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Plants Zero in on Wastewater Discharges

Efforts increase to drastically reduce or even eradicate releases

By Seán Ottewell, Editor at Large

Water optimization programs increasingly are focusing on zero liquid discharge (ZLD). Approaching or achieving that milestone may involve many different technologies. No single strategy suits every wastewater, note vendors such as Dow Water Solutions, SUEZ Water Technologies & Solutions, and Veolia.

"Water scarcity and stricter discharge limits are really putting industrial customers in a tough situation. Depending on the severity of the two sides of this equation, customers are being pushed to achieve minimal liquid discharge (MLD) or zero liquid discharge (ZLD) — and we are seeing a trend towards more and more ZLD," says Tina Arrowood, lead research scientist, Dow Water Solutions, Edina, Minn.

The company offers a broad set of technologies to help reduce the cost and energy requirements of treating wastewater. These include ultrafiltration (UF), reverse osmosis (RO), nanofiltration (NF) and ion exchange (IX). The latest additions are the Fortilife CR100, XC70 and XC80 RO elements, which specifically tackle biological and organic fouling, and the XC-N ion-separation membrane, which enables recovery of a large fraction of salts.

"We've really focused product development on technologies that convert large quantities of wastewater into purified, reusable water. RO elements are a fantastic technology for this and are much cheaper than using thermal distillation technologies. Our new filter elements are key to achieving high water recovery from high total dissolved solids (TDS) wastewater, leaving a high-quality permeate that is good enough for re-use," she stresses.

Fouling resistance was a key theme in the development of the new elements; each is designed for the fouling potentials expected within the successive water recovery processes. In addition, the elements must be durable because these harsher, more-fouling environments require more cleaning (Figure 1). Both the membranes and the spiral wound module itself must withstand exposure to extreme pHs, too. Also important is using the elements at a point in the concentration process where membrane separation efficiency is maximized.

TOUGHER CONDITIONS
Figure 1. Wastewater filter elements must contend with increasingly harsh environments. *Source: Dow Water Solutions.*

"The bottom line is: 'Can we concentrate and maximize water removal from the wastewater stream and reduce the amount of water going either to downstream processes such as thermal treatment, or to discharge?'" she explains.

The biggest push towards MLD and ZLD is coming from chemical manufacturers in Northern China and Indian textile producers, two regions posing the twin challenges of water scarcity and discharge restrictions, according to Arrowood. Meanwhile, the power industry increasingly is embracing the approach because of its fluegas desulfurization (FGD) processes. Other pockets also exist, particularly in North America and Europe; there, regulations and corporate sustainability goals, either singly or in tandem, are driving demand in the chemical, and petrochemical sectors as well as among food and beverage makers.

As an example, she cites a project in the coal-to-chemical industry in Northern China, where a large chemical complex typically generates more than 1,500 m3/h of wastewater with a total dissolved solids (TDS) level ranging from 1,000–2,000 mg/L. The plant was recovering and recycling over 65% of this water using conventional fouling-resistant RO products. However, it wanted to reclaim an additional 90% of purified water from the concentrate of the primary wastewater recovery system where TDS exceeds 5,000 mg/L. Deploying Dow Filmtec RO elements enabled the desired water volume reduction, significantly decreasing the cost of the downstream thermal dewatering process for achieving ZLD.

However, capital and operating costs for running a ZLD system represent only one challenge for a treatment plant of this size. Another is dealing with the about 40 t/d of final solid waste salts produced. The high TDS wastewater contains an unusable mixture of sodium sulfate, sodium chloride and a number of other trace contaminants. So, the plant installed a system with Fortilife XC-N elements to treat this complex salt mixture after being concentrated to above 50,000 mg/L using RO elements.

"More than 60% of this water was converted to a purified sodium chloride solution for reuse applications. Moreover, the 40 t/d of waste salts going to the landfill could be reduced by nearly half," notes Arrowood.

Another example involves an industrial park in Asia with a common wastewater treatment facility that long has used RO to reduce the amount of water discharged to the environment in line with the facility's strict discharge permit.

The industrial park hopes to expand by adding new manufacturing facilities. Increasing the wastewater discharge volume would require a new permit. So, the challenge was to recover and recycle even more wastewater while keeping within the existing discharge limit. Complicating matters, that water must be extremely low in both organics and TDS to be suitable for the sensitive production processes on the site.

Installation of Fortilife XC70 RO elements has allowed the facility to recover more reusable water and treat additional wastewater while staying within its discharge limit. This simple upgrade eliminated the wastewater treatment plant as the bottleneck for expansion.

"We are still far from the limits of the capability of XC70 technology in this project. We could add XC80 elements if we had to, or even ultra-high-pressure RO elements. So we have additional options in our toolbox to squeeze out more water before we need to consider the evaporation and crystallization processes required for ZLD," Arrowood emphasizes.

However, RO is approaching its thermodynamic limits, posing challenges for technology development. In response, Dow is working to create synergies between its own membrane developments and other firms' innovative process schemes such as closed-loop designs. "It's important that there is convergence here to meet the demand for technologies that can achieve high water recovery in harsh industrial environments such as high operating temperatures and pHs," she adds.

THREE KEY POINTS

"The primary driver for going all the way to ZLD is regulation/local government mandates. Then there is public perception, so we are seeing more and more desire for good stewardship and being proactive before any new regulations come in. In fact, many companies are now specifying wastewater recovery and ZLD systems in projects in anticipation of the changing regulatory climate," notes Bill Heins, global leader for market development, SUEZ Water Technologies & Solutions, Bellevue, Wash.

Three main points must underpin ZLD strategies, he advises. First, the key to continued innovation and process success lies in collaboration with the client. "All our developments are collaborative. We have to completely understand the process to come up with optimum solutions and products. That will be the face of improvement over the next 10–20 years," he says.

Second, as Arrowood also notes, is the need to develop innovative designs that achieve still more water recovery even as the physical limits of processes such as RO are reached.

Third is economics, especially in areas where freshwater is at a premium and the cost to treat difficult-to-dispose-of wastewaters is increasing.

The implementation of a ZLD project depends on the specific operational challenges. For example, U.S. refineries must contend with five: ageing plants; decreasing freshwater availability; reduced source water quality, e.g., greater brackishness; crude variability; and stringent discharge limits.

ESSENTIAL EVAPORATORS
Figure 2. Meeting very low TDS discharge limits usually requires use of evaporators. *Source: SUEZ Water Technologies & Solutions.*

Typically, membrane bioreactors handle organics in the wastewater stream. To meet TDS discharge limits, a plant usually will call upon technologies such as RO, electrodialysis, brine concentration and crystallization, either alone or in different combinations.

"In the situation where you have to meet very low TDS discharge guidelines, the ZLD design would definitely need evaporators (Figure 2) and crystallizers. Although they are higher-cost unit operations, they are the only way to meet very stringent discharge limitations," he explains.

Also, operators must consider that discharge limits always are evolving. This has led some refineries to adopt the company's ABMet process, which was originally developed to remove nitrates and selenium from wastewater streams in coal-fired power plants.

"The key to any project is always collaboration with the client. You need to understand all aspects of the process to devise the optimum treatment approach and, if five different operations are needed for the optimum approach and we only supply four of the technologies, we will work with other vendors to ensure that the best solution is implemented," adds Heins.

As an example of how profound such collaboration can be, he cites a project with an oil sands company in Alberta aimed at recovering as much water as possible from heavy oil. SUEZ spent three years embedded with the company, gaining a thorough insight into every aspect of its processes. Together, they developed a now patented process that involves feeding the recovered water to an evaporator. The distillate from this then goes to a steam generator, leaving evaporator blowdown containing almost all solutes from the produced water feed. The high-quality high-pressure steam is injected downhole to heat the oil formation, fluidize the oil and allow it to be pumped to the surface.

"This totally new process has been installed at 25 other sites. It is a paradigm shift in the industry," he says.

Manufacturers in India and China are particularly interested in ZLD systems, Heins agrees. In China, the drive is on to reduce the amount of mixed salt wastes going to landfill by instead producing purified salts that can be sold at a profit.

The 700-MW Jingneng Zhuozhou coal-fired power plant in Zhuozhou installed a ZLD system that allows reuse of 99% of FGD blowdown wastewater and produces approximately 10.5 t/d of marketable purified industrial salt. The process begins with three stages of physico-chemical treatment, the last being UF to remove saturated solids. IX resins then take out the ions responsible for water hardness. The next step involves NF and RO. Permeate from RO goes to the cooling towers for reuse while RO reject passes to a thermocompressor-driven forced circulation crystallizer prior to solids dewatering, drying and packaging for sale.

SUEZ is particularly focused on improving NF and RO membrane systems; it is working on new glues and membrane backings to counter temperature and osmotic pressure limitations. One R&D project — a collaborative effort with a refining company — aims to develop RO membranes that can work at 90°C and in very high pH environments. It's a strategy that could reduce or even eliminate the need for expensive heat exchangers in some circumstances.

Another project, spurred by the growing demand for lithium-ion batteries, looks at the recovery and purification of the lithium. "Here we are working on innovative membrane and thermal technologies which can operate in high TDS and high scaling environments," Heins says.

However, companies intent on implementing ZLD and similar strategies can overlook one important issue — materials of construction, he cautions. "The production plant might be built for an operational life of 30+ years, but some of the salts we are recovering are very corrosive. So the treatment plant will need to use the optimum materials of construction to handle this — which can involve more capital expenditure."

THERMAL TREATMENT

Meanwhile, Veolia, Paris, is helping plants achieve ZLD by integrating its proprietary HPD evaporation and crystallization technologies for specific effluent demands.

MULTIPLE INPUTS
Figure 3. Effluent plant handles 12 different wastewater streams and provides five qualities of recycled water. *Source: Veolia.*

Its biggest ZLD project to date is at Shell's Pearl gas-to-liquids (GTL) project in Qatar. The onshore plant produces 140,000 bbl/d of GTL plus 120,000 bbl/d of associated condensate and liquefied petroleum gas.

Twelve different wastewater streams enter the 45,000-m^3/d effluent treatment plant (Figure 3) at eight different locations. The plant must supply five different qualities of recycled water.

Veolia's treatment strategy includes flocculation, aerobic biological treatment, submerged UF, RO, evaporation, crystallization and sludge dewatering.

UF and RO are used to return water to the GTL process. Meanwhile, RO brine treatment as well as evaporation and crystallization stages ensure that ZLD is achieved, leaving only salt behind.

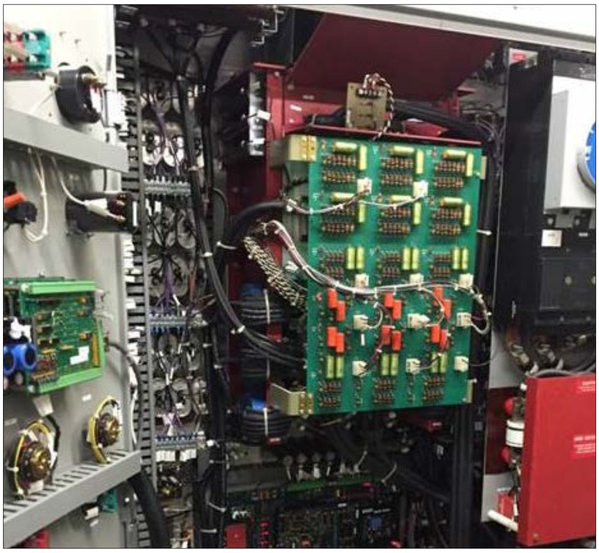
Retrofit Improves Water Treatment Plant's Efficiency

Compact stand-alone matrix drives replace aging 18-pulse drive

By Chris Jaszczolt, Yaskawa America, Inc.

A Massachusetts-based municipal water treatment facility needed to upgrade its aging 350-hp 18-pulse drives. Its four 350-hp pumps run 25 mgd on average but can reach 75 mgd in less than an hour with heavy rainfall. Three of these pumps can satisfy this peak demand. The fourth pump is used as backup in case one of the three were to fail. One pump's failure during peak flow without a backup could lead to a precarious situation. If the backup pump and the designated lag pump were to fail, the influent main's backup could cause overflowing manholes and flooded streets.

Based on the facility manager's recommendations, the city decided to move forward with updating all of the influent drives. It began by upgrading its aging 350-hp Robicon 18-pulse pump drives (Figure 1), which had become time-consuming and costly to keep in working order.



PRE-RETROFIT COMPLEXITY
Figure 1. Before the retrofit, the drive setup was very complex with a significant amount of cable and wiring.

RETROFIT UPDATE

It turned to a local Yaskawa drives distributor, which recommended a reliable, compact and cost-effective retrofit with Yaskawa's U1000 Industrial Matrix drive. The distributor realized that a complete replacement likely would require a different size cabinet. The facility's staff also would need time to become familiar with the new system.

After contacting a sister facility that already was using Yaskawa drives, the facility manager and the city agreed with the retrofit option.

POST-RETROFIT EFFICIENCY
Figure 2. After the retrofit, the system was simpler, more compact and more efficient.

Because the drive is a stand-alone, low-harmonic drive with regenerative capability, many components inside the cabinet were unnecessary and thus eliminated. The previous system's circuit breaker also was reused.

RESULTS

The new drive meets the input harmonic current capabilities of the previous 18-pulse package at rated power and also provides excellent harmonic current levels throughout the load range.

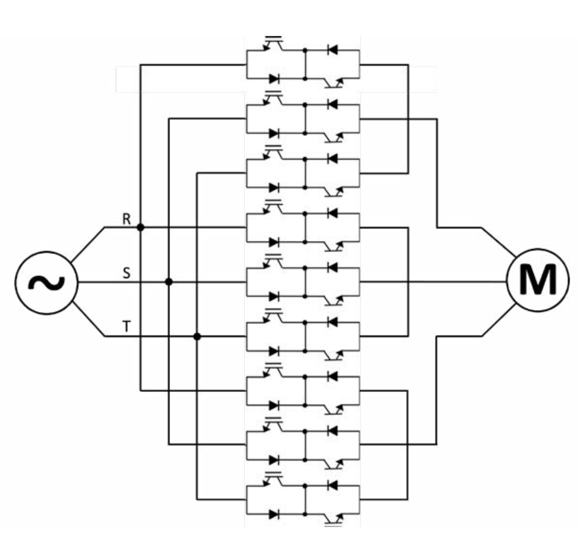
The efficiency improvement was so dramatic that the water treatment facility was able to shut off the additional cabinet fans required to cool the previous system. It realized an immediate increase in efficiency from reducing the building's cooling requirements.

Reusing the existing cabinet saved space but also meant that almost nothing had changed for the staff. All the old controls on the door easily were integrated into the new drive (Figure 2).

The drive provided all of these benefits at a cost of approximately half of a new 18-pulse configuration. As a result of this project, the water treatment facility has moved forward with updating several more of its outdated 18-pulse drives with the U1000.

HOW DO MATRIX DRIVES WORK?

The Matrix drive design removes the DC bus by using nine bi-directional insulated gate bipolar transistors (IGBTs) in a matrix arrangement to generate the variable-frequency AC output directly from the AC input. This reduces the effects of



MATRIX DRIVE TOPOLOGY
Figure 3. Bi-directional IGBTs help reduce the effects of harmonic distortion on the output signal, resulting in a smoother output waveform.

harmonic distortion on the output signal dramatically, producing a smoother, cleaner output waveform. With no DC bus to charge, the associated nonlinear input current draw can be eliminated, providing cleaner power to the load. Figure 3 shows the Matrix topology.

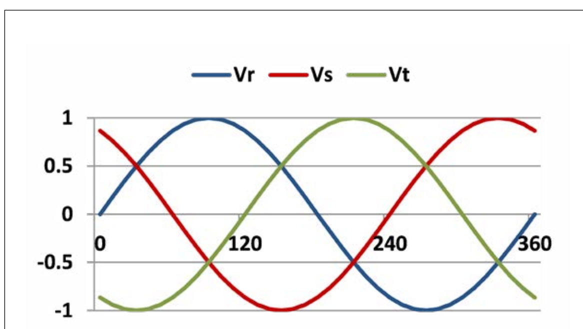
Note that, in the Matrix design, any input phase can be connected directly to any output phase at any time. The key to the Matrix operation is its ability to turn the bi-directional switches on and off at the correct times to generate the proper output voltage and frequency required to operate the motor.

To better understand, let's look at the three input phase voltages, shown in Figure 5.

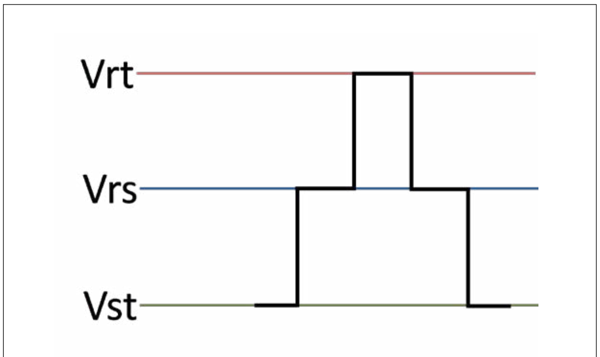
In operation, the control built into the Matrix variable-frequency drive (VFD) monitors the voltage difference between each of the phases continually.

All drives use a pulse width modulation (PWM) waveform to generate motor voltage, including the Matrix drive. A standard drive pulses the DC bus to the motor to create the output voltage waveform. The time each pulse is ON (the pulse's width) helps to determine the output voltage and final root mean square (RMS) voltage of each cycle of voltage.

Instead of using a DC bus, the Matrix drive pulses the motor using its input voltage (Figure 5). This is done in two steps. The low- and mid-input voltage are used for the first step and the mid and high voltage are used for the second step. The reverse order is used to turn off the pulse. This process is repeated over and over to generate the PWM output waveform



INPUT PHASE VOLTAGES
Figure 4. The control built into the Matrix VFD monitors the voltage difference between each of the phases.



MATRIX STEPPED PULSE
Figure 5. The Matrix drive pulses the motor using its input voltage in two steps. The low- and mid-input voltage are used for the first step and the mid and high voltage are used for the second step.

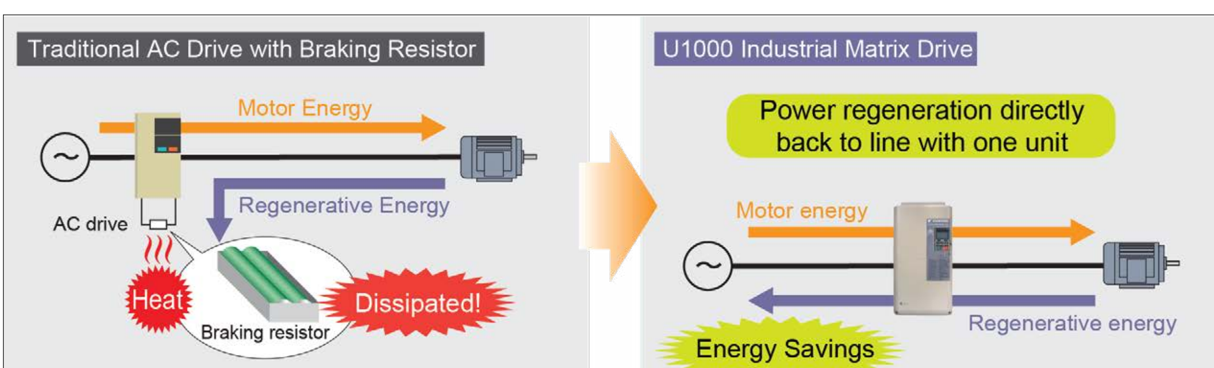
constantly adjusted along with the ever-changing three-phase input voltage.

The continuous use of the input voltage means current constantly is being drawn. Therefore, the Matrix drive does not mitigate harmonics. Instead, it draws input current naturally with less than 5% iTHD automatically as it provides motor control.

MATRIX DRIVE REGENERATION

In addition to the low harmonics and near-unity power factor, the Matrix design also provides energy savings through regeneration. When a motor is being driven by a load, as opposed to driving the load, it acts as a generator, sending the extra power back to the VFD. The extra regenerative energy then is put pack onto the grid to be dispersed to other loads on the grid, which reduces the utility power demand. Examples include applications such as pump jacks, where the load oscillates between motoring and regeneration, and downhill conveyors that are in a continuous regenerative state.

In conventional drives, dynamic braking resistors can be used to divert the regenerative energy away from the VFD and prevent a DC bus overvoltage condition. The Matrix drive's nine bi-directional IGBTs enable the regenerative energy to be



REGENERATIVE ENERGY
Figure 6. The Matrix drive offers cost savings by directing regenerative energy back to the supply.

directed back to the supply to be credited against the user's power bill (Figure 6).

MONITORING

Some Matrix VFDs can monitor power in several ways to give instant feedback on energy saved. When provided with the $/kwh billing rate, the drive's display can show the following information on request:

- Power output
- Power consumption
- Regenerative power
- Power saved
- Power bill

REDUCED COMPONENTS

Other means to mitigate the harmonics of VFDs exist, including active front ends and multi-pulse transformers, which require additional components in combination with the VFD, adding bulk, cost and wiring connections.

In comparison, the Matrix design accomplishes low harmonics all within the drive — three wires in, three wires out. ■

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Oil Recycling Company Presses On

Pipe press helps speed installation and reduce costs at new oil recycling facility

By Kristen White, Viega

Sustainability businesses are booming in Ohio. From energy to oil, companies are making their mark in the renewable resources industry. One such company is Valicor, who recycles oil, light bulbs, batteries, oily wastewater, plastic, cardboard, paper, ballasts, electronics, inks and more.

Every year, some of the largest companies in North America — including Honda, Ford and Harley Davidson — rely on Valicor to treat over 200 million gallons of wastewater. Most wastewater is treated at one of Valicor's eight centralized waste treatment (CWT) facilities located in Ohio, Alabama, Missouri and West Virginia (Figure 1).

Valicor also helps customers treat wastewater streams in-line with manufacturing processes by designing, building and servicing industrial oil recovery solutions. One of

OIL RECYCLING PROCESS
Figure 1. Valicor uses its eight waste treatment facilities to recycle oil and wastewater.

PIPE INSTALLATION
Figure 2. Thousands of feet of pipe, with a variety of flanges, tees and 90-degree elbows, were installed over the course of four months.

the people responsible for overseeing new builds and remodels for Valicor is Steve Hayes, project manager for Valicor. Valicor asked Hayes to work on a new oil recycling facility in Middletown, Ohio.

In 2016, Valicor recovered more than 36 million gallons of oil. That's a lot of oil for one company to process in one year. Even with multiple facilities in the mix, Hayes knew he needed to look for a solution that would speed up the building process.

The process fluids Valicor uses to process the oil have varying pH levels, so finding a product that could withstand those changes was important.

"I had been looking for something that could withstand the full spectrum of pH levels and was reading on the Internet, and that's how I found out about Viega," Hayes said.

"When we process fluids to clean them up it can be from a 1 pH to a 10, so we always use the 316 stainless and that will withstand the difference in pH levels,"

"I would say we probably cut our [installation] time in half."

— Steve Hayes, project manager for Valicor

he explained. "It also has to be able to withstand temperatures of 180°F, so that's why we don't use plastic."

The best option for Valicor was to choose Viega's ProPress for 316 stainless steel. Thousands of feet of pipe, with a variety of flanges, tees and 90-degree elbows, were installed over the course of four months (Figure 2). Out of that, Hayes said they spent half as much time pressing as they did welding.

"We used Viega ProPress in sizes ranging from two to four inches and it's really pretty easy to install," Hayes said. "I would say we probably cut our time in half."

According to the Viega sales representative for that region, this was one of the larger Viega jobs in the area. Although the rep's support of the project wasn't needed much, Hayes said he knows Viega will be there if he needs them

"He was great. I got his card and he told me I could call him anytime day or night. I haven't had to call him yet, but I might sometime just to see if he was serious," Hayes joked. "But that's how more companies should be. If you have something you should stand behind it."

STAINLESS STEEL PIPE FITTINGS
Figure 3. Viega's ProPress for 316 stainless steel cut pipe installation time in half at Valicor.

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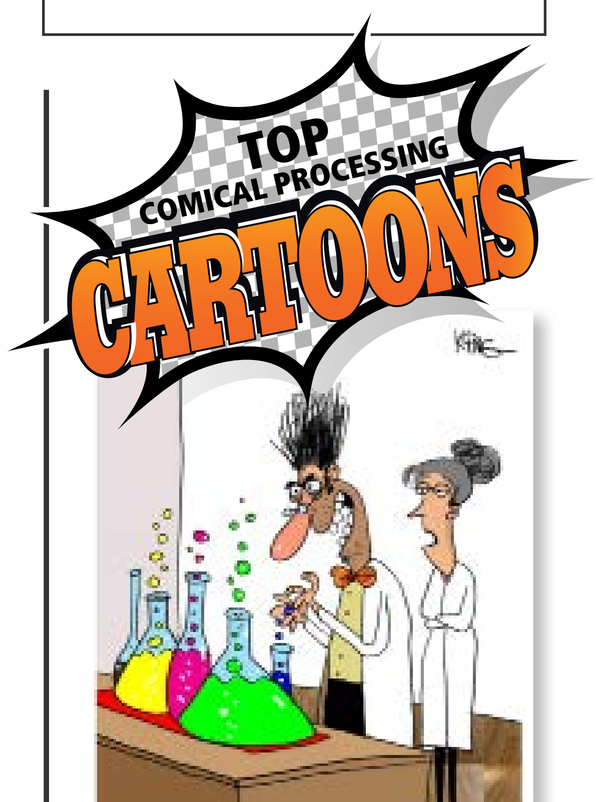

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