion of the sewer system which connects the building to the collector sewer in the public right-of-way. The building sewer is usually of small diameter, on both public and private property and may be laid with rather abrupt changes in grade. Access to the bulidng sewer from the overlaying ground surface usually is not available without excavation.

Existing Equipment - All equipment owned by the private and public sector used for the internal sealing of small diameter sewers. Such equipment may have been fabricated by a major manufacturer of equipment or assembled from separately purchased components by the owner. The equipment may or may not be in regular use at this time and may be limited to use with only one type of chemical system.

Infiltration - The flow of groundwater into a sewer through open joints, cracks or other defects in the sewer pipe or its appurtenances.

Retrofit Cost - A cost to convert an existing internal sewer sealing equipment unit to allow the use of a different chemical system. The minimum retrofit cost becomes the cost of such retrofitting with consideration of the cost of the amount of chemical required to effect a seal, and the cost of manpower and equipment to achieve the seal, all compared to the cost of sealing with the chemical system for which the equipment was designed.

Sewer Sealant - A chemical system which can be applied with appropriate equipment to internally stop the infiltration of groundwater into joints of sewers.

Soil Box Tests - A series of tests conducted to evaluate a sewer sealant under controlled laboratory tests prior to field testing. Such tests allow rapid evaluation of its ability to handle the chemicals and to effect a seal under various soil bedding and hydrostatic head conditions.

SECTION VII

REFERENCES

1. American Public Works Association, "Control of Infiltration and Inflow into Sewer Systems," 11022EFF12/70, U.S. Environmental Protection Agency, NTIS PB 200 827, 1970.

2. Sullivan, R., et al, "Sewer System Evaluation, Rehabilitation and New Construction," EPA-600/2-77-017d, U.S. Environmental Protection Agency, NTIS PB 279 248, 1978.

3. The Western Company, "Improved Sealants for Infiltration Control," 11020DIH06/69, U. S. Environmental Protection Agency, NTIS PB 185 951, 1969.

4. Conklin, Gerard F., "Evaluation of Infiltration/Inflow Program - EPA Project 68-01-4913, U.S. Environmental Protection Agency, Municipal Construction Division, Washington, D.C., July 1980.

SECTION VIII

APPENDIX

List of Presently Available or Announced Chemical Systems of Internal Sealing of Small Diameter Sewers

	Trade Name	Base	Manufacturer/Supplier
1.	AV-100	acrylamide monomer	Avanti, International Houston, Texas
2.	AC-400	organic monomer	Geochemical Corporation Ridgewood, New Jersey
3.	Chem G-9	acrylamide monomer	Polymer Corporation Ft. Lauderdale, Florida
4.	CR-202	urethane foam	Minnesota Mining and Manufacturing (3M) St. Paul, Minnesota
5.	CR-250	urethane	Minnesota Mining and Manufacturing 3M) St. Paul, Minnesota
6.	Injectite-80	poly-acrylamide	Cues, Incorporated Orlando, Florida
7.	Q-Seal	acrylamide monomer	Cues, Incorporated Orlando, Florida