The Largest Water Tank

Many years ago, I was having lunch with a sales engineer for a steel fabricating company. I asked if he would be interested in bidding on a 140-meter-high surge tank (probably a world record) at a project with which I was associated. He was interested, saying the height reminded him of his recent experience with a record-sized water tower.

About three years previously, as a recent graduate engineer and a new employee of his firm, he had the task of selling a new line of water tanks in the southern U.S. His company had just developed a series of pre-engineered tanks, all of which were supported on a single cylindrical column enclosing the tank legs, water pipe, and ancillary controls. The tank had a flattened spherical shape and resembled a fat flying saucer. The company had developed a variety of tank sizes that could be supported at various heights above the concrete foundation.

After a six-month training period, Jack began his sales career armed with brochures and a price list for the new tanks. The price list was in the form of a table, with tank volumes on one axis, heights on the second axis, and a price for each volume-height combination. After covering most of his territory and making several sales, he came upon a municipal water utility with an unusual situation.

The town had planned for a new water tower, but there was some controversy over the tank size and location. Apparently, a new interstate highway soon would bypass the town. The town council, concerned about the potential loss of business, saw an opportunity in the new water tower. They instructed the water utility to build the water tower near the new interchange, with the town name prominently painted on three places around the tank circumference. The town had a long name, and to make the letters legible from the highway, the height and size of the tank became considerably larger than were required for water storage.

The water utility naturally was reluctant to increase the tank's cost to accommodate advertising, but eventually agreed to the large tank. The utility manager called Jack on a Friday morning, asking for a firm quotation by noon on the following Monday. The proposed tank was large indeed — considerably larger than any of the products covered in Jack's price list.

Jack called his home office, only to be informed that all staff were attending the annual company picnic. Rather than risk losing the sale to a competitor, Jack set out to see if he could work up a price based on data in the price chart.

Looking over the chart, he noted a consistency in the prices. They appeared to be a systematic function of both tower height and tank volume. Jack multiplied tank volume by tower height and plotted the result against the price on logarithmic paper. He found that all the points fell within a band described by two parallel lines. The prices on the lower line were about 85 percent of the prices on the higher line. Jack then estimated a price for the proposed tank by extending the higher cost line up to a value equal to the new tank's height multiplied by its volume. He then added 5 percent for safety and wrote up a quotation.

When the Monday deadline arrived, Jack still had not reached his supervisor in the home office, so he submitted the quotation and waited. On Tuesday, he was advised that his quotation had been accepted. He then filled in an order form and, with some trepidation, mailed it to the main office. The unusual tank size drew no attention until three weeks later when the shop foreman discovered that Jack's tank matched none of his standard drawings.

Jack soon received the expected call from his supervisor, who congratulated him on the sale and asked where he had obtained the price. When Jack told him how he had worked it out, he was instructed to return to the home office immediately.

Back in the home office, a team was put to work designing Jack's water tower. The combination of height and volume made the structure more than

2.6 times larger than the company's largest standard water tower. To everyone's relief, the cost was found to be well within the price Jack had quoted. In fact, due to economies of scale, the profit margin more than doubled, helped, no doubt, by Jack's extra 5 percent safety margin. Jack's commission also was doubled, much to his satisfaction!

Lessons learned: This story prompted me to see if the same logic could be applied to hydro equipment. Much to my surprise, I found that it could. For ten years, I was involved with the purchase of five three- or four-motor powerhouse cranes with capacities ranging from 20 to 210 tons. All had roughly the same specification, with two hoist brakes and pendant control with inching provision. I found that the ex-factory cost (excluding transportation and erection) of the cranes plotted as a straight line on log paper against the value given by adding the main hoist capacity and half the auxiliary hoist capacity, and multiplying this sum by the square of the span. The price deviation from this line was less than 5 percent. In a similar analysis of 11 turbine butterfly valves, I found the cost to be a function of the diameter raised to the fourth power, times the head.

Keeping this type of cost formula up-to-date is relatively simple, usually requiring only an adjustment for inflation. On occasion, however, there can be a change due to the introduction of new technology or manufacturing processes. For example, in the crane formula, the exponent has slowly decreased in value over the past 30 years as more automation was included in the manufacture. The cost also is deflating as companies move the manufacture of the cranes to less costly labor markets.

Another example is in pricing water-to-wire equipment. A manufacturer overwhelmed by requests for cost estimates might find it expedient to analyze the relationships between cost and key design parameters such as capacity, head, and runner diameter. In an analysis of about

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eight units with capacities less than 10 MW, I found the cost could be estimated from the runner diameter, raised to a power of 1.8 and multiplied by a factor (A), plus the generator KVA, raised to a power of 0.4 and multiplied by another factor (B). The two coefficients are constant for a given type of turbine and generator, but change with different configurations. For example, coefficients derived for a horizontal unit could not be applied to a vertical unit.

The constants A and B can be estimated from price quotes for just two different-sized units. If quotes on four different units are available, the two exponents (1.8 and 0.4 in my analysis) also can be ascertained with more precision. If there is a wide variation in generator speeds, the second term of the cost formula should use the ratio of KVA to RPM, instead of KVA alone.

Many consulting companies have developed cost formulae for electromechanical equipment. Other formulae have been developed to determine a quantity such as weight (see the article on estimating surge tank weight in *HRW Volume 6, No. 4*). These weight estimates can then be multiplied by a cost factor to obtain a cost for the component. This type of formula presently is used in computer programs designed to optimize the dam height and powerhouse installed capacity.

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