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The Blue Valley Fish Culture Station

Treatment and Beneficial Use of Abandoned Mine Drainage Little Toby Creek Watershed, Pennsylvania

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Introduction:
Acidic drainage containing dissolved metals from abandoned mines is a major cause of impaired water quality in many areas of the country, the coal mining regions of Pennsylvania being especially hard hit. With most of the active mining having taken place in the late 19 and early 20 th centuries, there are no responsible parties available to remediate the problem with the result that the state and federal governments have taken up this task. Pennsylvania has been a leader in the area of remediation of abandoned mine drainage with long running programs such as Scarlift and Growing Greener providing needed funding. In particular, the Growing Greener program has encouraged some innovative projects, such as the Blue Valley Fish Culture Station.

The "Blue Valley" abandoned mine discharge has a flow which varies between 250 and 500 gpm, a pH of 6.1, and contains on average 19 mg/l total iron (almost 100% ferrous) and 3.8 mg/l total manganese. An interesting property of this drainage was that upon aeration, the pH would increase to as high as 7.2 due to removal of dissolved carbon dioxide, resulting in oxidation of the iron with subsequent precipitation without addition of any alkaline materials.

The idea for the Blue Valley Fish Culture Station was formulated by William Sabatose, President of the Toby Creek Watershed Association, Inc., (TCWA - a volunteer group organized in 1967 to address abandoned mine drainage in the Little Toby Creek watershed), and a member of the Pennsylvania Fish and Boat Commission (PFBC), in late 2000. This idea combined treatment of the Blue Valley mine discharge with subsequent use of the treated water as makeup to a recirculating fish culture station. This would solve two problems; treatment of a significant discharge of abandoned mine drainage and demonstration of an advanced concept in fish culture, water recirculation.

ProChemTech International, Inc., (PCT), a water management firm organized in 1987 by former employees of the Brockway Glass Company, was approached concerning the technical aspects of the project in mid 2001 based on previous work at the Integrated Food Technologies recirculated water fish culture station in Emmaus, PA, the Brandy Camp abandoned mine drainage treatment system upgrade, and extensive industrial wastewater treatment expertise. On review of the idea, PCT agreed to a design – build project for treatment of the incoming abandoned mine drainage and out-going fish culture station wastewater.

Funding for the first phase of the project, treatment of the mine water discharge and a demonstration fish grow out unit, was obtained by the TCWA from the Pennsylvania Growing Greener Program, Pennsylvania Department of Environmental Protection, PFBC, Federal Office of Surface Mines, and The Stackpole-Hall Foundation.

Design Considerations

Based on treatability data developed by William Sabatose, a basic design for treatment of the incoming mine discharge consisting of a diversion structure, lift station, aeration tank, flocculant polymer add/mix tank, inclined plate clarifier, multimedia filters, and sludge dewatering was proposed. A concept drawing of the system as designed is attached. Maximum flow capacity was set at 500 gpm, with the long term average expected to be 300 gpm. In addition to the aeration pH adjust-oxidation, backup subsystems for pH adjustment by caustic soda addition, and oxidation by potassium permanganate addition, to the aeration tank were provided based on past experience by ProChemTech with treatment of heavy metals containing wastewaters.

An initial concern by the PFBC was the effect of the flocculant polymer proposed, PCT 8727 a long chain anionic polyacrylamide product, on fish. To answer this concern, PCT provided a 5 gpm pilot inclined plate clarifier unit which was set up in the field at the Blue Valley mine discharge site to treat water using the proposed polymer for a bioassay study. The bioassay study was undertaken by Free-Col Laboratories of Meadville, PA, with the pilot unit treated mine water being delivered to their laboratory on October 28, 2002.

Based on their laboratory bioassay study, Free-Col concluded that the polymer treated mine drainage water was not toxic to trout. This conclusion was accepted by the PFBC as sufficient to satisfy their concern.

In addition to using carbon dioxide removal by aeration for pH adjustment, two other innovative processes were incorporated into the abandoned mine wastewater treatment system design, use of inclined plate clarification for removal of precipitated iron and sludge recirculation.

Inclined plate clarification has been used in industrial wastewater systems for many years as the process provides for high capacity at minimal cost in a small area. Until the recent Brandy Camp abandoned mine drainage system upgrade, another TCWA – PCT-Growing Greener project, this process had never been applied to treatment of acid mine drainage. Based on the excellent results obtained in the Brandy Camp project, inclined plate clarification was selected for the BVFCS project. Specific features of the proprietary inclined plate clarifiers designed and built for the project include the use of short, 36 inch, length plates, 60 degree plate angle, and polished fiberglass plate construction, In addition, the clarifiers are operated with no sludge blanket, all settled sludge is either recirculated or sent to the sludge holding tank.

Sludge recirculation has been used in a substantial number of industrial heavy metals treatment systems designed by PCT since 1987 to obtain significant improvements in treated water clarity, improved settling rate, and denser sludge. The BVFCS is the first acid mine drainage treatment system that has incorporated this innovative technology. With sludge recirculation from the clarifier, total iron levels in the aeration tank are typically 1000 to 1500 mg/l, not the 15 to 20 mg/l as in a standard system design.
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Design/Construction
Based on the preliminary design, PCT proceeded with final system design and construction of the BVFCS. Specific process steps and equipment provided are as follows.

Diversion Structure
A concrete diversion structure was designed and installed to divert the mine discharge to a wet well within the Blue Valley Fish Culture Station building. The structure was equipped with valves and an overflow to permit work within the wet well and was totally sealed to prevent biological contamination of the mine discharge water so as to protect the fish from outside infection or disease.

Piping to the wet well is completely underground with the water flow being by gravity.

Wet Well/Pumps

A concrete wet well is provided inside the BVFCS building and is equipped with two Goulds two stage vertical turbine pumps, 7.5 hp, 1750 rpm, TEFC motors, 1750 rpm, rated 500 gpm each at 40 ft tdh. The pumps are each capable of providing 100% of system rated flow and are switched for automatic backup in case of primary pump failure.

Building equipment layout is such that easy access is provided for future maintenance.

Aeration (Mix #1) Tank
This tank is constructed of welded steel and has a volume of 5000 gallons. Compressed air is supplied by two 7.5 hp blower units, one on line and one backup, rated at 93 cfm @ 7 psi and injected in the tank via fine bubble diffuser assemblies at the bottom of the tank. The water in the tank is saturated with oxygen at this point.

Influent water carbon dioxide content, typically around 55 mg/l, is reduced by over 50%, to around 20 mg/l, by the aeration in this tank, which results in a sufficient increase in the water pH.

With the pH increase, oxidation of ferrous iron to ferric iron takes place with subsequent precipitation. As noted, mixed liquor suspended solids, mainly iron hydroxides, are typically maintained at in this tank at 1500 mg/l as total iron via sludge recirculation. The high level of iron solids present provides an ideal substrate for further precipitation of iron from solution, resulting in substantially larger sludge particles with a much higher density than obtained without sludge recirculation.

A 5% solution of potassium permanganate is made down on-site by a supplied mix tank. This solution is added to the aeration tank by a chemical feed pump drawing directly from the mix down tank. Feed of potassium permanganate at the rate of 8 mg/l has been found to be optimum for iron removal with the aeration and sludge recirculation in use.

Mix #2, Polymer Addition

A 0.25% solution of PCT 8727, a high molecular weight anionic polymer, is added to the flocculant polymer mix tank to flocculate the iron particles precipitated in the aeration tank by oxidation and pH increase. Mix 2 is again of welded steel construction with a capacity of 5000 gallons. This tank is mechanically mixed by a 1750 rpm, 3 hp motor driving a 4 bladed, 24 inch diameter prop at 300 rpm through a gear reduction box.

Madedown polymer is supplied by a chemical pump from a PCT designed and manufactured dual tank automatic polymer mix down and supply subsystem. This system is completely automatic requiring only that the operator charge dry polymer into the hopper as needed. Features of the subsystem include mixing in one tank, followed by transfer to a second tank which provides aging of the mix and the reserve for pumping.

From mix tank 2, the water flow is split between the two 250 gpm rated inclined plate clarifiers for removal of iron hydroxide suspended solids. Clear water overflows the effluent weirs and discharges by gravity into a clear well tank while sludge is pumped from the bottom of each clarifier by two progressive cavity pumps each equipped with variable speed drives. One pump, 0-26 gpm, on each clarifier discharges to the sludge holding tanks, while the other, 0-50 gpm, provides a recycled sludge flow back to the aeration tank.

Each clarifier is provided with a plate pack consisting of 88, 3 feet X 4 feet polished fiberglass plates set at a 60 degree angle giving a total projected settling area of 528 square feet per unit. Loading at the maximum design flow rate is 0.47 gpm/sq ft, somewhat higher than the commonly used criteria of 0.25 gpm/sq ft for hydroxide precipitation. The higher flow rate is obtainable due to the sludge recirculation producing a much denser sludge than typical for iron hydroxide. Influent is directed via a stilling well into the bottom of each plate pack with clarified water discharging at the top, sludge settling by gravity into the bottom of the clarifier.

Side view of clarifier #1, aeration and mix tank #2 to the immediate rear, flowed by clarifier #2 and the sludge holding tanks against the building exterior wall. The potassium permanganate mix down tank is to the right at floor level.

Following is a top view of a clarifier effluent weir showing clear water discharge and the top of a plate pack.

Note that plates are designed to be self cleaning and these units have not been cleaned, at this point in time, for the three months since start-up. Long term, the clarifiers have been cleaned once in three years, and that mainly to check the steel coating for signs of corrosion. Typical turbidity values for clarifier effluent are below 0.1 ntu as measured by an in-line unit.

Clear well, 5600 gallon capacity, turbidity monitor, and dual filter pump skid; clarifier discharge enters the top of the tank from the right hand side.

Clearwell pumps are Goulds end suction centrifugal, type SSH, equipped with 3500 rpm 20 hp TEFC motors and rated 500 gpm each at 110 foot tdh. As with the wet well pumps, automatic pump switchover is provided for in the event of pump failure.

Two multimedia pressure filters are provided to polish the clarifier discharge of any remaining suspended solids prior to the water entering the distribution tank. These filters have three separate media layers; anthracite, sand, and garnet; to provide excellent solids removal and retention while minimizing backwash cycles. The units are completely automatic, backwash based on pressure drop across the units with a PLC controller.

Due to the low turbidity produced by the inclined plate clarifiers operating with sludge recirculation, future systems will not be equipped with multimedia filters.

Fish tank #2 using treated, abandoned mine water as the sole water supply source is one of three, 25 foot diameter, fish grow out tanks containing approximately 15,000 rainbow and brook trout. Trout were first introduced to the tanks December 15, 2005; the above picture was taken February 7, 2006, with the fish being stocked in April and May, 2006.

Water from the fish culture tanks is discharged to a large pond with a capacity estimated at 10 million gallons prior to flowing into the Little Toby Creek. This pond serves to remove any residual solids from the fish tanks prior to discharge and also supports a good fish population itself.

Sludge produced by operation of the BVFCS is first pumped from the clarifiers to sludge storage tanks. From the storage tanks it is pumped to a 15 cubic foot capacity recessed plate filter press for dewatering into a solid cake for either disposal or use as a raw material in manufacturing. This sludge cake is a high purity, mostly iron, sludge due to lack of any alkaline reagent addition.

Dewatered sludge is a “dry” cake, generally about 23% solids with the solids consisting of about 75% iron hydroxide with minor amounts of calcium and silicon oxides. Further work is planned in use of this material as raw material for production of wastewater coagulants and/or ceramic pigments. At the current flow rate of 260 gpm, about 345 lb/day of sludge cake is produced. Once the water treatment system goes to its rated flow of 500 gpm, sludge cake production will increase to 663 lb/day.

Note that in contrast to most abandoned mine drainage treatment projects where the removed pollutants are typically retained in open ponds subject to debris contamination, the material at the BVFCS is both dewatered to an easily handled “cake” and is keep clean, free from contamination. A clean, dewatered “cake” will facilitate reuse of this material in the future.

Since construction of the BVFCS, the development of the Marcellus tight shale gas field in the surrounding area has resulted in a significant demand for hydrofracture water in amounts of 2 to 5 million gallons per developed well. EOG Resources, Inc., (EOG) contacted PCT concerning obtaining water needed for several hydrofracture projects in the BVFCS area in late 2008. After some discussion, it was agreed that the BVFCS would supply hydrofracture water to EOG and that in return the TCWA would receive a donation for continued operations, which would help off-set decreasing state support.

Tankers Loading Water at BVFCS Pond

This further reuse of the treated acid mine drainage water was first accomplished in February, 2009, when approximately 1.5 million gallons of water was obtained from the BVFCS final pond for use in makeup of Marcellus gas well hydrofracture water. This is believed to be the first use of treated acid mine to makeup gas well hydrofracture water.

Results

- The first phase of the BVFCS is providing treatment of 300 to 500 gpm of abandoned mine drainage with beneficial reuse of the water as makeup to a fish culture station.

- At full flow, approximately 660 lbs/day of iron hydroxide sludge will be prevented from entering the waters of the Commonwealth.

- Carbon dioxide removal by aeration has been demonstrated as an effective means to increase the pH of an acid mine drainage wastewater

- Use of inclined plate clarifier technology has been demonstrated with acid mine drainage, the results obtained, discharge turbidity generally below 0.1 ntu, are far superior to previously used clarification technology.

- Use of sludge recirculation has been demonstrated to increase produced sludge density allowing use of more compact, less costly inclined plate clarifiers.

- Pollutants, mainly iron, are reduced to a clean, easy to handle sludge cake which is suitable for future resource recovery.

- Reuse of treated acid mine drainage as Marcellus gas well hydrofracture makeup water has been demonstrated

The TCWA continues to run the BVFCS with one operator and a mix of public and private funding.

About the Authors

Timothy Keister, CWT, holds a B.Sc. in Ceramic Science from Penn State and is the Chief Chemist/President at ProChemTech International, Inc. He is an AWT Certified Water Technologist, Fellow of the American Institute of Chemists, Senior Member of the American Institute of Chemical Engineers, and member of ASHRAE, USGBC, Cooling Technology Institute, and the Water Environment Federation. Some spare time is also devoted to activities as Chairman of the Brockway Area Sewerage Authority and Technical Director of the Toby Creek Watershed Association.

James Sleigh holds a B.Sc. in Environmental Science from Penn State and is the Vice President, Engineered Services Division, at ProChemTech International, Inc. He is a licensed water and wastewater treatment plant operator and has been involved with design, construction, and operation of over 50 wastewater treatment systems.

William J. Sabatose is a founding member and President of the Toby Creek Watershed Association of Elk and Jefferson Counties. He also owns and operates Analytical Services, Inc., where he is the Chief Analyst, is well known as an advocate of clean water, and, in his spare time, has served as a Commissioner, currently Chairman, of the Pennsylvania Fish and Boat Commission for many years.

Appendix A, Analytical Results, Sampled 02/07/06

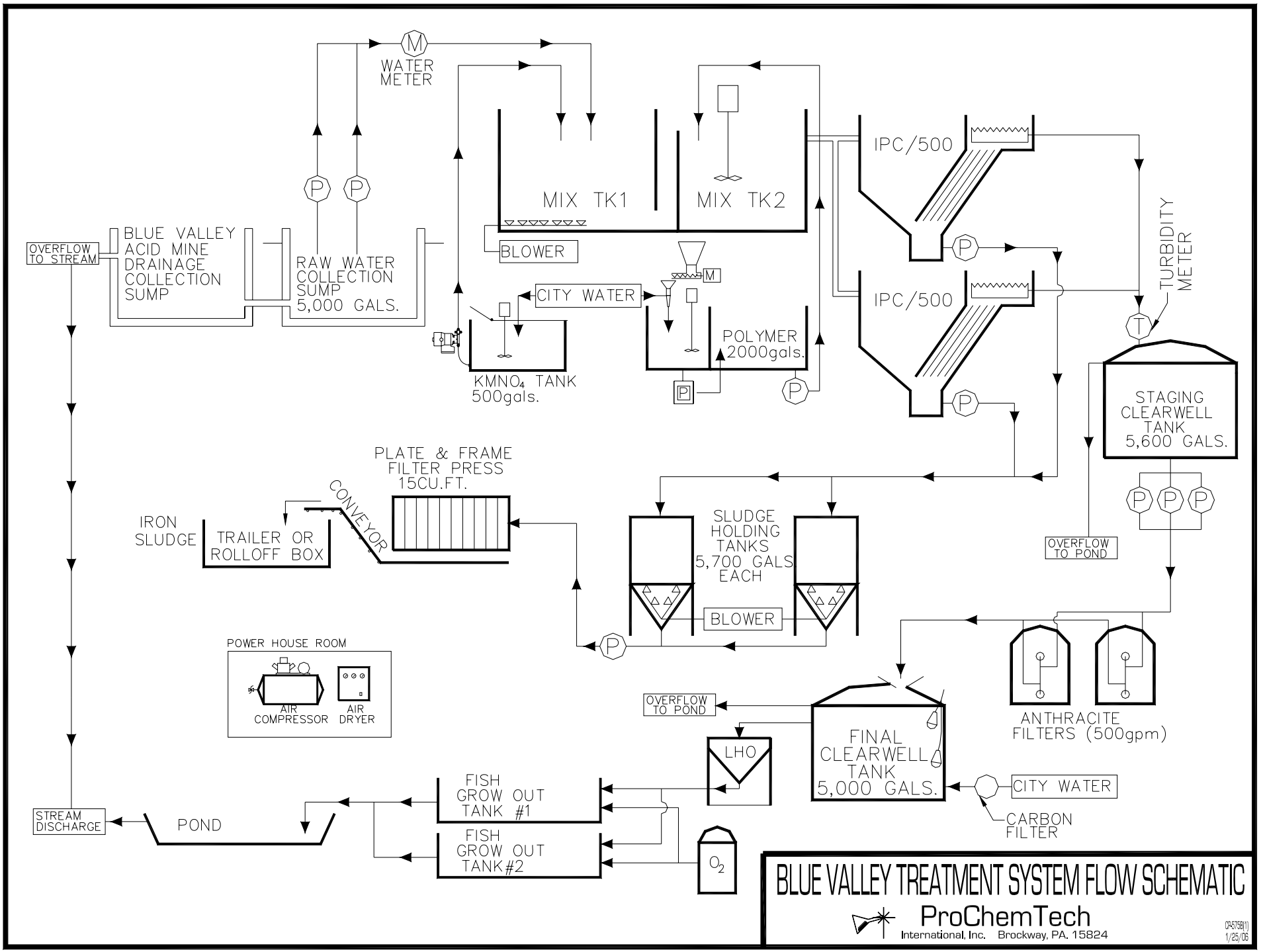
Parameter	Influent Raw Water	Clarifier Effluent
pH	6.30	6.65
total alkalinity	190	175
total acidity	6	<1
total iron	13.7	0.55
carbon dioxide	54.9	20.7
dissolved iron	11.8	0.42
total manganese	3.01	4.72
total calcium	220	226
total magnesium	60.2	61.2
conductivity	1511	1480
suspended solids	< 1	< 1
turbidity		0.34

In addition to these raw water and clarifier effluent results, iron levels were tracked through the process with the following results obtained.

sample location	total iron	dissolved iron
aeration tank effluent	1249	0.51
flocculant tank effluent	1105	0.31
filter effluent	0.40	0.32

A sample of sludge press cake was analyzed with the following results obtained.

Parameter	Result as % Dry Weight
Total solids	23.0
Total iron as Fe_2O_3	76.6
Total Manganese as MnO_2	0.47
Total calcium as CaO	2.74
Total magnesium as MgO	0.12
Total silicon as SiO_2	2.37



BLUE VALLEY TREATMENT SYSTEM FLOW SCHEMATIC

ProChemTech International, Inc. Brockway, PA. 15824

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