Low Pressure-High Output UV: Is it the Wave of the Future?

Gary Hunter and Tom Cummings

Low pressure-high output (LP-HO) ultraviolet radiation systems have recently made their way into the wastewater industry in North America. Advances in technology have led to the use of LP-HO lamps that produce the same monochromatic emissions at a wavelength of 254 nm as traditional low-pressure (LP) systems. This development reduces the number of lamps claimed by the vendors from 40-50 per mgd for LP systems to 2-12 per mgd for LP-HO systems.

The energy demand for LP-HO systems is similar to that of traditional low-pressure systems, ranging from 1.8 to 3.8 kW input power per mgd for disinfecting secondary effluent to 200 fecal coliforms per 100 mL, which is significantly lower than the 6.8-14 kW input power per mgd demand exerted by medium pressure UV systems. Vendors who supply LP-HO systems are also including automatic cleaning systems as part of the design package, making these systems very attractive to treatment plant personnel.

The purpose of this article is to identify the typical vendors of this type of equipment and to determine its acceptance into the wastewater markets, rather than to discuss the impacts of ultraviolet (UV) on wastewater markets. Information was collected from the identified vendors on U.S. and international installations. Results of the survey indicate that the LP-HO systems are being used to disinfect a wide variety of effluents, ranging from stormwater to reclaimed water. Staff members from a cross section of U.S. facilities using equipment supplied by each vendor were interviewed in a telephone survey to determine their opinions about the equipment.

Overall, LP-HO UV technology appears to have made an impact on the wastewater market worldwide. It is being used more and more often when disinfection systems are upgraded, making it the wave of the future for UV disinfection systems.

Key Words

UV disinfection, Low Pressure-High Output UV, wastewater

Over the past 10 years, UV radiation has become a common technology for disinfecting wastewater. UV disinfection involves passing effluent through a confined chamber with rows of underwater lamps emitting UV radiation. The high dosages of UV energy inactivate the viruses and bacteria in the wastewater, producing a disinfected effluent.

UV disinfection has several advantages over chlorine and other chemical disinfectants. It is a physical process that does not involve adding chemicals to the effluent and thus changing the basic chemistry of the wastewater. As a result, UV disinfection does not produce a chemical residual that would be toxic to aquatic plants or animals.

Elimination of transporting, storing, and handling potentially dangerous chemicals is another advantage of UV disinfection, which also offers lower operating costs than chemical technologies. Since there are no chemicals to be purchased, the main cost items are electric power and UV lamps.

The main disadvantage of a UV system is that it requires a higher capital investment than most chemical disinfection systems. Another disadvantage is the potential for reactivation of the pathogenic organisms if they do not receive a high enough dose and are then exposed to sunlight for an extended period before they are discharged from the wastewater treatment plant. In the presence of sunlight, some organisms can repair the cellular damage caused by UV radiation if a sufficient dose is not applied. Covering the channels downstream from the UV system can minimize this problem.

UV disinfection works by denaturing the DNA of the targeted microorganisms using electromagnetic radiation at specific wavelengths. UV light at wavelengths from 250 to 270 nanometers (nm) is readily absorbed by all DNA and makes the cells unable to replicate. The dose of UV light is measured as the product of intensity and exposure time in terms of either milliwatt-seconds per square centimeter (mW-s/cm^2), millijoules per square centimeter (mJ/cm^2), or joules per square meter (J/m^2). Typical design doses for disinfection of municipal wastewater are in the range of 20 to 45 mW-s/cm^2 or, 200 to 450 J/m^2 that must be verified during predesign through bench scale and/or pilot scale testing and through the use of the USEPA design program (UVDIS).

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Testing prior to design is important, since the UV dose is highly dependent on effluent quality. By far, the most important quality parameter is transmissivity, which is the measure of how much UV light at a specific wavelength is absorbed by the wastewater. Suspended solids can shield organisms from exposure to UV light, and color and organics can absorb UV radiation, reducing its effectiveness as a disinfectant. The device typically used for completing bench scale testing is shown in Figure 1. The collimating tube has been painted with flat black paint and o-rings have been added to the inside of the tube to minimize the variation of UV light being emitted.

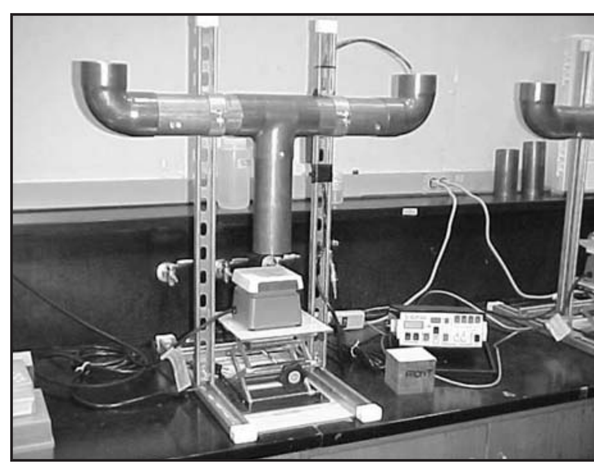

Figure 1. Typical bench scale UV testing device.

In UV systems, wastewater is disinfected as it flows past arrays of UV lamps that are submerged in narrow channels. Each UV lamp is enclosed in a sealed quartz sleeve for protection. Over time, solids carried in the wastewater will be deposited as a residue on the quartz sleeves.

The primary maintenance task in the operation of UV systems is cleaning the quartz sleeves by removing such deposits using either mechanical or both mechanical and chemical cleaning systems. There is considerable disagreement among vendors on the effectiveness of mechanical versus chemical/mechanical cleaning systems. The need for cleaning is determined by measuring the reduction in the intensity of UV light transmitted into the wastewater.

The intensity of UV radiation is measured using a monitoring system with sensors at a representative point within each group or bank of lamps. After the intensity drops below a given set point, the system control will indicate the need for cleaning. Modifications to the control systems provided by some UV vendors also allow the intensity sensors to be used for dose pacing. The newer systems usually include self-cleaning wiper mechanisms. Lamp life is estimated to range from 8,760 to 13,000 hours.

In summary, a UV disinfection system consists of a power supply, lamps, reactor chamber(s), cleaning equipment, flow control, and controls and instrumentation. Reactor chambers (either open or enclosed channels) are equipped with UV lamps in a horizontal or vertical configuration. The lamps are protected by quartz sleeves. The effluent flows through the reactor chamber(s), where it is exposed to UV light. Dose is determined by measuring the flow rate and therefore the retention time. The average intensity is determined by measuring the intensity of UV light at monitoring points along the channel. In an open-channel system, effluent weirs or automatic level-control devices are used to maintain the submergence of the lamps. The UV system may also be housed in a structure that shields it from the elements.

LP-HO systems have been used in a wide range of wastewater applications. Systems have been installed to disinfect effluent from both activated-sludge and trickling-filter biological systems, as well as effluent from chemically enhanced primary treatment systems. One vendor reports that its UV system has been tested and has received conditional acceptance by California Department of Health Services with the NWRI reuses requirements for UV systems. Other vendors are currently testing and expect to receive similar acceptance.

Conversion from applied power to UV energy ranges is slightly less than the traditional low-pressure systems because the lamps operate at a higher temperature. Lamps can be controlled to generate a UV dose paced to the transmittance and effluent flow rates.

Both open- and closed-channel configurations are available; however, in the wastewater industry the open-channel configuration is preferred. Like conventional low-pressure systems, the LP-HO systems operate at approximately 100 to 130°C. Like medium-pressure systems, LP-HO systems are capable of disinfecting low transmissivity waters.

While they are not as well established in the U.S. as the conventional low-pressure and medium-pressure systems, LP-HO systems have been used for some time in Europe, even in primary and secondary treatment plants that lack tertiary filtration.

Survey of LP-HO Installations

Information regarding the implementation of LP-HO ultraviolet systems into wastewater facilities worldwide as of January 2002 was collected from all major

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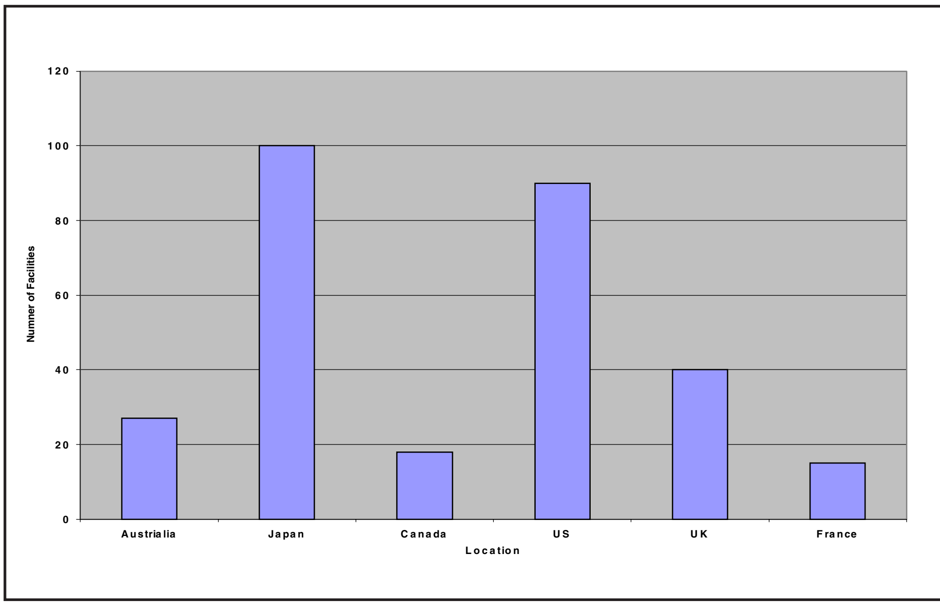

Figure 2. Distribution of Facilities by Location

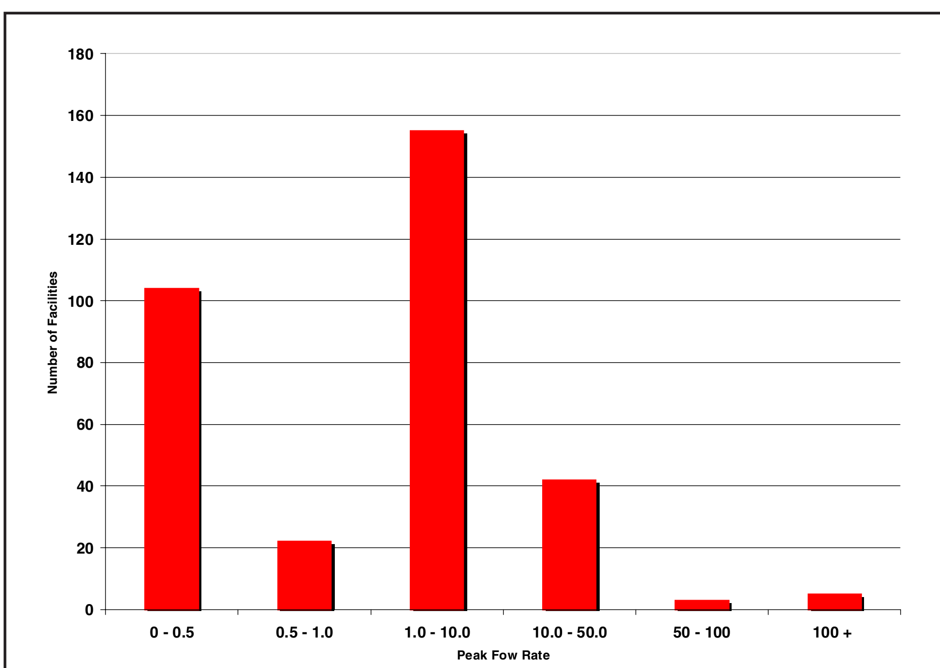

Figure 3. Distribution of Facilities by Flow

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vendors of UV equipment. According to this survey, the earliest LP-HO system was installed during the 1980s, and over 50 facilities have been installed and placed into operation in the U.S. within the last 18 months, indicating a high interest from engineers and communities alike. Results of the survey also indicate that worldwide there are more than 750 LP-HO systems being designed, under construction, or in operation. Design flow rates range from less that one mgd to more than 370 mgd. Most of the operating systems are located in Japan, the United States, and the United Kingdom, as shown in Figure 2.

From the data generated by the survey, the largest number of facilities being installed are in the one-to-10-mgd category as shown on Figure 3. The largest LP-HO system identified, with a design flow of 370 mgd,[1] is located in Auckland, New Zealand.

Three other LP-HO UV facilities with capacities greater than 100 mgd are either under design or operating.

A telephone survey of operating LP-HO UV systems in the U.S. was conducted in January 2002 to determine their acceptance by utilities. More than 90 percent of the systems surveyed were located at extended aeration facilities, which indicates that most of the operating systems are at installations with design flows less than five mgd. Vendor projections indicate that within a couple of years, LP-HO UV systems in the U.S. will be installed at facilities with design flows near 100 mgd.

Since most of the UV systems have been placed into operation within the last 18 months, only limited data are available on the frequency of lamp and ballast replacement. Results of the survey indicated that most users of the LP-HO systems had replaced neither lamps nor ballasts on their systems, so it was difficult to determine the actual replacement frequencies.

Even though the systems at the installations surveyed included provisions for on-line mechanical cleaning of the quartz sleeves, the systems had been taken off line at least once per year for manual cleaning. Typical set points for mechanical cleaning systems ranged from two to six times per hour to once per day, with an average of three times per hour.

Of the facilities surveyed, 90 percent had to maintain a 30-day geometric mean of 200 fecal coliforms/100 mL. None of the facilities surveyed had to meet high-level (reuse) disinfection requirements.

Operating personnel at the facilities surveyed indicated that the difficult part of learning to use the UV system is the PLC that operates the system. Staff responses were positive regarding the equipment that had been installed, and all who were interviewed stated that they would recommend LP-HO to another facility.

Low Pressure-High Output System Vendors

During the survey, five vendors were identified as manufacturing LP-HO systems. The vendors have been listed in alphabetical order so as to infer no preference. Listing of product names is solely for illustrative purposes and does not constitute any form of endorsement.

ONDEO Degremont
SUNTEC environmental
Trojan Technologies
UltraGuard/US Filter
WEDECO/Ideal Horizons

While all these systems are loosely grouped as LP-HO systems, there are considerable differences among them. Each vendor uses lamps with different wattages. All the systems are equipped with a mechanical cleaning system. Control systems range from transmittance and intensity control to flow pacing.

ONDEO Degremont

ONDEO Degremont (ODI) has developed a 40-module vertical LP-HO unit that can be retrofitted into existing ODI facilities, as shown in Figure 4. Each module is equipped with dose enhancing baffles that increase the velocity and turbulence within the UV channel. Like its predecessor, this system has all its electrical controls and connections above water for ease of maintenance. The lamps are mounted in a staggered array to facilitate particles in the water coming into contact with the UV being emitted from the lamps.

Testing by the manufacturer indicates that the LP-HO system can treat twice as much flow as its traditional LP-low output system. A mechanical wiper collar cleans the entire bank of 40 lamps at one time.[5,7]

The control system uses flow pacing to turn rows of lamps on and off, based on the flow through the UV system. The last module of lamps in the channel is never turned off to provide a margin of safety during low-flow conditions. The system uses 165-watt (input power) LP-HO mercury vapor lamps with a guaranteed lamp life of 13,000 hours.

Survey results indicated that ODI systems have been located at facilities with design flows ranging from approximately two mgd to above 90 mgd. The largest ODI facility in the U.S. that will have a design flow capacity of 90 mgd is located in Georgia.

The first ODI LP-HO system went online in 2001. ODI has over 200 LP low-output systems in the U.S., ranging in design capacity from two mgd to over 100 mgd that can be modified with this technology. The LP-HO system has the same lamp spacing as the LP-low output system.

Figure 4. ODI LP-HO system
Courtesy of ODI

SUNTEC environmental

SUNTEC environmental, located in Toronto, Canada, has installed more than 30 of its LPX200 systems. Most of these systems are small; however, a recent project in the U.S. has a capacity of over 50 mgd, based on information provided by SUNTEC. The first SUNTEC systems were installed in 2000; the first system in the U.S. was placed on line in 2001. Design dose calculations are based on using UVDIS.

In the SUNTEC system, both the lamp and the ballast are located below the water surface, as shown in Figure 5, which eliminates the need for special cooling systems,

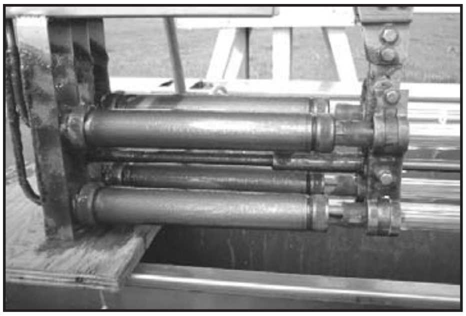

Figure 5. SUNTEC Submersible Ballast
Courtesy of SUNTEC environmental

enclosures, or buildings. The system uses 210-watt (input power) high-output lamps and incorporates a mechanical, electrically driven cleaning system. Lamp life is guaranteed for 12,500 hours. The lamp arc length is 64 inches. Control systems include self-diagnostics and online transmittance and intensity measurements. The lamps have variable output and the UV system can do dose and flow pacing.[4]
The lamp rack is modular and can be designed to hold up to 16 lamps, with one ballast per lamp. Worldwide, SUNTEC has more than 100 systems in design, fabrication, installation, or operation.

Trojan Technologies

In 1998, Trojan Technologies began to market its 3000+ LP-HO UV system. The company is now able to supply the following types of systems: low pressure, LP-HO, and medium pressure. The 3000+ system is very similar to the Trojan 3000 in that it is a horizontal system; that is, the arrangement of lamps is parallel to the direction of the flow. Typical sizing of the units is based on a bioassay collected either by the owner or by the manufacturer.[2]

The 3000+ is equipped with 250-watt (input power) lamps with a guaranteed life of 8,760 hours that are installed inside quartz sleeves as shown in Figure 6. An automatic cleaning device that incorporates both chemical and mechanical wiping

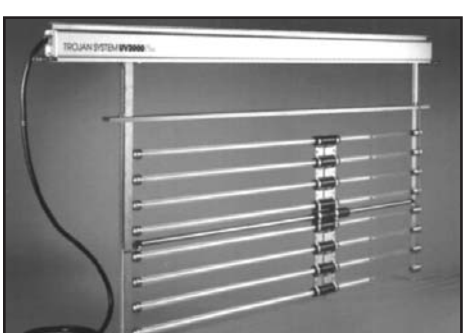

Figure 6. Typical Trojan LP-HO Low Pressure-High Output UV System.
Courtesy of Trojan Technologies

is incorporated into the system. The control system uses transmittance and flow rate to vary the delivered dose of UV light from 30 to 100 percent of maximum power. Ballasts are located above the lamps in a fashion similar to the Trojan Model 3000 low-pressure system.

Trojan has over 3,000 wastewater systems customers around the world and has sold 120 LP-HO systems with over 90 installed and operating. The first 3000+ system, with a design capacity of 58.5 mgd, was installed in York, Pennsylvania, in 1998. Since then, Trojan has installed systems ranging in flow capacities from less than one mgd to approximately 60 mgd.

UltraGuard/US Filter

The UltraGuard system consists of vertical lamp modules, a diffuser plate, mounting plates with single lamp reactors, a rectangular weir with pipes, and an automatic cleaning system. The system uses 1,410-watt (input power) lamps with a useful life of 8,760 hours.

Figure 7. UltraGuard LP-HO system
Courtesy of UltraGuard as subsidiary of US Filter

The diffuser plate, which spans the channel from one wall to the other, serves to dissipate the flow into the UV channel. The mounting plate supports the single-lamp reactors(SLRs). The UltraGuard design can incorporate up to 10 reactors across a single channel, with up to five plates in a single channel. The mounting plate can be used as a dam to divert flow to other SLRs and to provide redundancy. The UltraGuard system uses a lamp power controller that allows variable control between one and four amperes. The rectangular weir and pipes serve to keep the water level constant as the flow rate to the UV system increases. The automatic cleaning system provides both mechanical and chemical cleaning.[6] Figure 7 shows a typical UltraGuard system.

UltraGuard has installed several UV systems in the U.S. and Canada. The largest system being designed is a 24-mgd system located in Canada. The first UltraGuard system in the U.S. went on line in 1999 and is located in Hamilton, Alabama.

WEDECO/Ideal Horizons

WEDECO/Ideal manufactures an LP-HO system that has been used worldwide in applications ranging from disinfection of chemically enhanced primary treatment effluent to reclaimed wastewater. Design dose calculations are based on using UVDIS.[3]

In the WEDECO/Ideal Horizons systems, the lamps are positioned in a horizontal alignment parallel to the direction of flow. Typically a 300-watt (input power) LP-HO lamp is used with a guaranteed life of 12,000 hours at 100-percent output. A spiral Teflon wiper with multiple wiping edges is used to provide mechanical cleaning of organic and inorganic substances from the quartz sleeves. Each quartz sleeve has two wipers whose range overlaps to ensure that the entire length of the sleeve is cleaned. The control system uses intensity, transmittance, and flow rate to linearly vary the delivered dose from 50 to 100 percent of maximum power. A typical WEDECO facility is shown in Figure 8.

Should the dose drop below the target value, the PLC is programmed to activate an alarm. This is the only system that locates its solid-state ballasts remote from the channel. Control systems include monitoring and control of lamps, ballasts, wiper system, online transmittance, intensity, and dose. The arc length of the lamp is 56.3 inches. Each WEDECO solid-state ballast controls two lamps.

Figure 8. Typical WEDECO Installation
Courtesy of WEDECO/Ideal Horizons

WEDECO appears to be the fastest-growing LP-HO UV manufacturer, with nearly 400 systems worldwide in design, fabrication, installation, or operation. Data supplied by WEDECO indicates that TAK, the company's first system, was installed 13

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years ago at a 2.9-mgd wastewater treatment facility located in Germany. Since then, WEDECO has supplied systems ranging in design flow capacity from less than one mgd to more than 370 mgd. The first WEDECO system in the U.S. became operational in 1991.

Summary

LP-HO UV has become one of the most widely used disinfection systems in the world. Japan and the United States appear to be fastest-growing markets for this type of equipment. Features such as long lamp life and mechanical cleaning are appealing to plant operation and maintenance personnel.

The full impact of LP-HO UV systems on the wastewater industry will not be known until operations personnel have become familiar with the systems. With its rapid growth, LP-HO may truly be called the "Wave of the Future."

Acknowledgments

The authors appreciate the willingness of Trojan Technologies, WEDECO, UltraGuard/US Filter, ODI, and SUNTEC environemtal to provide the information used in the preparation of this article. The authors also appreciate the peer review provided by Dr. Vic Moreland, Dr. Elliot Whitby, and Steve Wolfe.

References

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[2]Personal Communication with Trojan Technologies

[3]Personal communications with WEDECO and TAK variable power ultraviolet disinfection specification.

[4]SUNTEC Environmental Design Manual.

[5]Personal Communication with ODI.

[6]UV Systems Technology Inc, "Evaluation of the Ultra Guard UV Disinfection System within the context of the wastewater decontamination project of the Cities of Rosemere and Lorraine", March, 1998.

[7]Aquaray 40 High Output, Inflico Degremont, Inc.

News Round-up

Clearwater Outreach Project Presented at AWWA Conference

A public outreach program conducted by the city of Clearwater was selected for a poster presentation at the American Water Works Association Annual Conference, held June 16-20 in New Orleans and attended by water professionals from around the world.

Steve Soltau, water superintendent with the city of Clearwater, and Linda Faulkner-Vaughn, director of marketing for the engineering and surveying firm McKim & Creed, conducted the presentation, entitled "Public Outreach Plan for Conversion to Chloramines." Three graphic panels illustrating how Clearwater used public outreach to advise residents about plans to convert the city's water treatment from chlorine to chloramines remained on display during the conference.

McKim & Creed worked with the city to develop the outreach program, which included a bulletin board display in its customer service office area, articles in the utility employee newsletter, press releases and fact sheets to the media, information posted to the community bulletin board of the government access channel on cable TV, interviews on local television, presentations to the environmental advisory board and the city commission, customer service briefings, and a link to the Clearwater Coalition of Homeowners Web site.

Brown Joins McKim & Creed

Eric Brown has joined the McKim & Creed's Clearwater office as an instrumentation and controls technician. He will be responsible for designing electrical circuits and SCADA (Supervisory Control and Data Acquisition) systems, and programming PLC (Programmable Logic Control).

Brown is a graduate of Tampa Technical College, where he earned a degree in computer and electrical engineering. McKim & Creed is one of Engineering News-Record's top 500 design firms and top 200 environmental firms in the U.S. The company also operates offices in Daytona Beach, Sarasota, North Carolina, and Virginia.