Man-Entry Applications ◆ Hydraulic Performance ◆ Design Considerations ◆ Structural Testing

danby PIPE RENOVATION ™

# Technical Data

## Man-Entry Pipe Renovation Systems


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# The Danby Pipe Renovation System
**for**
**Man-Entry Pipes, Manholes and Other Conduits**

## General

The Danby Pipe Renovation System has proven to be a very cost effective method of insitu lining (liner is manufactured in the host structure). The basic material used (PVC) is readily available and relatively low cost; also, it is delivered to the job site in standard form with little or no customization either in its design or manufacture. Grouting of the annulus between the liner and the old pipe is an important and integral part of the Danby process in all applications. Annulus grouting not only provides important structural properties, but also will produce some level of repair to the old pipe by filling cracks and voids. The effect of diameter reduction on hydraulic capacity is offset in most cases by the lowering of the hydraulic flow resistance of the new composite structure (PVC liner-grout-pipe).

The Danby Pipe Renovation System has the advantages of minimizing loss of internal pipe diameter, structurally improving the old pipe, and protecting it from further degradation. The PVC liner is impervious to hydrogen sulfide and many other corrosive substances and has passed the City of Los Angeles' "pickle jar" tests. The Danby Pipe Renovation System has been approved for inclusion since 1991 in the Southern California *Standard Specifications for Public Works Construction*, better known as the *"Green Book"*.

## Man-Entry Applications

Danby Panel Lok, which is used in a variety of man-entry applications, is simply ribbed plastic panels which are placed inside a pipe and locked together on the edges to form a continuous liner. The PVC panels incorporate male and corresponding female double locking edges. The edges form a circumferential joint which is simply snapped together by a smaller joiner strip. The joiner strip utilizes a flexible polymer co-extrusion to make the joint gas and water tight. Both the panels and joiner strips are manufactured from rigid PVC. Panel Lok is extruded in 12 in. (300 mm) widths with an overall profile heights of either 0.5 or 1.0 inches. The panels and joiner strip are light and easily handled and can be passed through a narrow opening or manhole, therefore, there is no need for excavation. Installation is quick and simple.

In 360° lining applications, Panel Lok is normally supplied to the job site in 200 or 300 foot coils. In these applications, Panel Lok is spirally wound into a liner from the coils of PVC strip. In partial lining applications, the panels are delivered to the job site in specified pre-cut lengths from the factory. The panels incorporate outer ribs and the inside surface is smooth. The ribs, when curved to the contours of the pipe, impart a hoop strength which supports the liner in place. Another feature of these ribs is that they provide a mechanical anchor for the PVC liner as the annular gap is filled with suitable grouts. In man-entry pipes, practically all of the annulus can be expected to be filled by the grout and almost any type of grout can be used. This allows greater freedom of design to address structural problems, including the possibility of adding steel reinforcing rods or wire mesh. Panel Lok has been successfully installed in a variety of applications including circular (360°), circular partial lining (270°, 240°, etc.), oval, and egg-shaped lines, as well as box structures, manholes, and wet wells.

## Hydraulic Performance

The hydraulic performance of the pipe may be significantly improved as the PVC panels generally can be placed close to the existing surface resulting in a minimum loss of diameter while providing a smoother surface to the flow. For example, a 54" RCP lined with Danby may result in a finished internal diameter of 52" and would have a theoretical flow capacity of 136% of the original RCP line. In pipe diameters 78 inches and larger the 1.0 inch

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profile height Panel Lok is recommended. Typical diameter loss is about 4 inches resulting in increases of flow capacities of 130 - 140%.

**Relative Flow Capacity (Q1/Q2)**
(% of Original Pipe Capacity)

| D1/D2 | Q1/Q2 |
|---|---|
| 1.00 | 150 |
| 0.95 | 131 |
| 0.90 | 113 |
| 0.85 | 97 |

Q1/Q2 = (n2/n1)*(D1/D2)^8/3; assumes S1 = S2
n1 = 0.01 (PVC Liner), n2 = 0.015 (cement or brick)
D1 = diameter of liner, D2 = diameter of original pipe

## Design Considerations

With proper planning and execution, the grouting of the Danby Liner can be accomplished without damage to the liner. The second significant design consideration with the Danby Pipe Renovation System is concerned with the strength of the composite structure after the grout has set and its ability to withstand expected loads while in service. Although small, isolated grout voids will not significantly affect the load carrying capacity of the composite structure (PVC liner-grout-pipe), it must be assumed that these ungrouted PVC arches will be exposed to any ground water present and must be capable of withstanding such hydrostatic pressure. Hydrostatic pressure load tests (NCSU, 1989) on the grouted Danby Liner with several different percent voids have shown good agreement with the following equation (Timoshenko and Gere, 1961) for critical buckling strength of the ungrouted arch whose half-angle is ø:

$$Pc = \frac{8EI}{D^3}(k^2-1) \quad psi$$

$$\text{Sin } k\text{ø Cos ø} = k \text{ Sin ø Cos } k\text{ø}$$

Where k is found by iteration for given value of ø.

**Long Term**
**Critical Buckling Pressure**
**For Ungrouted Arch**

| *Internal Diameter* Unlined (inches) | Danby Lined (inches) | *Pc* Panel Lok (psi) |
|---|---|---|
| 42 | 40 | 44 |
| 48 | 46 | 39 |
| 54 | 52 | 34 |
| 60 | 58 | 31 |
| 66 | 64 | 28 |
| 72 | 70 | 26 |
| 78 | 74 | 97 |
| 84 | 80 | 88 |
| 90 | 86 | 80 |
| 96 | 92 | 72 |

*NOTES:*
(1) Includes safety factor = 2.0;
(2) E (long term) = 200,000 psi; I = 0.004 in4/in;
(3) Assumes 6 inch grout void in all diameters.
(4) For ID ≥ 78", I = 0.015 in4/in

For man-entry pipes (≥36"), 100% grout fill can be accomplished in the annulus due to the ease of access to multiple grout injection points. Obviously, the structural characteristics of the composite structure (PVC liner-grout-pipe) will depend primarily on the character of the grout. Fortunately, due to the ease of access to multiple grout injection points, most any grouting material appropriate can be used without undue restrictions due to flow characteristics.

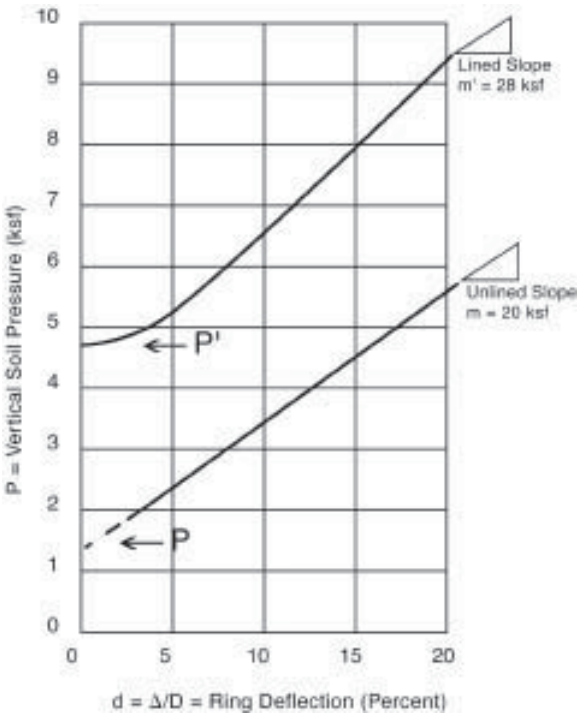
Where appropriate, high strength cementious grout or light-weight foam grouts can be used with compressive strengths of 8,000 psi down to 150 psi and with Young's moduli of 4,000,000 psi down to 300,000 psi respectively. Although the benefits are difficult to quantify, the grouting also will tend to fill holes and cracks in the old pipe (fill in where bricks and mortar are missing in brick lines) and generally rehabilitate the existing structure while "tying" the liner to the old pipe, and adding load-carrying wall thickness of similar material in rigid pipes. The composite structure is a rigid structure and should be designed using rigid pipe design principles.

## Structural Testing

Tests in the Large Soil Cell Laboratory at Utah State University (USU, 1993) showed that a 27" ID Danby Liner with grout of compressive strength of 8,600 psf improved the zero deflection load capacity of a fully deteriorated (broken by 4 longtitudinal cracks) of 30" unreinforced concrete pipe by over 3,000 psf (4,600 psf vs. 1,500 psf).

**Effects of Danby Liner**

Increase in Strength at d = 0, P' - P = 3,100 psf
Increase in Stiffness—Ratio of Slopes = m'/m = 1.4




**Load Deflection Data for Lined and Unlined Pipes**

In a more standard test for rigid pipes, the Danby Pipe Renovation System was subjected to D-Load (three edge bearing) testing supervised by the County Sanitation Districts of Los Angeles County (Rialto, 1993). These tests were conducted on old 24" RCP which had been salvaged when it was replaced. The upper half (approximately) of the pipe circumference was corroded away by 1.25"—1.50" of the original 3" wall thickness. One 4 foot section was lined with a 21" liner covering the full (360°) circumference. A second 4 foot section was lined over 270° (90° at the invert was not lined) resulting in a vertical diameter of 23" and a horizontal diameter of 22". The D-Load strength of the full (360°) Danby lined pipe was 2.17 times that of the unlined mating 4 foot section which was cut from the same original 8 foot pipe. The partial (270°) liner was 1.93 times as strong as its unlined mate.

## Summary

Use of the Danby Pipe Renovation System produces a renovated pipe which is a layered composite of PVC liner, cementious grout, and the original pipe. The combination of the ribbed profile on the PVC liner and the very fluid nature of the grout produces a highly integrated structure with the PVC liner "tied" to the original pipe through the grout which, in addition, provides additional load carrying capacity as well as some direct repair of the old pipe. For man-entry pipes, the structural strength of the renovated pipe is determined almost entirely by the grout characteristics and, of course, the condition of the old pipe. In this case, a wide range of design options are applicable to reinstating the structural integrity of the line. The cost effectiveness and functional advantages of the Danby Pipe Renovation System tend to increase with increased diameter. Design for structural repair is project specific following rigid pipe design practice.

The Danby Pipe Renovation System has been approved for use in major markets throughout North America, including the City and County of Los Angeles, City of San Jose (Calif.), the Greater Houston Wastewater Program, and the Washington (D.C.) Suburban Sanitary Commission (WSSC).

For more information on the Danby Pipe Renovation System or details on the tests referenced herein please contact: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