INNOVATIVE DESIGNS FOR POLYPROPYLENE TANKS[1]

Jacques Leroyer[2]
Robert Garness[3]
William Pugh[3]

Abstract
Polypropylene process equipment has steadily gained acceptance for use in the carbon and stainless steel industries since the first pickling tanks were introduced in 1970's by Allegheny Plastics, Inc. (now owned by Siemens). Siemens SIROLL [CIS] Allegheny Tanks are being used for surface treatment equipment in extremely corrosive environments that include most acids, alkalis, and plating solutions at temperatures up to 100° C. The engineering, design, and fabrication of this equipment has progressed to the stage that polypropylene is widely accepted for many process line applications. Trustworthy designs can now be produced using the engineering properties of this material. Siemens' experience with the design of steel mill duty polypropylene equipment has resulted in long lived plastic tanks in the most rigorous service. We have developed design solutions to answer the questions of material choice, expansion/contraction, elevated temperatures, strip control, and protection. Innovative designs have been developed through the collaboration of steel industry personnel with plastic designers. This cooperation has revolutionized process lines by providing cleaner, lighter, less costly equipment that is easily repaired and requires minimal maintenance. Polypropylene equipment is now the latest technology for replacing tanks on existing deep catenary type and on new shallow turbulent type pickling lines. Siemens SIROLL [CIS] Allegheny Tanks group are the pioneers and designers of polypropylene tanks for these applications.
Key words: Polypropylene; Pickling tanks; Corrosion resistance; Plastic tanks.

PROJETOS INOVADORES PARA TANQUES DE POLIPROPILENO

Resumo
Os tanques da Siemens SIROLL [CIS] Allegheny Tanks estão sendo utilizados em equipamentos de tratamento superficial em ambientes extremamente corrosivos, incluindo a maioria das soluções ácidas, alcalinas e de chapeamento operando a temperaturas de até 100°C. A engenharia, projeto e fabricação destes equipamentos se desenvolveram até o ponto em que o polipropileno é amplamente aceito para muitas aplicações em linhas de processo. Projetos confiáveis podem ser agora implementados usando as propriedades de engenharia deste material. A experiência da Siemens com o projeto de equipamentos de polipropileno para aplicações siderúrgicas tem resultado em tanques plásticos de grande durabilidade sob as mais rigorosas condições operacionais.
Palavras-chave: Tanque para linha de decapagem; Polipropileno

[1] *Technical Contribution to the 45th Rolling Seminar – Processes, Rolled and Coated Products, October 21st to 24th 2008, Ipojuca - Porto de Gainhas - PE*
[2] *Siemens VAI Metal Technologies, France*
[3] *Siemens Energy and Automation, Metal Technologies, USA*

This paper presents the advantages of using polypropylene for process equipment, the history of its use in the steel industry, the engineering and design criterion, and the innovative application of this material to tanks on new and existing pickling lines.
In 2007 Siemens E&A Inc. acquired all of the Allegheny Process Equipment assets that originally belonged to Allegheny Plastics, Inc. In 2008 Siemens introduced the Siemens Siroll ^{CIS} Allegheny Tanks brand.
The Allegheny group is the originator and pioneer of polypropylene tanks for carbon and stainless steel strip pickling. They have performed this service since 1964.

Figure 1 – Inclined Plate Clarifier (4 M high)

BENEFITS OF POLYPROPYLENE

The benefits of polypropylene as a material for the construction of process equipment include:

- Excellent chemical and corrosion resistance
- Long life span
- Strong, tough and resilient material
- Cost effectiveness
- Light weight
- Easily repaired
- Excellent thermal insulating properties
- Excellent electrical insulating properties
- Readily thermo-formed

- Readily welded
- Easily cut and machined

We expect 30 years life for carbon steel applications and up to 20 years for stainless steel applications.

TYPES OF POLYPROPYLENE

Polypropylene materials of interest to the process equipment designer are limited to homopolymer and copolymer polypropylene plus flame retardant grades of these types.

Copolymer polypropylene is the material of choice for applications that must stand substantial mechanical abuse. Homopolymer polypropylene is stiffer than copolymer and is used for equipment that sees little or no direct impact. Copolymer material is tougher, less brittle and more suitable for most steel mill applications. Siemens uses copolymer material for all pickling tank applications.

At extreme cold temperatures, homopolymer polypropylene becomes brittle and is susceptible to crack initiation and propagation from notches and sharp corners.

Flame retardant grades of polypropylene are available. Because of poorer properties, as the result of the flame retardant additives, these materials are limited to lower stress applications such as fume exhaust covers and ductwork.

COST EFFECTIVENESS

The initial installed cost of process equipment fabricated from polypropylene can be lower than traditional materials. The installation cost is lower because the installation is simplified and much less time consuming, especially for cases where there is no longer a need for brick lining of the tanks.

There are many long-term advantages that favor this material's application. Maintenance costs are reduced since polypropylene is a monolithic material that has the same corrosion resistance throughout. There is no need for external maintenance since corrosion resistant coatings are not required. Also, internal maintenance is minimal and it can be accomplished quickly. Simple welding techniques are used to make repairs and modifications without extensive preparation. There is no time lost for curing or other delays. There are many reports of a significant reduction of maintenance costs through the use of polypropylene construction.

Polypropylene tanks are fabricated offsite and are shipped ready to install. Long tanks can be manufactured in sections and welded together on site. Tanks up to 28 meters long have been installed in one piece. Because of the light weight of polypropylene equipment, the support structure is less expensive.

There is a significant time savings when replacing existing tanks. For many pickling tank replacements several days per tank can been saved.

Also, the thermal qualities of this material provide the same insulation value as brick linings in steel tanks.

For process equipment, polypropylene has usable temperature range from 4°C up to 100°C. At extreme low temperatures brittleness becomes a design consideration. At elevated temperatures, loss of strength and stiffness must be considered in the design and additional reinforcement provided.

ENGINEERING DESIGN AND STRESS ANALYSIS

Design engineers use the DVS-2205, Part I (a German thermoplastic design standard) "Design calculations for containers and apparatus made from thermoplastics characteristic values." This reference provides the design values for material strength and creep modulus and how to vary those design values with the type of welding, chemical exposure, design life, and type of loading, i.e. static or cyclic. However, Siemens' experience has shown that these DVS standards are the minimum requirement and, often, additional reinforcement is needed for steel mill duty service to assure satisfactory equipment life.

A successful polypropylene equipment design considers the allowable stresses of the material, the deformation under load, and the thermal expansion experienced by the equipment. The thermal expansion of polypropylene can be expected to be nearly eight times that of carbon steel. This makes thermal expansion a significant concern to be addressed in the design of polypropylene process equipment.

The design of polypropylene process equipment, using the appropriate design parameters and material properties, can be completed with a combination of hand calculations and computer-run Finite Element Analysis (FEA). Field measurements of fabricated polypropylene structures indicate the linear-elastic FEA approach to be a viable and relatively accurate prediction of equipment deformations.

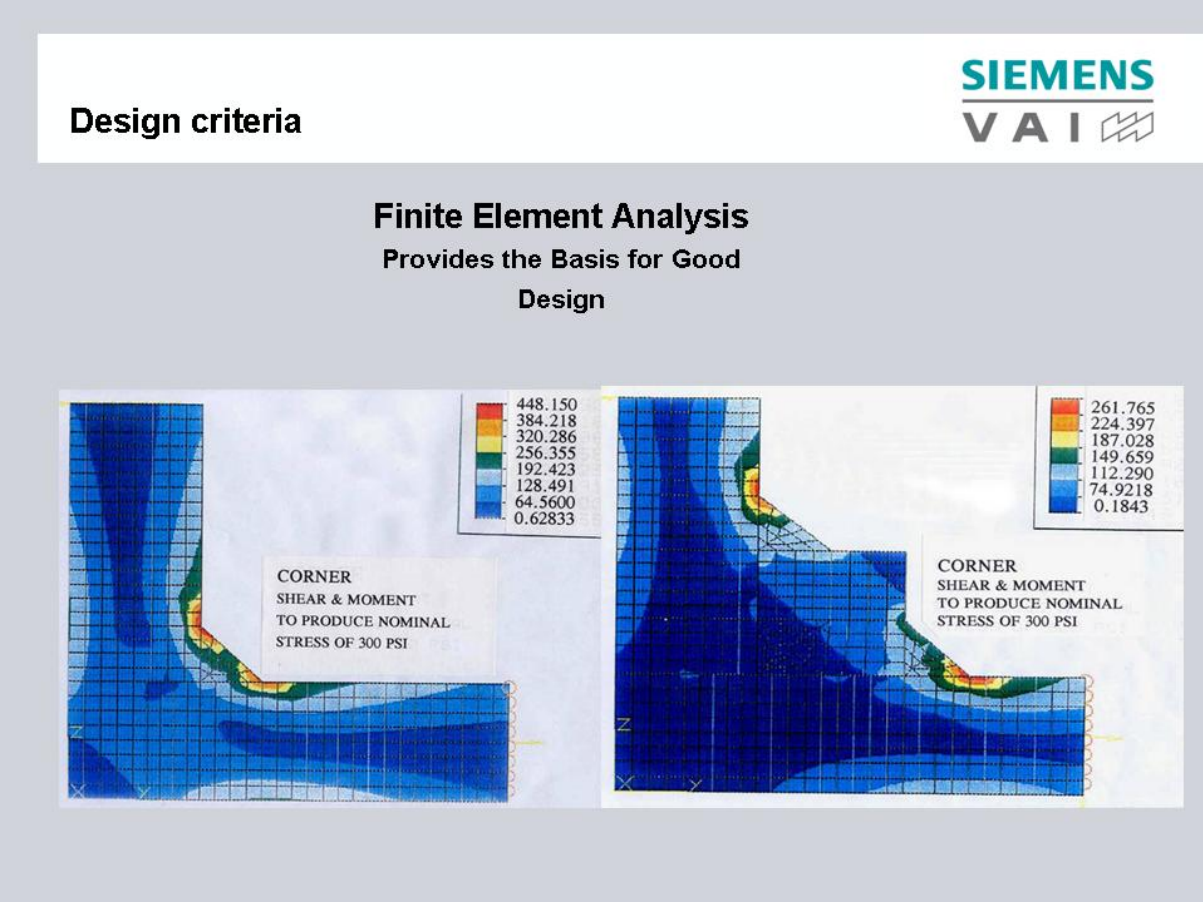

Figure 2 – FEA Analysis of Corner Weld Design

Polypropylene process equipment has been successfully used to contain solutions such as:

- 20% Hydrochloric Acid up to 100°C
- 15% Nitric + 5% Hydrofluoric Acids up to 65°C (Mixed Acid)
- 25% Sulfuric up to 100°C
- 10% Sodium Hydroxide up to 95° C
- 20% Sodium Sulfate up to 95°C

Higher concentrations of these solutions have been used at lower operating temperatures.

Polypropylene is flammable and safety precautions must be observed around this equipment. Steel welding and burning must be monitored in the vicinity of polypropylene equipment. Flame retardant grades of polypropylene are generally used for covers, hoods, exhaust ductwork, and fume scrubbers.

HISTORY

Traditionally most equipment that was used for containing corrosive solutions and fumes was fabricated from steel with a rubber-lined interior and with a coated exterior. An additional acid resistant brick lining was used to protect the rubber lining and to act as thermal insulation.

In the early 1960's polypropylene was introduced to the steel industry by Siemens' Allegheny Process Equipment group (then operating as Allegheny Plastics, Inc.). The first applications were electrolytic wire cleaning cells and pickle tank covers.

The design and use of heavy wall polypropylene fabrications began in the USA. The first pickling tanks for stainless steel strip were installed around 1972.

In 1988 the first replacement pickling tanks for carbon steel strip were installed and in 1994 Siemens VAI installed the first polypropylene tanks in a new continuous pickling line at Steel Dynamics, Inc. Since then most new pickling lines have specified plastic tanks.

The Siemens Allegheny group has over 40 years of experience providing heavy duty thermoplastic tanks and equipment to the metals industry.

- 52 project references in the Stainless Steel industry
- 245 Continuous Carbon Steel Pickle Line projects

Installations: United States – USS, NAS, AK Steel, ALSCo, Mittal, & many more
United Kingdom – CORUS
Venezuela – SIDOR
Brazil – Acesita
Argentina – Sidera
Korea – POSCO
Canada – Dofasco, Atlas Stainless
Australia – BlueScope LTD
Japan – Nippon Steel
Taiwan – Tang Eng
France – Arcelor Ugine
Germany – Stahlwerke Bremen
China – Qingdao
Russia - Novolipetsk
Netherlands – CORUS
Indonesia – Maspion (Jindal)
Mexico – Mexinox, IMSA

Turkey – Erdemir, Borcelik
Hungary – Dunaferr
Ukraine – Zaporizhstal
India – SAIL Bokaro

Currently, Siemens has polypropylene fabrications manufactured by several fabricators under exclusive agreements. These shops have been trained by Siemens to achieve the quality and to use the standards developed from our 40 years of experience.

Siemens has developed designs for the following pickling applications:

- Replacement tanks for deep catenary type lines
- Replacement tanks for shallow forced circulation type lines
- Replacement tanks for push pull type lines
- New pickling lines with polypropylene tanks

Figure 3 – Comparison of existing technology with new

DEEP TANK REPLACEMENT PROJECTS

Siemens' designs can accommodate the replacement of one or all of the tanks in a pickling line. A single tank can be replaced at any position in the line.

Siemens has designed a "U" shaped combination expansion joint and granite skid cap dam. This design permits thermal expansion and contraction of the polypropylene pickling tank while incorporating a U-Seal that provides positive containment of the solution and fumes.

It also provides the strength necessary to support the granite dam, the steel strip, and the dynamic forces applied during operation. The first installation (using this U-Seal) has been in continuous operation in hydrochloric acid at 95-100°C since 2000.

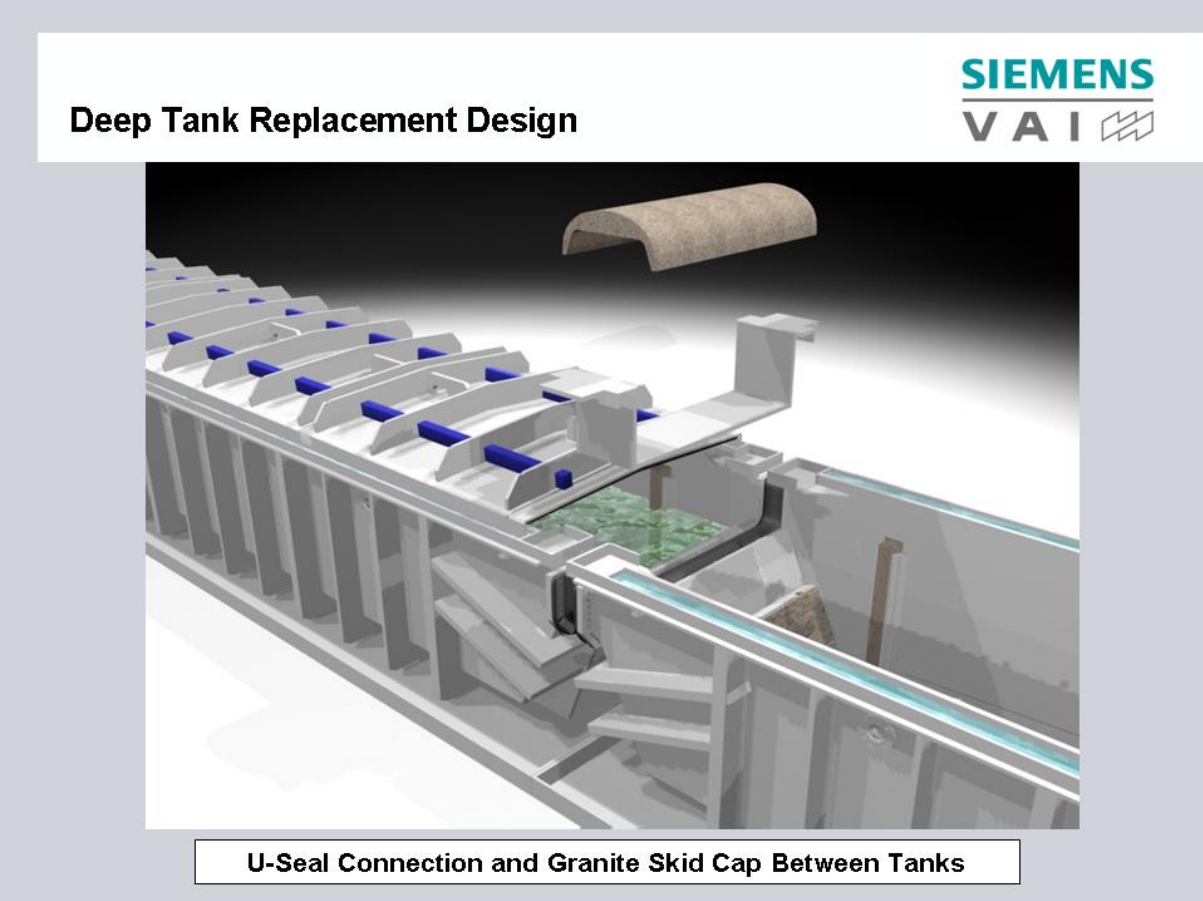

Figure 4 – U-Seal with protection plate and granite dam

The interior of the plastic tank is protected by using granite blocks at the entry, bottom, sides, and end of pickling tanks for sulfuric or hydrochloric acid. These blocks are contained in polypropylene brackets.
A granite dam is used between tanks as on existing catenary type pickling lines.
Granite protection is also provided for heat exchangers, steam spargers, etc.
The internal clearances and elevations are the same in replacement tanks as in the original steel tanks.
A full, continuous, flat steel plate is required below the plastic tanks to provide adequate support. On existing lines there is usually sufficient space between the existing support beams and the tank bottom for an additional structure.

TURBULENT TYPE SHALLOW PICKLING TANKS

Polypropylene has proven to be an excellent material for the design and fabrication of shallow forced circulation (turbulent type) pickling lines for both carbon and stainless steels. The adaptability of this material to many shapes and configurations provides designers with the necessary flexibility to achieve complex fabrications.
Siemens' Allegheny group has supplied the polypropylene designs for every major pickling line supplier.

Figure 5 – Shallow pickling tanks with forced circulation

Siemens Labyrinth Seal Description - US Patent No. 5,566,694

A Labyrinth Seal is used to accommodate expansion and contraction of the tank body. This seal is also a fume seal to keep acid fumes from exhausting in this area. This seal is used for lines with forced circulation of the acid.

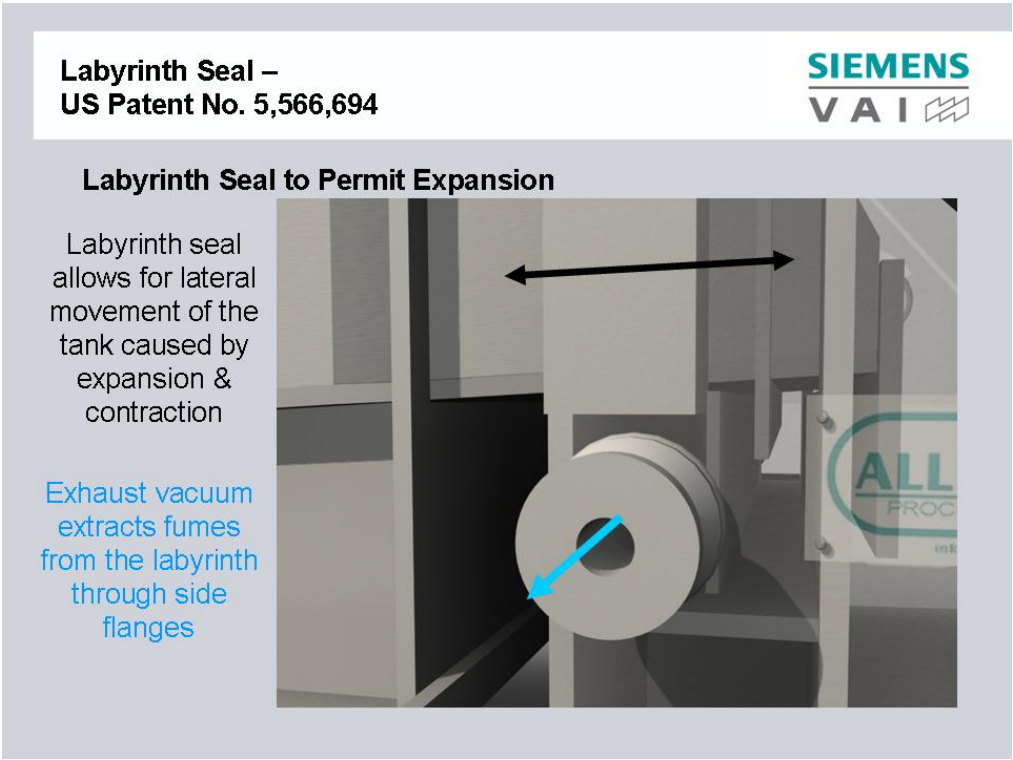

Figure 6 – Labyrinth seal to accommodate expansion

The tank body extends into the wringer roll well and the acid from the tank overflows into and immediately out to the wringer roll well. There is an open annular space around the tank body with plates welded to the tank body and to the wringer roll well opening to form a labyrinth. The expansion of the tank is contained within the labyrinth area. An exhaust plenum is included in the wringer roll well opening. This plenum captures any fumes that may get past the labyrinth seal. This permits tank expansion without rubber seals or other mechanical means.

STEERING ROLL HOUSINGS

Siemens' standard tank design is to provide a separate steering roll housing made from polypropylene to accommodate the steering rolls. This separate unit is required so it may be locked in place at the steering rolls. In this manner there is no need to allow for accumulated expansion from the center of the last pickling tank. The steering housing includes a sloped tray so that all solution is returned to the last pickling tank. This separate unit provides better sealing around the roll necks and better fume exhausting.

Figure 7 – Housing for steering rolls

CASCADE RINSE TANKS

Polypropylene multi-stage cascade rinse tanks have been designed with polypropylene spray bars and roll window closures. These rinse tanks are light weight and durable. They provide better sealing at the rolls and better fume containment. They can be preassembled off line with the roll stands and rolls and then lifted in place. With polypropylene equipment there are many means to shorten

the time required to install this equipment.

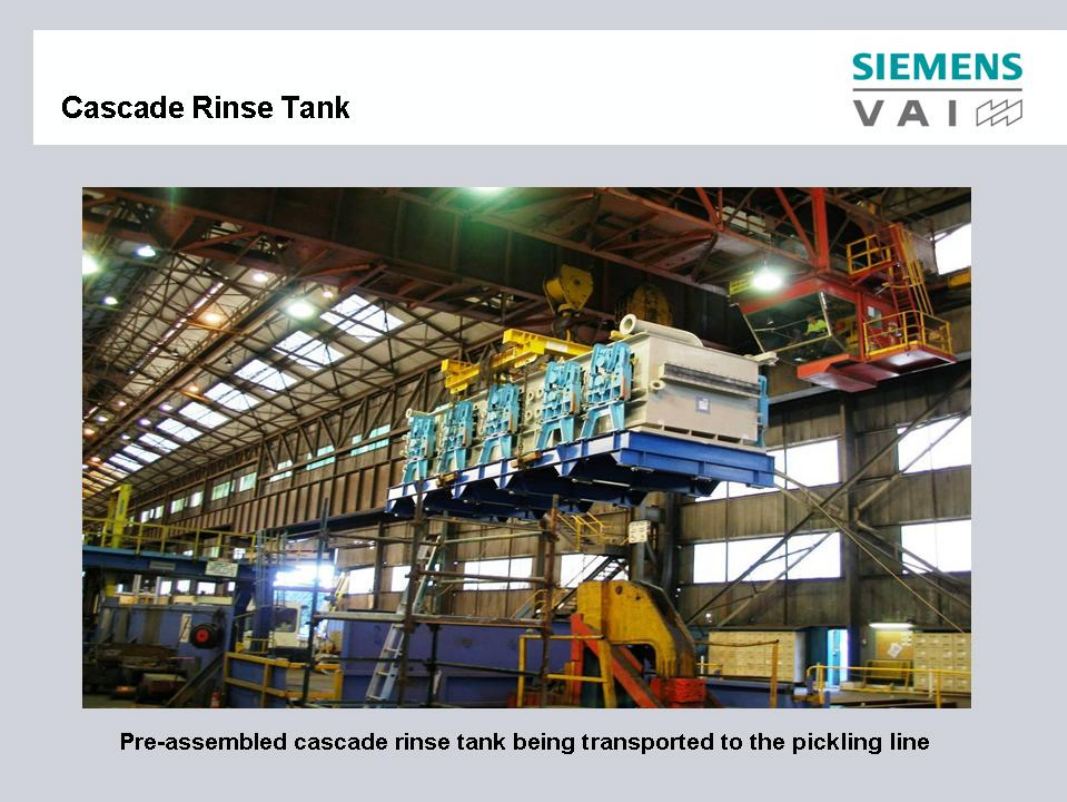

Figure 8 – Cascade rinse tank

There have been various applications for polypropylene tanks in steel cleaning and finishing.

Figure 10 – Typical applications for polypropylene tanks

CONCLUSION

Polypropylene design and fabrication has advanced from the trial-and-error stage to the fully engineered stage that allows for the supply of trustworthy, mill duty equipment. The impact that polypropylene process equipment has made in the steel industry is the direct result of the development of an engineering discipline.

Present engineering and fabricating technology has led to a breakthrough into areas previously thought to be beyond the capabilities of polypropylene equipment. Future stainless steel pickling, electrolytic cleaning and other process lines will use this material to its best advantages. They will operate at lower cost, with less maintenance, and with less environmental concerns.