FABRICATION OF GRP/FRP HUGE STORAGE TANKS

A new proven Technology…..

SATYEN POLYMERS PVT LTD

Presentation by R. Raghavan
TRIBUTE TO GOD

GOD HAS FORETHOUGHT AND DID NOT CREATE FIBERGLASS TREES, LEAVING THIS JOB TO FIBERGLASS AND RESIN INVENTORS.

TRIBUTE TO GRP MANUFACTURERS

GOD CREATED HUMAN BEING AND NATURAL RESOURCES. HOWEVER HE ALLOWED MAN TO CONVERT FIBERGLASS AND BINDER INTO MATERIALS OF HIS CHOICE.
FABRICATION OF GRP/FRP HUGE STORAGE TANKS
A new proven Technology

Satyen Polymers
• Max Fabricating Capacity: 500m³ up to 10000m³ volume
• Max Fabricating Diameter: 6 meter up to 30 meter
• Suggest Fabricating Height: 10 meter up to 15 meter

Satyen Polymers
In this paper, I am trying to introduce a new concept to manufacture Large GRP tank fabrication developed by a Taiwanese company M/s Kigent corp. Ltd.

The Kigent Corporation Ltd was established in 1979, devoted to chemical resistant tanks by helical filament-winding process. Since 1989, by the new advanced helical filament winding technology.

Kigent has developed and manufactured these products widely in petrochemical, steel, food and electronic industries and military-use. Providing high strength, best corrosion resistance, good performance composite-products for customer is Kigent’s first responsibility.

Satyen Polymers
They are a professional FRP manufacturer of special chemical tanks and equipments such as pressure vessels, scrubbers, fume stacks. Their products have been widely used in a variety of industries including petrochemical, power generation, electronics, marine, and paper etc.

No-failure incident in Kigent’s projects is the greatest accomplishment and honor since 1979. With the successfully developed helical filament-winding machine for field production, this company has produced 500m³ FRP storage tanks, 6 sets of 8 m dia x 10m H, for 32-37% Hydrochloric acid for Formosa and withstood shake-test from the famous 921 (Richter 7.6 scale) earthquake that happened in 1999 in Taiwan. Kigent now has confidence and capability to produce any larger size of FRP storage tanks.

*Satyen Polymers*
With 30 years experience and excellent design, Kigent has developed the on-site Helical Filament Winding technology to produce the huge & high qualified FRP tanks for industrial service.

According to the capacity of Kigent’s Helical FW machine, we could fabricate the tank when diameter is up to 30 m and 15 m for height, the volume could be up to 10000m³.

Satyen Polymers
During the last 5 years the constitution material- viz metal material cost has group by about 300-500\% that had seriously affected the budget of various projects. In order to reduce down the investing cost, Kigent follow ASTM, ASME, NBS, PS 15-69, BS 4994, CNS 11656-K308 standards, and promote steps to manufacture GRP products instead of “costly stainless steel and carbon steel equipments for chemical-resistance market.

**Satyen Polymers**
Technical Data of on-site fabrication:

• Working Capacity: Diameter from 5M to 30M, Height up to 20M
• Max-Application: 2000 m³, 16M dia x 10M Height
• Manufacture Code: ASME RTP-1, ASTM D-3299, NBS PS 15-69, BS 4994, CNS 11656-K308
• Resin to be used: Novolac Vinyl ester, Epoxy Vinyl ester, Halogenated Resin, Het acid resin
• Fiberglass to be used: Nexus Polyester Tissue, C-veil, Chopped strand mat, Woven roving, Filament hoop roving
• Helical winding angle: 10-15 degree relative to circumference
• Physical properties: ASTM requirement to be matched
LAMINATE
Characters of kigent on-site fabrication

• No-limits of tank’s diameter. Only 6-10 pcs of FRP pipes required to support steel or wooden mold

• No-vibration of rotation caused by driven motor to affect mold stability

Satyen Polymers
Supporting poles or frames: No-R.C. Foundation required for mold or machinery supporting

• Fast fabrication: 4-8 days supposed only to produce one segment for 100 m³ FRP tank

• Fast erection & lifting: 4-8 working days only for 1000 m³ FRP tank

• Working labors required: 5-10 persons for one 1000 m³ FRP Tank

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TANK FARM

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(TANKS, VESSELS, AND EXHAUST SYSTEMS WITH DIMENSIONS BELOW 5 M DIA X 15 M LENGTH)

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VIEW OF THE KIGENT WORKS

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PRESSURE VESSEL – VAC TESTED

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VIEW OF TANK ERECTION

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FILAMENT WINDING PROCESS

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GRP TANK ERECTION

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Field-fabrication FRP tanks

- 6-30 M dia X 10-15 M Height

Consideration before fabrication

- Resin selection

In order to select the suitable resin to resist the chemical corrosion, we do concern about the specimens dipping test especially in the industrial waste water. It might contain some trifing chemicals but damage FRP structure or affect the service life.

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Normally before fabrication, we shall test
Put various resin casting as specimens and dip it on various chemicals at elevated temperature to observe the colour change, and determine suitable resin to be used to match the chemical environment requirement.

Barcol hardness test to analyse the laminate strength reduction that caused by curing systems, percentage of hardeners, or soften by chemicals. Check the weight loss and calculate corrosion rate, to calculate the service life.

Test results to determine the thickness of the anti-corrosion barrier and make sure the service life.

Satyen Polymers
Normally the guarantee for the products is up to 5 years, and the service life that definite by corrosion rate per corrosion barrier shall be more than 50 years:

<table>
<thead>
<tr>
<th></th>
<th>LENGTH (mm)</th>
<th>WIDTH (mm)</th>
<th>THICKNESS (mm)</th>
<th>SURFACE AREA (mm²)</th>
<th>ORIGINAL WEIGHT W₀ (g)</th>
<th>FINAL WEIGHT W₁ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1-1</td>
<td>10.78</td>
<td>23.49</td>
<td>3.08</td>
<td>718</td>
<td>0.9159</td>
<td>0.9112</td>
</tr>
<tr>
<td>Test 1-2</td>
<td>11.19</td>
<td>24.32</td>
<td>3.2</td>
<td>772</td>
<td>0.9787</td>
<td>0.9735</td>
</tr>
<tr>
<td>Test 2-1</td>
<td>10.62</td>
<td>23.03</td>
<td>3.12</td>
<td>699</td>
<td>0.8817</td>
<td>0.8796</td>
</tr>
<tr>
<td>Test 1-1</td>
<td>10.70</td>
<td>24.73</td>
<td>3.08</td>
<td>747</td>
<td>0.9525</td>
<td>0.9502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ORIGINAL WEIGHT W₀ (g)</th>
<th>FINAL WEIGHT W₁ (g)</th>
<th>WEIGHT LOST (W₀-W₁) (g)</th>
<th>(W₀−W₁)*1000/DENSITY (G/CM³)</th>
<th>Corrosion Rate (mm/week)</th>
<th>Corrosion Rate (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9159</td>
<td>0.9112</td>
<td>0.0047</td>
<td>4.02</td>
<td>0.006</td>
<td>0.291</td>
</tr>
<tr>
<td>0.9787</td>
<td>0.9735</td>
<td>0.0052</td>
<td>4.44</td>
<td>0.006</td>
<td>0.300</td>
</tr>
<tr>
<td>0.8817</td>
<td>0.8796</td>
<td>0.0021</td>
<td>1.79</td>
<td>0.003</td>
<td>0.134</td>
</tr>
<tr>
<td>0.9525</td>
<td>0.9502</td>
<td>0.0023</td>
<td>1.97</td>
<td>0.003</td>
<td>0.137</td>
</tr>
</tbody>
</table>
Fiberglass selection

In order to maximize service life and protect the inner layer from industrial waste water that contains various kinds of corrosive acids, caustic alkalinity, or solvent chemicals, normally double synthetic veil should be used in the corrosion barrier to prevent attack caused by the trifling caustic, solvent or corrode the inner fiberglass from Hydrofluoric Acid. The synthetic veil also provides toughness at elevated toughness at elevated temperatures and acidic oxidizing environments.
A VIEW OF RAW MATERIALS

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RAW MATERIALS-VEIL,WR

a. Glass veil made from Germany or double synthetic veil Polyester Tissue will be used for Inner liner contacted layers.

b. Woven roving should be used to increase impact strength and avoid delamination during fabrication.

c. Typical Properties of Kigent laminate.

Satyen Polymers
<table>
<thead>
<tr>
<th>Property</th>
<th>SI</th>
<th>US Standard</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>130 Mpa</td>
<td>19,000 psi.</td>
<td>ASTM D-3039/ISO 527</td>
</tr>
<tr>
<td>Tensil Modulus</td>
<td>12 GPa</td>
<td>1.7 x 1000000 psi</td>
<td>ASTM D-3039/ISO 527</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>210 MPa</td>
<td>30,000 psi.</td>
<td>ASTM D-790/ISO 178</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>8.5 GPa</td>
<td>1.2x1000000 psi</td>
<td>ASTM D-790/ISO 178</td>
</tr>
<tr>
<td>Glass Content</td>
<td>40%</td>
<td>40%</td>
<td>ASTM D-2584/ISO 1172</td>
</tr>
</tbody>
</table>

25 mm(1") construction – 3t CR + Reinforced layers.

M= Chopped strand mat, Fw= Glass roving; 3200 g/m2 by Hoop winding and Helical winding. Wr= Woven roving, 800 g/m2

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STEPWISE PROCESS
Advantages of Helical FW Process

a. Good strength in axial and longitudinal directions; excellent vacuum resistance; not easy to rupture; no safety worry, and specified in ASTM D-3299

b. Good seismic resistance; suitable for fabricating extra-large FRP storage tanks

c. Keep high flexural ability, when the height & diameter ratio is greater than 2

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Laminate construction:
Fiberglass content and sequence

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b. Laminates procedure for filament winding process.

- SM : Surfacing Mat, 30g/m2, 0.25m/ply.
- CSM : Chopped Strand Mat, 300g/m2, 0.6mm/ply.
- WR : Woven Roving, 800g/m2, 0.8mm/ply.
- Hp : Hoop Winding, 1600g/m2, 1.5mm/ply.
- Hx : Helex Winding, 1600g/m2, 1.5mm/ply.
- TC : Top Coating, 0.25mm/ply.
Character of Kigent Helical FW Process

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The laminate contains woven roving, hoop winding & helical winding on tank to provide high flexural & tensile strength for FRP huge tanks to resist earthquake moment or vibration of liquid vortex.

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Quality System:
WCS ISO-9001: 2008 Quality Certification

- Process quality control
- Delivery quality control
- Process capability statistics and analysis
- Internal quality auditing
- Customer complaints handling
- Failure and quality variation handling procedure
- Management auditing procedure
- Feeding stock quality control
Certificate of Registration

Kigent FRP Corporation

No.225, Lidong Rd., Kaochu Township, Pingtung County, 972, Taiwan
No.129, Zhongqiao Rd., Changhui Township, Pingtung County, 995, Taiwan

ISO 9001:2008

For the scope of business described below:
Synthetic fibre textile manufacturing

This Certificate was first awarded by
WORLD CERTIFICATION SERVICES LTD.

Satyen Polymers
### Comparison of different materials used for 4600m³ waste water tank
When FRP or metal lined with others and panels to be considered

<table>
<thead>
<tr>
<th>4600m³ waste water tank</th>
<th>FRP tank</th>
<th>Carbon steel Lined w/ rubber</th>
<th>Carbon steel Lined w/FRP</th>
<th>SS 316 Tank</th>
<th>FRP Panel tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion resistance</td>
<td>Excellent</td>
<td>Inside: Excellent</td>
<td>Inside: Excellent</td>
<td>Excellent</td>
<td>FRP: Excellent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outside: Poor</td>
<td>Outside: Poor</td>
<td></td>
<td>Supports: Poor</td>
</tr>
<tr>
<td>Maintenance</td>
<td>none</td>
<td>Periodic</td>
<td>Periodic</td>
<td>none</td>
<td>FRP panels: No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Supports: Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gaskets: Poor</td>
</tr>
<tr>
<td>Aging by thermal stress</td>
<td>Good:</td>
<td>Poor</td>
<td>Poor 3% less aging.</td>
<td>No Aging</td>
<td>FRP panels: 3%</td>
</tr>
<tr>
<td></td>
<td>3% less aging. Non peeling.</td>
<td>Rubber: Aging Easy to peel off</td>
<td>Easy to peel off</td>
<td></td>
<td>less aging. Gaskets: Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corroded on seams</td>
<td>Corroded on seams</td>
<td></td>
<td>Corroded on Supports</td>
</tr>
<tr>
<td>Welding points</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration for Construction</td>
<td>4-6months per one set</td>
<td>8-10months</td>
<td>8-10months</td>
<td>4-6months</td>
<td>4-6months</td>
</tr>
<tr>
<td>Service Life</td>
<td>50 years more</td>
<td>20 years less</td>
<td>20 years less</td>
<td>50 years more</td>
<td>20 years less</td>
</tr>
<tr>
<td>Cost</td>
<td>100 % (approx)</td>
<td>150 % (approx)</td>
<td>150 % (approx)</td>
<td>300 % (approx)</td>
<td>100 % (approx)</td>
</tr>
</tbody>
</table>
FILAMENT WINDING – IN ACTION

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Al Newberry — DESIGNED THE GRP TANK
Wound On Knuckle
ERECTION OF TANK IN PROGRESS

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Joining Shell With Bottom Knuckle
• The FEA model was for a simplified dished head since the detailed dished head design has been done with a separate FEA.

• Since seismic loading will allow only one plane of symmetry one half of the vessel was modeled.

• The center section of the flat bottom needed not be modeled so this area was not filled with element in order to reduce the size of the model.

• The perimeter of this area was restrained in order to make the model mathematically stable.

• The shell was designed for two load cases. The first load case was hydrostatic head pressure

• The second load case was for hydrostatic head plus seismic acceleration. The seismic zone used was zone 3

• The analysis was performed using COSMOS M Version

• Design Evaluated by Mr. Al Newberry

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Joining Shell To Shell
GRP TANK UNDER ERECTION

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• The dished top cover was fabricated in 16 segments with a crown radius of 20 m and a knuckle radius of 350 mm.

• The inside height of the dish was 2883 mm.

• Each segment was stiffened with a trapezoidal stiffener.

• The stiffener core size was 230 mm high, 125 mm for the crown and 200 mm for the base.

• The stiffener overlay thickness was 13.6 mm and was extended out onto the dish by 150 mm minimum.

TOP DISH END - DETAILS
GRP TANK TOP DISHEND UNDER ERECTION

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JOINING THE COVER WITH THE SHELL
GRP TANK TOP DISHEND UNDER ERECTION

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## KIGENT VS OTHERS

<table>
<thead>
<tr>
<th></th>
<th>Others</th>
<th>Kigent Corp, Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Machine design</strong></td>
<td>Steel mold bolted on center pole</td>
<td>Steel mold stand on ground</td>
</tr>
<tr>
<td></td>
<td>Mold rotated by driven vehicle</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>No machine rotation</td>
<td>Machine rotates along steel rail</td>
</tr>
<tr>
<td><strong>Limitation</strong></td>
<td>A huge RC foundation required to buried to keep the balance of the center pole</td>
<td>No RC foundation required</td>
</tr>
<tr>
<td></td>
<td>Tank’s diameter is limited by the weight of mold and FRP tank, the heavy weight Only loaded on the center pole</td>
<td>No–limits to tanks diameter due to weight of Mold &amp; FRP tank stands on ground</td>
</tr>
<tr>
<td></td>
<td>Vibration caused by driven motor to affect mold stability and balance</td>
<td>No vibration (because the steel mold stand on ground)</td>
</tr>
<tr>
<td></td>
<td>Laminate forming to be affected by unstable mold, when mold rotation.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Laminate easily collapsed or demolded to destroy the strength before curing</td>
<td>None</td>
</tr>
<tr>
<td><strong>FW angle</strong></td>
<td>90° degree by hoop winding only</td>
<td>80° degree by helical winding interactively</td>
</tr>
</tbody>
</table>
Advantages of Kigent process

- No-limits to tank’s diameter: 30 m dia x 15 m H. 10000 M$^3$ FRP tank is available

- Supporting poles or frames: No R.C. foundation required to machinery supporting

- No-vibration or rotation: By driven subject to affect mold stability
Inspection methods

Solvent Test

Satyen Polymers
Hydrotest

Satyen Polymers
Torsion Test

Satyen Polymers
Pressure Test

Satyen Polymers
Satyen Polymers
Thanking for the patience to know about a new concept to fabricate successfully large GRP/FRP tanks to save valuable land space/ time savings /manual labour which save cost in the new environment of Green energy era.

(Every Penny saved in construction material, land area gives satisfaction as the new generation will enjoy the fruit of savings)