The advantages of Glass-Reinforced Plastic (GRP) FLOWTITE® pipes over commonly used metallic and nonmetallic pipes have now become well known among designers, engineers and users.

Saudi Arabia is an arid desert country with limited ground water supplies and dependable surface sources. The available ground water supplies are deeply buried and do not replenish themselves. Moreover, these are fossil waters with an excessive concentration of dissolved salts, making them unacceptable for either direct domestic consumption or even for industrial applications. Soils in the Kingdom are salt-laden and exhibit low electrical resistivity, with a varying water table coupled with the environment which is characterized by wide fluctuations in temperature and humidity. In other words, it's an aggressive service environment for conventional pipe materials both under and over the ground.

The Kingdom of Saudi Arabia has always been conscious that water is the key to its long-term economic well-being. The Kingdom established a goal to provide that most fundamental of human needs in both the urban and rural areas: a safe water supply and adequate sanitation. Therefore, Saudi Arabia is working to develop both natural and artificial sources of water.

The shortage of water in Saudi Arabia has been exacerbated by a number of factors, including increasing population, substantial growth in the standard of living, and increasing industrialization. These and other conditions, such as the limited ground water resources and difficulty of water treatment by conventional processes, led to the decision of the Saudi government to use desalinated sea water as the main source of potable water for all major metropolitan areas in the Kingdom.

Currently, a number of desalination and power plants on the Red Sea coastline supply water to Jeddah, Makkah, Al-Madinah and Yanbu, etc.; and on the Arabian Gulf coastline to Riyadh, Dammam, Al-Khobar, Al-Jubail and Dhahran, etc. And the constantly growing population of Saudi Arabia, coupled with industrial expansion, mandates the construction of additional desalination plants. Several such plants are in the design or fabrication phases, with a total of approximately 40 plants as the nation’s long-term goal.
Choosing Glass-Reinforced Plastic (GRP) Pipes and Fittings

A desalination plant is subjected to different forms of deterioration because of the presence of diverse properties as well as diverse types of environments. Sea water, condensed sea water (brine) and uncondensed gases are responsible for the majority of the failures reported. Desalination plants utilize significant quantities of pipes of varying sizes for both operational processes and transmission lines. The characteristic properties of the piping materials, particularly their mechanical strength, and long-term maintenance-free performance in conjunction with availability and cost-effectiveness, are taken into consideration when selecting construction materials. Also, Saudi Arabia has learned that in order to achieve trouble-free operations, material selection must be supported by proper design and stringent operating practices to achieve long-term performance.

Given the harsh environmental conditions in desalination and power plants, a strong, nonmetallic material has been chosen to resist the problem of corrosion and other degradation processes. This material is glass-reinforced plastic, commonly known as GRP or FLOWTITE® pipe. FLOWTITE pipe is a flexible, filament-wound, corrosion-resistant structural composite produced by combining thermosetting polyester resin, glass fiber reinforcements and specially selected fillers (such as finely graded silica sand) in a carefully-controlled process.

The advantages of FLOWTITE pipes over commonly used metallic and nonmetallic pipes have now become well known among designers, engineers and users. A few advantages are:

• Inherent internal and external corrosion resistance
• Long service life
• Lightweight (high strength-to-weight ratio)
• Ease and economy in installation
• Rapid field fabrication
• Freedom from maintenance
• High flow capacity (smooth bore)

Because of these advantages, there is now a growing awareness of the installation and operational cost savings offered by FLOWTITE pipe. This has resulted in its worldwide application for desalination and power plants, potable water transmission and distribution lines, sanitary and storm sewers, irrigation, firefighting and many industrial effluent applications. Nowhere are the advantages of the material more apparent than in Saudi Arabia.
Phase I of the Desalination and Power Plant was built in the year 1980. The raw material of this plant, i.e., sea water, is supplied through a sea water intake system consisting of four 2000mm diameter concrete cylinder pipes. However, the sea water and high salinity of the Saudi environment eventually took their corrosive toll. The intake structure at the plant comprises three main parts: the intake mouth, which is submerged under the sea; the drawing channel that is fed by the intake mouth; and the intake forebay which is fed by the drawing channel.

The four intake lines were built for redundancy; only two of them are in use at any given time, with the others acting as standby systems. After underwater video and other visual inspections of the existing lines, two conclusions were reached:

1. The intake mouth, which was completely submerged under the sea, would not need to be renovated or rehabilitated.
2. The pipelines after the intake bay thrust block – the drawing channel and intake forebay – would need complete rehabilitation.

Following the evaluation of several different options based on cost, ease of construction, corrosion resistance, durability and maintenance, it was decided to replace the exposed portion beyond the thrust block with GRP pipes and double bell and spigot flexible joints. Reasons cited for the decision include:

A. No change would be required in the ID of the pipe, so hydraulic capacity of the pipes would not be affected. In fact, the flow capacity would be enhanced by approximately 40 percent because of the superior hydraulic characteristics of the GRP surface versus that of concrete.

B. Lower cost of installation compared to other options, including slip lining.

C. The corrosion resistance of FLOWTITE pipe would prevent a recurrence of the degradation and corrosion problems.

During the demolition of the existing lines, three of them were always kept in service so that plant operations would not be interrupted. At the intake forebay, a 2000 mm x 1000 mm x 600 mm GRP double tee was constructed and encased in concrete to withstand a vacuum of -0.8 bar, 4000 N/m² stiffness pipe was used, providing a safety factor of 2.5.

Pipe was produced for the project in 12 and 18 meter lengths, which were strung into 44 runs. As the DN2000 GRP runs were attached to the system, they were covered by an embankment, part of which supports an access highway.
Al-Madinah – Yanbu Desalination and Power Plant Update

The Saline Water Conversion Corporation (SWCC) is the body engaged for the planning, execution and oversight of desalination and power plants in the Kingdom. In 1992, SWCC commissioned the services of a consortium to construct a water supply system and an electric power supply scheme for Yanbu and Al-Madinah. The project consists of a Reverse Osmosis (RO) desalination plant and four Multi-Stage Flash (MSF) desalination units and auxiliaries. Each MSF unit produces 150 m$^3$ per day. The facilities operate with a top brine temperature (TBT) of 108°C for distilled water with total dissolved solids (TDS) of less than 25 mg/kg at design conditions.

The MSF units required large quantities of pipe to be installed for both above ground and underground applications. The total length of the pipes and fittings is 8,064 meters, with diameters ranging from 80 mm to 2600 mm.

A New Venture for Amiantit Fiberglass Industries Ltd. (AFIL)

Until undertaking the Al-Madinah – Yanbu project, AFIL had been engaged only in manufacturing and supplying FLOWTITE pipes for various applications. But for this particular project, AFIL ventured into a new field – as a subcontractor for the erection and installation of the piping systems. The main contractor, Belleli Saudi Heavy Industries, entered into an agreement with AFIL for the supply and installation of all FLOWTITE piping required for the project, including such engineering tasks as piping stress analysis, calculation and preparation of data sheets for supports, anchors, expansion joints and bolting, as well as field hydro-testing. It was a unique opportunity for AFIL to design, manufacture and install the complete GRP piping system in close coordination with the construction consortium.

Stress analysis was performed using the pipe stress computer program CAESAR II, in order to avoid stressing the system beyond allowable limits. Following the installation of the system, the actual measured vertical deflections were much lower than the allowable values. This was determined to be a result of the stringent stiffness specification (10,000 N/m STIS) written by the engineer Kuljian Corporation (USA).

### RO Desalination Plant at Al-Madinah – Yanbu

AFIL also designed and manufactured FLOWTITE piping systems for the Reverse Osmosis plant built within the Al-Madinah – Yanbu Desalination and Power Plant complex at Yanbu by MITSUI Engineering and Ship Building Co. Ltd. (MESCO). The table below depicts the various diameters with design service conditions and linear meters of pipe used for this project.

**Table 1: Design conditions of FLOWTITE pipes used partially in RO process of Al-Madinah – Yanbu Desalination and Power Plant**

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Temperature (°C)</th>
<th>Pressure (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>41</td>
<td>5</td>
</tr>
<tr>
<td>450</td>
<td>39</td>
<td>F.V.</td>
</tr>
<tr>
<td>600</td>
<td>39</td>
<td>8</td>
</tr>
<tr>
<td>600</td>
<td>39</td>
<td>F.V.</td>
</tr>
<tr>
<td>600</td>
<td>40</td>
<td>F.V.</td>
</tr>
<tr>
<td>900</td>
<td>39</td>
<td>8.8</td>
</tr>
<tr>
<td>1000</td>
<td>32</td>
<td>F.V.</td>
</tr>
<tr>
<td>1100</td>
<td>32</td>
<td>5.5</td>
</tr>
</tbody>
</table>

*F.V.= Full Vacuum*

### Table 2: Operating conditions of various service applications of the MSF Desalination Plant

<table>
<thead>
<tr>
<th>Application</th>
<th>Operating Pressure (bar)</th>
<th>Vacuum (bar)</th>
<th>Operating Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid cleaning</td>
<td>3</td>
<td>No</td>
<td>70</td>
</tr>
<tr>
<td>Blow down</td>
<td>4</td>
<td>Full</td>
<td>70</td>
</tr>
<tr>
<td>Brine water</td>
<td>11</td>
<td>Full</td>
<td>40</td>
</tr>
<tr>
<td>Drinking water</td>
<td>9</td>
<td>No</td>
<td>78</td>
</tr>
<tr>
<td>Evaporator drainage</td>
<td>3</td>
<td>No</td>
<td>70</td>
</tr>
<tr>
<td>Hypochlorite solution</td>
<td>3</td>
<td>No</td>
<td>70</td>
</tr>
<tr>
<td>Incondensable vapor</td>
<td>6</td>
<td>Full</td>
<td>84</td>
</tr>
<tr>
<td>Sea water</td>
<td>7</td>
<td>Full</td>
<td>40</td>
</tr>
</tbody>
</table>

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*Power and Desalination Plants in Saudi Arabia (cont’d)*
In 1980, Amiantit also had signed a contract with Hitachi-Zosen Engineering Company of Japan to design, engineer and manufacture a portion of the GRP piping system for the Al-Jubail II Power and Desalination project on the Arabian Gulf.

Portions of the GRP piping system on this project were above and below ground. The below ground system included outfall lines, sea water intake lines and product water piping. The above ground system was primarily piping around the evaporators. Pipe sizes range from 350mm to 2,550mm in diameter. In addition to straight pipes, approximately 4,000 fittings were supplied, including flanges, elbows, reducers, tees and wyes.

Loads on the various piping components of the above ground system were determined through flexibility analysis, while the behavior of the individual complex components was examined using finite element analysis (FEA). Now approaching 20 years of service, the Al-Jubail plant has proven the efficacy of GRP pipe in highly corrosive environments.

Amiantit Fiberglass Industries Ltd. (AFIL): One of the World’s Largest Producers of GRP Pipes and Fittings

Amiantit Fiberglass Industries Ltd. (AFIL) was established in June 1977 as a joint venture between the Saudi Arabia Amiantit Company (SAAC) of Dammam, Saudi Arabia, and a wholly owned subsidiary of Owens Corning. The main objective of the company is to supply quality GRP pipes and fittings for the growing needs of the Kingdom in the markets of:

- Sewer
- Water
- Power and desalination
- Industrial applications

Currently AFIL employs 350 people who produce 200 kms of FLOWTITE pipe per year, or an average of 5,500 tons of pipe annually in the diameter range of 80mm to 3700mm. With 20 years of experience in large diameter pipes, AFIL is now one of the world’s largest GRP pipe plants, having supplied over 3,000 kms of pipes not only in the Kingdom of Saudi Arabia but also in other parts of the world. In fact, AFIL FLOWTITE pipes have been tested and approved for conveyance of potable water by many of the world’s certification agencies, such as National Sanitation Foundation (NSF). As a first step to reach highest quality, AFIL achieved ISO 9001 certification.

The company’s 60,000 square meter Dammam facility utilizes the latest developments in equipment and technology to manufacture quality FLOWTITE pipes as well as fittings and tanks for use in transmission and storage of water, sewage and petroleum products. These pipes meet customer-approved standards and international engineering requirements, and provide customer satisfaction in all respects.

The supply of FLOWTITE pipes for the power and desalination plants in Saudi Arabia are among the largest and most sophisticated projects undertaken in glass-reinforced plastic pipe.