Smart Choices for Composite Manhole Covers

Since 1984, thirty composite manhole cover products have been introduced to the petroleum market. The Young Group's James E.

The technology of composite manhole covers has advanced so far that customers now have legitimate alternatives to steel manhole covers in certain applications.

Composite manhole covers were introduced into the marketplace for petroleum service applications in 1984. Since then, total worldwide sales of composite manhole covers have not exceeded the number of steel manhole covers sold each year, but that is about to change. This article provides an analytical framework for evaluating steel and composite manhole covers and deciding on the best alternatives for given uses.

Uncle Sam's research pays off

Research on composite materials by, or for, the US military dates back to the 1960s and has led to today's use of composite materials in the transportation and recreational vehicle industries, as well as in the construction of highway bridges and other structures. To replace metal materials for these applications, the composite material has to be lighter and at least as strong.

The petroleum industry has benefited from the development of composite materials, using them in pipes, valves, fittings, underground tanks, manhole covers and other components. The plastics companies that created the original market for plastic moldings have given composite manhole cover manufacturers access to the resin-transfer-molding technology.

Since 1984, approximately 30 different designs of composite manhole covers have been introduced to the petroleum marketing industry. At least half were not successful, and others had to be redesigned and changed. Today, there are a number of different composite manhole covers on the market that have stood the test of time. How do you tell the good ones from the not-so-good ones? How do you select the one that best meets your needs at the lowest cost? Would a steel manhole cover still be the best choice for your situation?

Safety and efficiency

Two important considerations in assessing manhole covers are their safety and efficiency. The safety and efficiency of manhole covers in the petroleum marketing industry are controlled by three critical

design characteristics:

Strength—Stresses resulting from vehicle traffic loading should not exceed the design strength of the manhole cover.

Flatness—Every time the vehicle loading weight approaches or exceeds the manhole cover's design strength, the material "yields." This can cause the center of the manhole cover to be permanently "dished," or to incur what engineers call "permanent set." Each instance of similar loading results in further permanent center dishing, which can exceed safe levels. I discuss how to determine an unsafe condition later in this article.

Weight—If the cover is too heavy for one person to remove and reposition easily, maintenance and other tasks requiring access to the manhole can become inefficient and unsafe.

Finding out the weight of a manhole cover and deciding what weight would be most suitable for your purposes is relatively easy. But what standards or criteria are there for evaluating whether a given manhole cover is strong enough to hold up under the vehicle loading weight (see Figure 1) without failing or permanently dishing?

Figure 1: Manhole covers must hold up under weight exerted by each set of dual-tire wheels that run over them. Courtesy of EBW, Inc.

Searching out the standards

There are no clearly established rules, regulations or standards in the US governing the manufacture of manhole covers used in petroleum marketing as such. But, as discussed in detail in a previous article I wrote for PE&T, there are some general standards in the US and some more specific standards in Europe that provide guidance on the performance and safety of manhole covers (see "What Makes Steel Manhole Covers Unsafe?," Feb. 1999, p. 27). In my opinion, these standards should be used carefully as a guide in the design of manhole covers. By the same token, the standards provide sound criteria for deciding which manhole covers to purchase.

In the US, Standards Specifications for Highway Bridges, published by the American Association of State Highway and Transportation Officials, details the criteria for highway traffic loading situations. That publication cites another document which should also be consulted: United States Federal Specification RR-F-621 (frames, covers, gratings, steps, sumps and catch-basin manholes). Together, these two documents provide loading criteria that should be used in the design of manhole covers and in evaluating whether the criteria have been met.

Under that criteria, the maximum legal axle load on US highways is 32,000 pounds, or 16,000 pounds for each set of dual-tire wheels. This means that every manhole cover subject to truck traffic must be designed to withstand up to 16,000 pounds of loading. The US criteria do not include an allowance for permanent center deflection from such loading. This is because the US standard was written with only cast-iron manhole covers in mind. Cast-iron manhole covers crack and fail once the loading exceeds their load design limit, and as a consequence, permanent center deflection is not an issue. In the case

of steel and composite manhole covers, permanent center deflection can occur even though the cover does not crack or fail under loading. As discussed in the following paragraph, the European standard includes criteria not only for total loading weight, but also for maximum permanent center deflection.

In Europe, standards for manhole covers are more clearly established than in the US, but still require careful application. European standard BS EN 124:1994 covers design requirements, type testing, marking and quality control for gully tops and manhole tops for vehicular and pedestrian areas. This standard recognizes that different designs and materials are used to make manhole covers. The standard defines six classes from which to choose the weight loading requirement; it is the responsibility of the designer to select the appropriate class for manhole covers used in the petroleum marketing industry.

According to European officials, classification “B125” is the appropriate classification under the standard for manhole covers at petroleum service stations. B125 calls for test loading of 18,827 pounds, five different times for 30 seconds each. After each such loading, the permanent deflection of the geometric center of the manhole cover is measured (see Diagram A). The European standard limits acceptable permanent center deflection to 1/100 of the cover’s diameter. For a 39.5-inch diameter manhole cover, this would be 0.395 inches.

The European standard is now under review, but no date is set for revisions. Even though some manufacturer literature indicates that the standard has been modified, a British Standards Institution official advised me by letter about two months ago that this was not the case. Although some composite manhole covers are being designed to a specification under which the loading weight is twice the 18,827 pounds called for under classification B125 of the European standard, British officials—as stated above—advise that B125 is the appropriate classification for service station applications.

I do not believe that future changes in the 1994 standard will include changes in loading requirements for manhole covers. Vehicle weight limits allowed on roadways probably will not change. I believe that the testing procedure in the 1994 standard for classification B125 is fair and should continue to be used. Among other benefits, conformance to the standard improves the safety of manhole covers.

Safety and the dishing problem

As explained above, the European standard provides guidance both to the manhole cover designer and purchaser—guidance that can be used in determining loading requirements based on the application, testing loads and design limits for strength and flatness. Once a manhole cover suffers permanent center deflection or dishing, it begins to “rattle” or “rock” in its skirt rim each time an automobile drives over it. Once the permanent center deflection exceeds 1/100 of the diameter, the cover can flip when it is driven over, or the outside edge can protrude above ground level, causing an

unsafe condition. Diagram B illustrates a safe (flat) manhole cover and an unsafe (dished) manhole cover.

Materials and technology

Resin-transfer molding is an effective technique for producing composite manhole covers. The technique produces continuous-fiber reinforced, high-strength composite designs. This process works as follows:

• Woven glass fibers are positioned on an open
"first-half" mold for the manhole cover.
• A matching "second-half" mold is mated to the first-half mold and the two halves are clamped together.
• A catalyzed resin mix, specifically designed for this product's application, is pumped into the cavity.
• A chemical reaction takes place, which causes hundreds of degrees of heating to occur. After a suitable waiting time for the material to cure, the manhole cover is removed from the mold. Two good sur- faces—the cover's top-side and under-side— are created.

The glass fiber material, the configuration of the woven fibers, the polyester resin, the mold quality and the quality controls to be used in the molding process are determined during the product design phase (see Figure 2). The molding process itself is closely monitored and controlled to ensure product consistency and integrity.

Continuous "outside" (independent) testing of the manhole covers should take place to ensure that the covers perform as designed. Composite materials do not behave in a linear manner, and the molding process does not guarantee a predictable performance pattern. This means the user must have access to outside laboratory test results to confirm that the covers being purchased will perform as advertised.

Also, the composite materials are sensitive to significant changes in temperature in the region where the manhole cover is installed. In earlier test work, I found that low temperatures (16Þ F and less) reduce overall composite manhole cover strength by as much as 15 percent. Sustained high temperatures (above 140Þ F) reduce strength by as much as 30 percent. Also, low and high temperature ranges increase the potential for product chipping or delaminating. Steel manhole covers, on the other hand, behave in a linear manner and are not sensitive, strength-wise or performance-wise, to such temperature swings.

Figure 2: This cross-section drawing shows the layers of fiberglass and resin that go into the construction of composite manhole covers. Courtesy of OPW Fueling Components.

Performance testing

To provide a definitive approach to selecting manhole covers for different uses, I selected and tested several manhole covers, and obtained and analyzed the results of tests by an independent laboratory

for another manhole cover. I had already tested a number of steel manhole covers for my February 1999 PE&T article and, as you will see later, I have included in this article the results for one such steel cover—the only steel one among those selected that had met the European loading and permanent deflection criteria.

Because of the number and variety of composite manhole covers manufactured since 1984, a random or scientific approach to selecting covers for my analysis was neither practicable nor desirable. Rather, I wanted to focus on covers that had met with some success over several years. Therefore, I subjectively selected composite covers that had the following characteristics:

• Materials of construction included glass fibers, polyester resin and foam.
• Resin-transfer molding was used to produce a monolithic (one-piece) manhole cover.
• The manhole covers had a developmental or field-use history of from five to 15 years.

My selection of covers using the above characteristics does not mean that other manhole covers—produced using different technology—will not perform satisfactorily. In my judgment, however, such covers do not offer cost/performance advantages over those selected for this article.

For all but one of the manhole covers selected, I acquired test samples through normal purchasing channels and had the samples tested by an independent laboratory. For the last one, I obtained the results of testing that had already been performed by an independent laboratory. In any event, all of the testing discussed in this article was done independently, using the rigorous requirements of the European standard of subjecting the covers to a weight loading factor of at least 18,827 pounds, five times for 30 seconds each, and of measuring permanent center deflection for comparison to the maximum of 1/100 of the cover's diameter.

In all, my analysis covered five different brands or models of manhole covers, which I have identified as Cover A, Cover B (two different but very similar models), Cover C and Cover D. Additional information about the covers that were selected and the testing of the covers is presented in the next section.

Test results

The following Table shows some key characteristics of the manhole covers and summarizes the test results for each. Cover A is made of steel and the others are made of composite materials. The covers' weights vary significantly, as do their thickness. All covers tested have 39.5-inch diameters, which means that the maximum permanent center deflection (shown in the table as "No load deflection") allowable under the European standard is 0.395 inches for each cover.

As indicated in the Table, all composite covers held up without cracking or failing under loading weights of at least 20,000 pounds, thus meeting both the US standard of 16,000 pounds and the European standard of 18,827 pounds. All composite covers also met the maximum center deflection criterion of 0.395 inches for loadings to 20,000 pounds. In this regard, some interpolation of the test data is required for steel manhole Cover A. Cover A incurred 0.32 inches of permanent deflection after

17,500 pounds of loading weight and 0.48 inches after 20,000 pounds of loading weight. Interpolating, the deflection after 18,827 pounds of loading weight would be 0.400 inches, or 0.005 inches more than the European standard would allow.

Characteristics	Cover A	Cover B	Cover C	Cover D
Material	Steel	Composite	Composite	Composite
Weight (lb.)	183	60	85	66
Diameter (in.)	39.5	39.5	39.5	39.5
Thickness (in.)	0.5	1.0	1.25	3.75
Clear skirt opening (in.)	38	38	38	35.5
Loading performance				
10,000 lb.				
Load deflection	0.71	1.14	NT	NT
No-load deflection	0.03	0.17	NT	NT
12,500 lb.				
Load deflection	0.84	1.46	1.21	NT
No-load deflection	0.06	0.19	0.01	NT
15,000 lb.				
Load deflection	1.02	1.73	1.46	0.32
No-load deflection	0.18	0.23	0.05	0.00
17,500 lb.				
Load deflection	1.17	1.95	1.74	NT
No-load deflection	0.32	0.27	0.09	NT
20,000 lb.				
Load deflection	1.30	2.26	1.93	NT
No-load deflection	0.48	0.33	0.12	NT
24,000 lb.				
Load deflection	1.43 0.55	Some layers cracked before 24,000lb.	2.25	NT
No-load deflection			0.15	NT
30,000 lb.				
Load deflection	1.69	NT	2.67	0.59
No-load deflection	0.95	NT	0.19	0.08
35,000 lb.				
Load deflection	NT	NT	2.99	NT
No-load deflection	NT	NT	0.25	NT
40,000 lb.				
Load deflection	NT	NT	3.34	0.67
No-load deflection	NT	NT	0.33	0.12

NT = Cover not tested at this loading weight.

Table: Loading Performance Test Results for Selected Manhole Covers (Deflection Measurements in Inches)

The permanent deflection results for Covers B, C and D were all well under 0.395 inches after 18,827 pounds of loading weight. For Cover B, the deflection after 20,000 pounds of loading was 0.33 inches; for Cover C it was 0.33 inches after 40,000 pounds; and for Cover D, it was 0.12 inches after 40,000 pounds.

Before getting into my views on what the test results mean in terms of which cover should be selected for a given application, let's first consider the following additional facts about the covers and the tests.

Relative costs and other factors

Cost is an important consideration because there are wide price variances among the covers tested. Cover B is about twice as expensive as Cover A. Cover C costs about 30 percent more than Cover B, and Cover D costs about twice as much as Cover B. This means that using composite rather than steel manhole covers results in substantially higher cost—anywhere from twice up to four times as much—no matter which composite cover is selected.

Another important factor in selecting manhole covers is what is known as the clear skirt opening (see Figure 3). This tells you how much room there is for entering and exiting the manhole for servicing and maintenance. As shown in the Table, Covers A, B and C have 38-inch clear skirt openings and Cover D's is 35.5 inches. Other facts about the covers tested are as follows:

• **Cover A** was not tested at 35,000 or 40,000 pounds because permanent deflection had rendered it unsafe beyond 20,000 pounds of loading. Steel covers do not "fail" in the sense of cracking. Instead, they become per- manently deflected beyond the safe limit of 1/100 of their diameter.

• **Cover B,** in fairly similar versions, is avail- able from three different manufacturers in the US. Two of the three versions were included in my testing and analysis. Because some layers cracked before

24,000 pounds, it was not tested at higher weight intervals.

• **Cover C** was introduced at PEI Convex ‘99 in Toronto in October. It uses technology gained from recent advances in glass prod- ucts. The goal of using this proprietary inter woven glass fiber is to double the product strength of Cover B and minimize the chances of delamination.

• **Cover D’s** loading performance at 40,000 pounds—only 0.12 inches of permanent center deflection—negated the need to test it at lower weight intervals.

Figure 3: Construction of manhole skirt makes the clear skirt opening smaller than the manhole cover. Courtesy of EBW, Inc.

Putting the data to use

For the petroleum equipment distributor selling composite manhole covers and the end user buying them, the purchasing analysis should be the same. Because steel manhole covers are substantially less expensive than any composite manhole cover, there must be compelling reasons not to use a steel cover. Examine the following key factors in determining when to use a composite cover in place of a steel one.

• How often will the manhole cover be removed? Usually, handling any cover that weighs more than 100 pounds requires two people. As shown in the Table, a 39.5-inch steel cover weighs closer to 200 pounds, while composite covers of the same diameter weigh significantly less than 100 pounds.

• What are the advantages of a composite manhole cover over a steel manhole cover? Manufacturer claims not withstanding, I believe the most important reason to use a composite cover is their lighter weight (see Figure 4). When the manhole is positioned over equipment such as a sump, an oil-water separator or an underground component that needs frequent servicing, the cover’s weight becomes important. These are large- diameter covers. Safety and efficiency con- cerns can justify the additional cost of composite over steel manhole covers.

• Will the manhole cover be subjected to much loading? Under US and European load rating standards, 18,827 pounds of man- hole cover loading is an adequate design objective. Composite materials are tem- perature sensitive, whereas steel is not. If composite manhole covers are installed in areas where climates have either low or high temperature swings, then the loading design safety factor built into Covers C and D is required because Cover B is not strong enough. In normal temperature ranges, Cov- ers A and B will suffice unless the user requires covers that will hold up under loads of more than 18,827 or 20,000 pounds, respectively.

• What other factors are important for man- hole covers ? What about flame resistance, chemical resistance, petrol and diesel exposure and surface resistivity? Sure, they are important, but steel manhole covers meet test criteria for these factors, as do the composite manhole covers tested. So these factors are not critical to the decision.

• What level of permanent center deflection is safe? Every cover described in this article was tested independently to the rigorous requirements of the European standard. That standard limits

permanent center deflection to 1/100 of the cover's diameter after the cover is subjected to 18,827 pounds of loading. All covers tested met this criteria, and Covers C and D stayed within the criteria even after 40,000 pounds of loading.

• How do you evaluate a manhole cover's water tightness? This is a difficult question. Claims that a manhole cover is watertight should be viewed with skepticism. Several conditions must exist for this to be true. First, the manhole must be installed properly to ensure that water runs away from the manhole cover. Second, the removal and repositioning of the cover must be done carefully so that the seal is not damaged. Before the cover is put back on the manhole, the seal and rim area must be cleaned thoroughly. For Covers A, B and C, the bolts must be put back in place and tightened properly. In the case of Cover D, the seal must be reseated properly. Also, if the cover has been permanently deflected due to loading, the lack of flatness can result in the seal no longer being watertight. The user needs to check these conditions in the field on an ongoing basis to ensure water tightness for any manhole cover, steel or composite.

• Is delamination an issue for composite man- hole covers? Cover D has a long history con- firming that it does not delaminate. Cover C is not likely to delaminate under any extreme temperature ranges, because of its advanced technology and design strength. Cover B versions have delaminated on occa- sion when subjected to heavy loading in high and low temperature ranges. If the user knows that the cover will be used where such temperatures occur, Cover C or Cover D would be better choices than Cover B.

Figure 4: Light weight, "slide action" and separate upright handle of this composite manhole cover enable easy, one-person removal. Courtesy of EBW, Inc.

My personal choices

Based on my research and experience, here are my choices of manhole covers for specific situations: Cover A—This would be my choice in situations where getting the lowest price is the only important factor. Cover B—When the cover's weight and price are the important factors, this would be my choice. Cover C—This cover would be my preference when price, weight, strength (under loads at or above the 18,827 pound European standard), and climate are all important. Cover D—I would chose this cover when price is not important and minimal permanent deflection under extremely heavy loading (up to and exceeding 40,000 pounds) is desired. I have been involved in the design and manufacture of steel and composite manhole covers for years, and I hold patents in the field. From my experience and the research I have done for technical articles since 1995, one common theme is clear: the adage "a manhole is a manhole" is not true. There have long been significant price and performance differences among manhole covers. The information and analytical approach in this article is intended to help you make an informed decision on which manhole cover best suits your needs.

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