Office of Water Programs
California State University Sacramento
Sacramento County Sanitation District No. 1

Energy Requirements for the Manufacture of Piping Materials Vitrified Clay Pipe (VCP) and Polyvinyl Chloride (PVC): A Comparison

Final Report

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Introduction

The Sacramento County Sanitation District No. 1 (CSD-1) is considering revising the engineering design standards in its new trunk sewer design manual to include allowed use of polyvinyl chloride (PVC) sewer pipes. Historically, CSD-1 has specified exclusive use of vitrified clay pipe (VCP) for small diameter sewer piping applications. Inclusion of PVC pipe is being considered to allow designer selection of the piping material best suited for each application and to limit market restrictions that can be caused by reliance on one type of piping material.

Prior to including a new piping material into its infrastructure design standards, CSD-1 staff felt it prudent to investigate issues related to PVC piping manufacture and use.

Those issues are:

1. Engineering sustainability of PVC pipe in sanitary sewer applications.
2. Comparison of energy requirements to manufacture VCP and PVC pipe.
3. Generation of toxicants in the manufacture, use, and destruction of VCP and PVC pipe.

CSD-1 staff contracted with the Office of Water Programs, California State University, Sacramento to conduct an independent literature study of the three issues listed above. The report describing the results of the study of manufacturing energy requirements follows.

Background

California's energy crisis in 1999-2000 raised awareness of energy demands for all activities. Agencies, both public and private, are taking a new look at the energy implications of all decisions. Consistent with that awareness, CSD-1 staff has been tasked with investigating the energy demands associated with the use of VCP and PVC sewer pipe. Associated energy demands result from raw material acquisition, pipe manufacturing, and transportation of the finished product to the job site.

CSD-1 staff asked the trade organizations for piping material manufacturers to provide technical information about the energy requirements for manufacturing their respective pipe materials. This report describes the evaluation of the supplied technical information, provides a comparison of the energy requirements for manufacturing and delivering VCP and PVC pipe, and discusses the strengths and weaknesses of the evaluation and of using energy requirements as a basis for selecting pipe materials.

Evaluation of technical materials

The National Clay Pipe Institute and Uni-Bell PVC Pipe Association provided technical materials to CSD-1 staff reporting the results of previous studies of the energy requirements for manufacturing VCP and PVC pipe. Both organizations' reports were conducted in the 1970s and resulted from studies conducted in response to the energy crises induced by the Arab oil embargo and subsequent OPEC oil price controls during that period. Although the reports and studies are dated, they represent the latest investigations into the energy requirements for manufacturing VCP and PVC piping materials and remain applicable to current manufacturing processes.

VCP – The National Clay Pipe Institute (NCPI) provided a report of a VCP manufacturing energy study conducted by the Illinois Institute of Technology Research Institute, an independent research university center. The NCPI funded the study in 1979.

Clay pipe is manufactured in several sizes ranging from 4 inches to 42 inches in diameter. Eight inch diameter sewer pipe was selected for the study because it is the predominant manufactured size, constituting 40 to 50 percent of the pipe manufactured for sanitary sewer use. Three pipe manufacturing plants were included in the study, which provided a variety of regional locations and environments, plant ages (from 10 years to over 30 years), and ambient temperatures.

The energy study included all processes from mining of raw materials to completion of finished pipe product at the manufacturer's plant. Approaches and measurement techniques were well defined and well described. The total energy consumption ranged from 70,600 to 81,600 BTU/L.F. of 8" pipe, with an average value of 77,685 BTU/L.F. for the three manufacturing facilities (L.F. = lineal foot).

PVC – Uni-Bell provided five documents describing various studies conducted to measure the energy requirements to manufacture various PVC products, including sewer pipe. For the purposes of this evaluation, the portions of the studies applicable to 8" diameter sewer pipe were used.

It appears that all of the studies were conducted by the Research and Development Department of Ethyl Corporation, Baton Rouge, LA. The reports are addressed to Uni- Bell PVC Pipe Association, so it is assumed that the studies were sponsored by Uni-Bell. Energy utilization measurement approaches and techniques are not well described in the reports and references are made to earlier reports, which were not provided to CSD-1.

Energy utilization for 8" PVC sewer pipe is reported to include all processes from acquisition of raw materials to delivery of the finished product to distribution locations. The reported total energy consumption for 8" PVC sewer pipe production and delivery is 144,960 BTU/L.F.

Discussion

Evaluation of the reports provided to CSD-1 by the trade organizations representing manufacturers of VCP and PVC sewer pipe indicate that energy demands for producing PVC sewer pipe are about 86 percent higher than for producing clay sewer pipe, a significant difference. Faced with such a large difference in production costs for products that are price competitive, it is prudent to further evaluate the source reports to assess the equivalency of the basis of study for each product to better assess the validity of the reported values.

A good first step in assessing the validity of the provided reports is to evaluate the original purpose for conducting the studies to try to infer potential for bias. For example, studies conducted for marketing purposes would be viewed much more skeptically than studies conducted to assess internal industry efficiencies. In the first case the intent of the study would be to convince customers to purchase a product, whereas in the latter case the study purpose would be to assess process efficiencies and the intended audience would be internal to the industry.

The reports provided to CSD-1 by each industry group were originally intended as internal documents. Each reported study was commissioned to assess product manufacturing energy demands during a period of national energy shortages. It is reasonable to assume, therefore, that the results are accurate and reported without bias.

The next step is to assess the equivalency of the studies to validate comparison of the reported energy utilization values from each report. Both studies purport to include all energy utilized to acquire raw materials, manufacture a finished product, and deliver the finished product to a location. There are differences in the levels of detail in the reports that make it difficult to assess their equivalency. Whereas the measured energy components are well documented in the NCPI report, the Uni-Bell reports lack detail.

The lack of detail in the Uni-Bell reports make it difficult to assess the equivalency of the reported energy demand for acquiring raw materials. Naphtha, a byproduct of crude oil refining, is used to make ethylene, a primary component in PVC pipe manufacture. The Uni-Bell reports cite the inclusion of energy to acquire the raw materials, ethylene, chlorine, and oxygen, but do not provide enough detail to determine if the energy accounting includes crude oil extraction and transportation or if the accounting starts with refining. For the purposes of this evaluation, it will be assumed that the reported energy requirements for raw material acquisition and transportation include acquisition at the source (i.e. crude oil extraction). It must be pointed out that this is an assumption and, if incorrect, would imply that energy requirements for PVC pipe manufacture are higher than reported. The energy values for PVC pipe production provided by Uni-Bell were found to be consistent with data reported in the literature (References 8, 9).

Another component of equivalency is transportation energy cost for final product delivery. The PVC studies included a transportation energy component for delivery to a distribution point. Distribution points were not defined in the reports and it will be assumed for this evaluation that the distribution point is close to the point of use. A transportation energy component for finished product delivery was not included in the NCPI report for clay pipe, so one was determined for this evaluation. The energy required to transport 8” sewer pipe from the Gladding McBean production facility in Lincoln, CA to Sacramento is 464 BTU/L.F., which increases the total energy utilization for clay pipe to 78,149 BTU/L.F. (see appendix for calculations), an increase of less than one percent.

After assessing the information contained in all provided reports and adding one component to the clay pipe energy values for equivalency, it can be concluded that clay sewer pipe manufacturing requires significantly lower energy utilization than does PVC sewer pipe. It should be pointed out that the clay pipe numbers are disputed in some of the Uni-Bell reports. However, in our evaluation of the NCPI report, we can find no merit for the disputes.

One additional topic merits discussion in this evaluation of manufacturing energy requirements for sewer pipe, the importance of its consideration when deciding on an infrastructure product. Energy is an important topic in California now. Recent power shortages have increased conservation awareness and prompted organizations to consider energy requirements when making purchasing decisions.

Although manufacturing energy demand is a factor to be considered when deciding which piping products qualify to be part of a community’s infrastructure, there are other factors with greater importance. It is important to note that sewer pipe is expected to remain serviceable for about 100 years. Therefore, although manufacturing energy demand may have immediate importance, engineering sustainability of pipe is a much more important decision factor. Piping with lower engineering sustainability will require greater energy expenditure over the life of the pipe with increased maintenance demands and accelerated replacement requirements. Therefore, a purchasing decision based on lower manufacturing energy requirements could result in greater energy demands throughout the service life of the pipe.

Another issue is positioning to benefit from competition. By CSD-1 qualifying more than one piping material, manufacturers will be forced to compete with rival products to sell materials. In that environment, if one product is more energy intensive to produce, that will be reflected in its cost and will preclude it from being selected. To be competitive, each industry will be forced to improve efficiencies. End users will benefit from the competition as manufacturers endeavor to improve products and reduce costs. Conversely, by qualifying only one product, end users subject themselves to a monopolistic economic environment, which rarely provides cost, quality, or supply benefits.

Conclusions

1. The reports provided to CSD-1 by industry trade organizations provide valid information about the energy requirements for manufacturing 8” sewer pipe.
2. With interpretation, a few reasonable assumptions, and calculation of one additional energy demand, the provided reports allow for equitable comparison of the energy requirements for production of VCP and PVC sewer pipe.
3. The energy requirements to produce 8” sewer pipe and deliver it close to the point of use are 78,149 BTU/L.F. for vitrified clay pipe (VCP) and 144,960 BTU/L.F. for PVC pipe.
4. Given that sewer pipes should remain serviceable for about 100 years, engineering sustainability is a far more important piping material selection criteria than manufacturing energy demand.
5. CSD-1 will benefit from improvements in quality, cost, and availability resulting from competition by qualifying more than one piping material for use in its service area.

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Appendix

Calculation of energy requirements to transport 8" vitrified clay pipe (VCP) from manufacturing plant to point of use.

Assumptions:

1. Manufacturing plant is Gladding McBean in Lincoln, CA.
2. Point of use is downtown Sacramento (distance 30 miles).
3. One truck load contains 1,600 L.F. of 8" VCP (Kay Licuanan, Gladding McBean Co., Lincoln, CA, by phone, 1/16/02)
4. Heavy duty truck fuel economy is 5.6 MPG (Reference # 7)
5. One gallon of diesel fuel = 138,700 BTU (Reference # 1)

Calculations:

$$\left[\frac{\text{1 truckload}}{\text{1,600 L.F. VCP}}\right]\left[\frac{\text{30 mi.}}{\text{truckload}}\right]\left[\frac{\text{1gal. diesel}}{\text{5.6 mi.}}\right]\left[\frac{\text{138,700 BTU}}{\text{gal. diesel}}\right] = \boxed{464\ \frac{\text{BTU}}{\text{L.F.VCP}}}$$