A Simple Specification That Guarantees State-of-the-Art Operating Efficiencies

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ABSTRACT

The Detroit Wastewater Treatment Plant is one of the largest wastewater treatment facilities in the world. It also happens to be one of the oldest high-purity oxygen (HPO) facilities in the world. With equipment approaching 30 years of age at the turn of the century, the secondary system was sorely in need of upgrading. Once economic and performance evaluations indicated the appropriate upgrade technology, attention turned to how to prepare specifications for that technology so that "state-of-the-art" energy efficiencies would be purchased.

After considering and discarding previously used specifying techniques to accomplish this, the Detroit engineering team developed a new specification technique that locks in state-of-the-art energy efficiencies for the owner. The new specification technique requires all bidding vendors to guarantee the same, high, state-of-the-art energy consumption (expressed either as Standard Transfer Efficiency, SAE or as a total aeration system power draw). The winning bidder then conducts factory and field energy consumption tests to determine the equipment's actual energy consumption. Monetary penalties in the form of liquidated damages are meted out to punish the winning vendor for failure to meet the state-of-the-art energy consumption guarantee. The monetary penalties, calculated to equal the life cycle cost of the energy consumed that is in excess of the guaranteed power consumption, limits Detroit's secondary system power cost exposure to the cost of "state-of-the-art" energy consumption for the life of the equipment.

The Detroit specification was easy to prepare, easy to understand by the bidders, provided high quality, cost effective equipment, and absolutely "capped" Detroit's power costs for the life of the equipment to those associated with prevailing "state-of-the-art" surface aerator energy efficiencies. The specification technique developed could potentially be used for any equipment that has a significant operating cost component.

KEYWORDS: bid specifications, surface aerators, energy efficiency, power savings

INTRODUCTION

The Detroit Wastewater Treatment Plant was originally constructed in early 1940. Since its original commissioning, the plant's equipment and processes have been upgraded as required to meet ever more stringent regulatory requirements. With a current rated capacity of 930 mgd, the plant is one of the largest wastewater facilities in the world.

The original secondary system aeration technologies, which were commissioned in the 1970s, consisted of a combination of conventional diffused air and high-purity oxygen (HPO) systems.

The plant was one of the first wastewater facilities in the world to implement HPO because of severe space limitations. Initially two aeration basins of identical volume were constructed; one with an open top equipped with medium bubble diffused air equipment and the other with a concrete cover equipped with Union Carbide's UNOX System technology. The resulting secondary system was, in essence, a full scale pilot facility, with the HPO tank rated at twice the capacity of the air tank. Initial HPO performance was such that after a relatively short period two more covered HPO basins were designed and constructed. Since the late 1970s, three of the four Detroit secondary aeration basins were equipped with high purity oxygen dissolution systems (including cryogenic oxygen generators), while one aeration basin, considered the standby basin, was fitted with a medium bubble, conventional diffused air system. Tank characteristics and original design capacities for each basin are shown in Table 1.

Table 1

Detroit Aeration Basins

Basin	1	2	3	4	Total
Process	Dif. Air	HPO	HPO	HPO	--
Rated Capacity, mgd	150 (standby)	310	310	310	930
Dimensions, L x W x D, ft. (approx.)	600 x 135 x 30	600 x 135 x 30	410 x 191 x 30	410 x 191 x 30	--
Tank Volume, mg	8.98	8.98	8.64	8.64	35.24
Original Installed Power, Hp.	14,000 (standby)	2,490	3,430	3,430	9,350 (operating basins)

As is often the case with publicly bid equipment, there was little consistency among the equipment supplied by the contractors that built the four aeration basins. For example, the two newest HPO basins were equipped with OASES System HPO equipment (designed and supplied by Air Products and Chemicals) while the oldest HPO basin, as mentioned, had UNOX System equipment (designed and supplied by Union Carbide Corp.). Although designed for identical design criteria, each manufacturer supplied dissolution and oxygen generation equipment that met their preferred standards. This resulted in a very eclectic mix of oxygen dissolution equipment and two different, manufacturer specific oxygen generators. And of course the diffused air basin had equipment not at all similar to the 3 HPO basins. Periodic equipment updates and improvements to various portions of the secondary system further exacerbated the mix of mechanical equipment associated with Detroit's secondary system.

Since the 1970s, the Detroit Water and Sewer Department staff operated this medley of equipment very well. During this approximately 25 year period, the Detroit secondary system operated virtually 100% of the time as a high purity oxygen system. As the millennium changed, secondary system equipment failures and NPDES permit changes dictated that the secondary system equipment be replaced. Performance and economic evaluations, which are not discussed herein, indicated that the most cost effective technology for the upgraded secondary treatment process at Detroit was the HPO system. Metcalf & Eddy of Michigan (M & E), who had previously done upgrade work on portions of the original secondary system, was retained by

Detroit to engineer the upgrade of the secondary system, which included replacing all of the old existing aeration equipment with new state-of-the-art, HPO compatible technology.

During preliminary design activities, a quick survey of HPO compatible aerator vendors indicated that significant improvements had been made in aeration mass transfer efficiency since Detroit's original aeration equipment had been installed. Essentially all of the surface aerator manufacturers had developed and commercialized high mass transfer efficiency devices capable of operating in deep tank environments. If the vendors were to be believed, preliminary estimates indicated that if state-of-the-art aeration equipment could be specified and purchased, the installed and operating horsepower of the original HPO aeration basins could be reduced by between 35% and 40%.

METHODOLOGY

Analysis of process performance and process economics for the secondary system upgrade alternatives was conducted using methods normally applied by the engineering profession. A detailed discussion of these methods and their results will not be presented here. Process alternatives that fit the physical constraints of the existing facilities were subjected to side-by-side technical and economical evaluation, resulting in the selection of high-purity oxygen as the most economically attractive upgrade process (Metcalf & Eddy, 2002).

Once the process was selected, detailed evaluation of the energy efficiency of the overall system commenced. Virtually all HPO plants operating today employ slow speed surface aerators, since these devices are by far the most economic for use in elevated oxygen purities. During initial discussions with various surface aerator vendors, it quickly became apparent that significant improvements in the mass transfer efficiency of these devices had occurred during the 30 year operating period of the initial Detroit system.

Several attempts were initiated to evaluate the magnitude of these efficiency improvements. With each attempt, it became apparent that (1) much of the efficiency improvement had occurred relatively recently (which was probably the result of a somewhat belated response to the market pressures exerted for years by fine bubble diffuser technologies) and (2) determining the veracity of the varying claims made by the manufacturers would require an intimate knowledge of surface aerators, including uncovering technical minutia not normally available to non-manufacturer personnel.

Complicating the effort would be the fact that the HPO vendors would be an additional "layer" between the Detroit engineering team and the actual surface aerator suppliers. Because it is such a specialized technology, most HPO systems are purchased as a "black box" from one of the two HPO system suppliers. Each of the HPO suppliers has preferred surface aerator vendors which can complicate (i.e., inhibit) the free flow of unbiased technical information.

Early in the development and design phase of the project, the Detroit engineering team developed a set of criteria that would form the basis for plans and specification development. Those criteria are shown in Table 2. Since the secondary system aerators consume considerable energy, if there is one paramount criterion in Table 2, it would be for specifications that would ensure the supply of "state-of-the-art" aeration efficiencies. Almost from project outset the

Table 2
Specification Criteria
1. Easy to understand and unambiguous
2. Provides cost effective equipment
3. Guarantees client only pays for energy consumption associated with state-of-the-art energy efficiency
4. Excludes no qualified bidders
5. Eliminates the subjectivity associated with "after bid opening" evaluations.

Detroit engineering team began work to either find or develop just such a specification.

DISCUSSION

To be sure, there are as many bid specification writing techniques as there are specification writers. That being the case, the initial effort of the Detroit engineering team was to find specs that met the criteria shown in Table 2 that had either been developed for other M & E projects or by others for similar projects. The internal M & E search uncovered examples of "Evaluated" bid specifications. An evaluated bid specification is quite common in the municipal wastewater treatment marketplace. In a typical example of this specification the bidders are required to enter on the bid response forms the amount associated with their bid for the equipment being supplied. Additionally they provide a design point energy consumption magnitude (also on the bid forms) for the equipment being supplied. To ensure that realistic energy consumption values are being provided, the equipment supplier is required to guarantee the energy consumption magnitude the bidding contractor enters on the bid forms. After bid opening, all responsive bids are then "evaluated" by the engineer using a calculation procedure called out in the specifications. The evaluated bid specification, as do all of the specification approaches discussed herein, includes detailed technical specifications for the equipment being purchased. But the intent of the evaluated bid specification (and the evaluated bidding process itself) is for the engineer to obtain enough information on the equipment's capital cost and operating cost to determine the life cycle cost of that equipment. The bid response forms for the evaluated bid specification are structured to obtain this information.

Table 3
Evaluated Bid Spec. Advantages/Disadvantages
Advantages:
1. Better than non-evaluated bid
2. Accounts for total life cycle cost of equipment purchased
Disadvantages:
1. It's a lot of work (engineer has to be expert in the technology being bid).
2. Doesn't necessarily get you "state-of-the-art" energy efficiency
3. Subject to complaints about exclusion from upset vendors
4. Can result in complicated/misunderstood bid response forms

Evaluated bids have been used for years, especially for equipment with relatively large operating cost components. Secondary system aeration equipment, with its large operating energy component, is exactly the type of equipment suited for an evaluated bid. Initially, the engineering team considered using this bidding approach. The advantages of the Evaluated bid specification, which are summarized in Table 3 along with its disadvantages, appeared attractive for the Detroit upgrade. However the disadvantages of this bidding technique were significant for a project such as Detroit. As stated, the improvements in surface aerator mass transfer efficiency proved to be relatively recent "discoveries" by the vendors. To prepare an evaluated bid specification, including a post bid evaluation procedure, would require an intimate knowledge of surface aerator operation and efficiency, especially with respect to the recent improvements the vendors were claiming. And even if this knowledge could be developed in the short time available to the Detroit engineering team, there would be no guarantee that the best, or "state-of-the-art" efficiencies would be bid and purchased. Indeed it is usually the case that the vendors "pad" their energy figures with conservatism at bid time to ensure that the guarantee power can be met. It was therefore quickly decided to search for some other specification technique with fewer, or more manageable disadvantages.

A second, initially attractive specification approach is a bid specification written to provide monetary incentives to the vendors to entice them to develop "state-of-the-art" energy efficiencies after bid award. This approach, dubbed by the Detroit engineering team as the "Incentive" bid specification, was used to upgrade the Sacramento Regional Wastewater Treatment Plant (Narayanan, 1996) in the early 1990s. This approach differs from the evaluated bid specification in that all bidding vendors are required to guarantee a "reasonable," or attainable energy efficiency at bid time. The specification then contains incentives for the winning bidder to improve on this attainable energy efficiency after contract award. The incentives are monetary, and are paid based on proven energy efficiency improvements over and above the attainable magnitudes that the vendor originally guarantees.

The Sacramento Regional Plant has aeration tanks that presented particular and somewhat unique geometric constraints for surface aeration equipment circa 1990. Similar to what the Detroit engineering team was experiencing, the surface aeration equipment vendors were making what appeared to be optimistic, if not downright specious energy efficiency claims to the Sacramento design engineer. Especially since no vendor had data specific to the geometry of the actual Sacramento tanks. Being unable to validate the vendor claims, the Sacramento design engineer developed the incentive bid specification in an attempt to secure for Sacramento "state-of-the-art" energy efficiencies.

The incentive bid specification circumvents the need for an evaluation process, which among other things saves the engineer from post bid complaints concerning the evaluation process. With the incentive bid specification each vendor is guaranteeing (at bid time) the same power consumption. So if the specifications are properly structured, the low capital cost bid will be the most cost effective, without having to perform a set of life cycle cost calculations. The monetary inducements of the incentive bid specification are intended to try to spur the winning bidder to improve the guaranteed power efficiency that he bid to. In the case of the Sacramento plant upgrade specification, the incentives appeared substantial. The incentive payments were "stepped" so that the larger the improvement in energy efficiency, the larger the incentive payment. The maximum attainable incentive payment could have been in excess of $250,000 for "maximum" improvement in all of the performance parameters for which incentives were offered. However, the time consumed by the vendor as he attempted to improve his energy efficiency proved to be significant. This fact alone would tend to rule out the incentive bid specification for any type of "fast track" project.

Like Sacramento, the Detroit engineering team was faced with vendor claims for energy efficiencies that were largely unsupported by actual operating data. So in order to prepare an incentive bid specification for Detroit with the "correct" realistic energy efficiency for the base guarantee, the Detroit engineering team would have to study and understand the nuances of surface aerator operation and energy efficiency. From this effort a base energy efficiency would have to be established (and in all likelihood that base efficiency would not be a "state-of-the-art" magnitude), then a monetary incentive magnitude and incentive test procedure would have to be developed for the winning vendor. These steps themselves would require a significant amount of time, since most of the factors necessary to complete these steps would involve assumptions about the winning vendor. For example, the incentive magnitude would have to be large enough to offset the normal costs the vendor would incur to engineer then fabricate and test aerator design improvements. These costs not only vary among vendors, but are generally unknown to outsiders. And even if a rational, cost based approach could be developed to establish an incentive magnitude, there still would be no assurances that the whole incentive approach wouldn't fall victim to the "satisfied vendor" syndrome. A "satisfied vendor" is one that is content with his "take" at bid time, so any financial incentives offered as an inducement (no matter how large) to improve his offering may not be of interest to him. That being the case, the owner could be "stuck" with the originally bid equipment, paying for the excess operating power associated with this less than state-of-the-art equipment.

The incentive specification approach seems to have worked for Sacramento. The energy efficiency of the equipment purchased for Sacramento was both higher than the devices the surface aerators replaced, as well as higher than the guaranteed energy efficiency at bid time. However, this improvement came at the expense of the time spent by the vendor engineering and testing the improvements. But the similarities between the projects and the successful experience at Sacramento originally suggested to the Detroit engineering team that the incentive bid specification might be worth considering for Detroit. In the end, the disadvantages of the incentive bid specification, shown in Table 4 along with the incentive specification's advantages, were a large impediment to its implementation for a "fast track" type of project like Detroit. To the Detroit engineering team, the negatives of the incentive bid specification far outweighed the advantages of this specification technique for Detroit.

Table 4
Incentive Bid Spec. Advantages/Disadvantages
Advantages:
1. Eliminates the need for an evaluated bid.
2. All vendors are guaranteeing same base energy consumption.
3. Could result in "state-of-the-art" energy efficiency.
Disadvantages:
1. It's a lot of work (engineer has to be expert in the technology being bid)
2. Doesn't necessarily result in "state-of-the-art" energy efficiency
3. Could result in complaints about exclusion from upset vendors
4. Could fall victim to the "satisfied vendor" syndrome
5. Requires post-bid time for vendor engineering, testing, and fabrication of the upgraded (more energy efficient) equipment.

Having failed to uncover a previously implemented specification approach that met the team's objectives, the Detroit engineering team decided to develop an entirely new specification approach. The approach, dubbed the "Simple" bid specification, met all of the criteria shown in Table 2. Additionally, once developed, it proved relatively easy to set up and implement.

The simple specification has four basic components (in addition to detailed technical specification sections). The first is a "normal" bid form that requires only an entry for the capital cost of the equipment (or entire project) being bid. The second is a guaranteed energy efficiency selected by the engineer. The guarantee point only needs to reflect the engineers' understanding of the magnitude of "state-of-the-art" energy efficiency (or any other operating cost component). The third is an equipment performance test procedure that the vendor will use to confirm that the supplied equipment will meet the guaranteed energy efficiency. And the fourth is the cost the vendor must repay the owner should performance testing of his equipment indicate that the equipment fails to meet the guarantee energy consumption. The four components, as developed for and extracted from Detroit's simple bid specification, are shown in Table 5.

RESULTS

The Detroit upgrade contract (DWP-1005) bids were opened on May 22, 2003. Because the project was so large, bidder interest was high. However, at no time during the pre-bid period did the engineering team receive any indication that the bid specifications were exclusionary. At opening, bids were received from 2 qualified surface aerator bidders. Feedback since bid opening from other interested surface aerator bidders has indicated that those potential bidders decided not to bid of their own volition, not because the specifications excluded them. In essence, these potential bidders dropped because they were unable or unwilling to guarantee the "state-of-the-art" efficiencies called out in the specifications.

Did the structure of the simple bid specification effect how the bidders approached the bid? Well it is generally a difficult task getting feedback from individual vendors after bid opening. This probably has to do with the fact that bidding is more "art" than science, and vendors are loath to disclose anything about their actual bidding techniques. That being the case, the Detroit engineering team passively watched the winning bidder's activities after award to see if any information could be discerned about his bidding approach. From the winning bidder's post bid activities, it did appear as though he might have bid "on the come." As soon as the winning vendor was identified, that vendor began testing surface aerator turbines. Although it's impossible to confirm, the engineering team suspects that the testing activity was exclusively for the purpose of developing surface aeration equipment that could meet (or minimize the liquidated damages associated with) the Detroit energy consumption guarantee.

It should be mentioned at this point that Detroit and the engineering team were unconcerned about the vendor meeting the efficiency guarantee (as long as the vendor was not more than 15% lower than the guaranteed energy efficiency). This was a direct consequent of the way the specifications were written. The liquidated damages associated with failing to meet the guaranteed energy consumption was calculated to offset the life cycle costs associated with power consumption over and above what was guaranteed. In other words, the specified $4,123/kW liquidated damages is the estimated cost of 1 kW at the Detroit plant for the expected 20 year life of the surface aerator equipment. So in essence then the simple bid specification

Table 5

The Essential Parts of the Simple Bid Specification
(as extracted from the Detroit specifications)

1. The Bid Response Form

Item No.	Estimated Quantity	Description	Unit Price	Bid Price
6.2.1	LS	Full compensation for all work as specified and shown in the bidding documents for Aeration Basin Conversion and Improvements under DWP 1005, including Bid Schedule 6.5 and 6.6, but excluding the Bid Item Nos. 6.2.2 through 6.2.5 and the Bid Item Nos. 6.2.6 through 6.2.9 and Bid Schedule 6.1, 6.3, 6.4 and 6.7, listed separately, for the lump sum of:	N/A	$ ____________
6.2.2	LS	Provisional Allowance – Abatement and Removal of Asbestos Containing Material, Lead Based Paint, and Hazardous Material	N/A	$ 200,000.00
6.2.3	LS	Provisional Allowance – Construction Gate Access	N/A	$ 135,000.00
6.2.4	LS	Provisional Allowance – DWP Field Office Annex Operating Costs and Demolition/Removal	N/A	$ 135,000.00
6.2.5	LS	Provisional Allowance for unforeseen and changed conditions and Program Manager directed changes for DWP-1005 Aeration Basin Conversion and Improvements	N/A	$ 5,000,000.00
		BID SUBTOTAL FOR DWP 1005 - AERATION BASIN CONVERSION AND IMPROVEMENTS		$ ____________

2. The Energy Consumption Guarantee Point

4. The oxygen dissolution systems shall result in a total operating power consumption by the surface aeration and mixing systems installed in Aeration Basin Nos. 1, 2, 3 and 4 of not more than 4,075 kW, cumulative for all four basins, when each is operated under the conditions specified in Paragraph 1.06 A.1 above. Bidder is advised that power, expressed in kW, is as measured at the motor terminals of the surface aeration and mixing systems motors. Bidder is also advised that shop test power draw data for the surface aeration systems to be provided by others and installed in Stage 1 of both Basin Nos. 1 and 2 (see Mixer Schedule in the Drawings) will be made available, if requested

Table 5 (cont.)

The Essential Parts of the Simple Bid Specification
(as extracted from the Detroit specifications)

3. The Performance Test Procedure

3.01WARRANTY PERFORMANCE TESTING (For Basin Nos. 1, 2, 3 and 4):

A. In order to confirm the performance warranty described above, the OWNER will conduct a performance test of the oxygen dissolution system of each aeration basin that the Oxygenation Systems Supplier may witness. This test is in addition to the 30-day performance test required for each basin under Section 01655 “Starting and Placing Equipment in Operation”. Warranty Performance Testing shall be conducted as promptly as possible after the oxygenation system has been started up, has been leak tested, and has reached steady state conditions. If OWNER fails to conduct or complete such performance test six (6) months after startup, except if such failure is due to an act or omission of Oxygenation Systems Supplier, then the oxygenation system shall be deemed to have met said warranties and
Oxygenation Systems Supplier shall have no further liabilities to OWNER with respect to such warranties.

B. A four (4) consecutive day (24 hour) warranty performance test will be conducted for each aeration basin to confirm the oygen dissolution system’s capability to meet the warranties set forth above.

4. The Penalty

1. If the oxygenation systems exceed the power consumption stated in Article 1.06 of Specification Section 11338 by less than 15 percent during the field acceptance tests, then DWP may elect to declare the oxygenation systems defective or reduce the Subcontract Price by an amount equal to $4,123 per each kW that the electric power exceeds specified value. If the electric power consumption is more than 15 percent higher than the specified value, the oxygenation systems will be deemed defective.

approach limits Detroit's secondary system dissolution power cost exposure to the cost of "state-of-the-art" equipment power consumption, regardless of whether the equipment is "state-of-the-art" or not. This is because if the equipment supplied consumes more power than the "state-of-the-art" power guaranteed, the vendor pays liquidated damages equivalent to the cost of the excess power for the 20 year life of the less efficient equipment.

The other unique advantage of the simple bid specification is that selecting the "state-of-the-art" energy efficiency magnitude is a simple task requiring no detailed knowledge of surface aerator operation. The engineering team didn't have to reconcile the normal competing claims of various vendors to select an efficiency that would not be exclusionary. In fact, once the simple bid specification was chosen for the Detroit upgrade, the engineering team merely surveyed the surface aerator vendors, asking what constituted "state-of-the-art" efficiencies. By virtue of the guarantee, this efficiency then became the value Detroit would pay for during the life of the equipment. As long as one vendor committed to the energy efficiency guarantee (both bidders in fact committed to the guarantee), Detroit's power bill for secondary system energy consumption was "capped" by the amount of power associated with the guaranteed efficiency.

The simple specification worked very well for the Detroit upgrade. Table 6 summarizes the upgrade results. The bottom line is that the simple bid specification locked in a 40% reduction in operating horsepower for the life of the equipment (with a commensurate 38% reduction in installed horsepower on the operating basins). The specification was easy to prepare and did not require an extensive knowledge of the workings or efficiencies of surface aeration equipment by the engineering team. The incentives (i.e., the avoidance of liquidated damages) provided in the specifications to encourage development of true "state-of-the-art" equipment did, in fact, work to Detroit's advantage since the vendor spent considerable time testing and refining his offering so it met the energy consumption guarantee. And finally the specification did not create any pre- or post-bid complaints from the non-winning vendors.

Table 6

Detroit Aeration Basins

Basin	1	2	3	4	Total
Orig. Rated Capacity, mgd	150 (standby)	310	310	310	930
Orig. Installed Power, Hp.	14,000 (standby)	2,490	3,430	3,430	9,350
New Rated Capacity, mgd	310 (standby)	310	310	310	930
New Installed Power, Hp.	1,825	1,825	2,125	2,125 (standby)	5,775

CONCLUSIONS

Of the various methods of preparing bid specifications, especially for equipment that has a large operating cost component, the specification technique used for the Detroit aeration basin upgrade, herein called the Simple bid specification, proved very advantageous. The simple bid specification eliminated virtually all of the disadvantages associated with the other specification approaches discussed herein. The simple specification proved to be simple to prepare, simple to understand, did not require of the engineer an intimate knowledge of the mode of operation of the equipment being specified, spurred the supplying vendor to provide "state-of-the-art" energy efficiencies, and absolutely limited Detroit's secondary system operating cost exposure for the expected life of the equipment purchased. So Detroit reduced aeration costs by approximately 40% and the vendor developed a truly proven, "state-of-the-art" equipment offering that he can use to his advantage on other projects. In the end, the simple specification resulted in the proverbial "win – win" situation for both parties.

REFERENCES

Metcalf & Eddy (2002), Aeration Basin Conversion and Improvements. *DWP Contract 1005 Basis of Design Report, Technical Memorandum 1.A.1,* Wakefield, MA

Narayanan, B., Hough, S. G., Williams, C. R., Lewis, W. P., Gay, D. W., Kubera, P. M. (1996) A Modified Approach for the Design and Specification of Surface Aeration Equipment. *Proceedings of 1996 WEF Conference,* Dallas, TX.