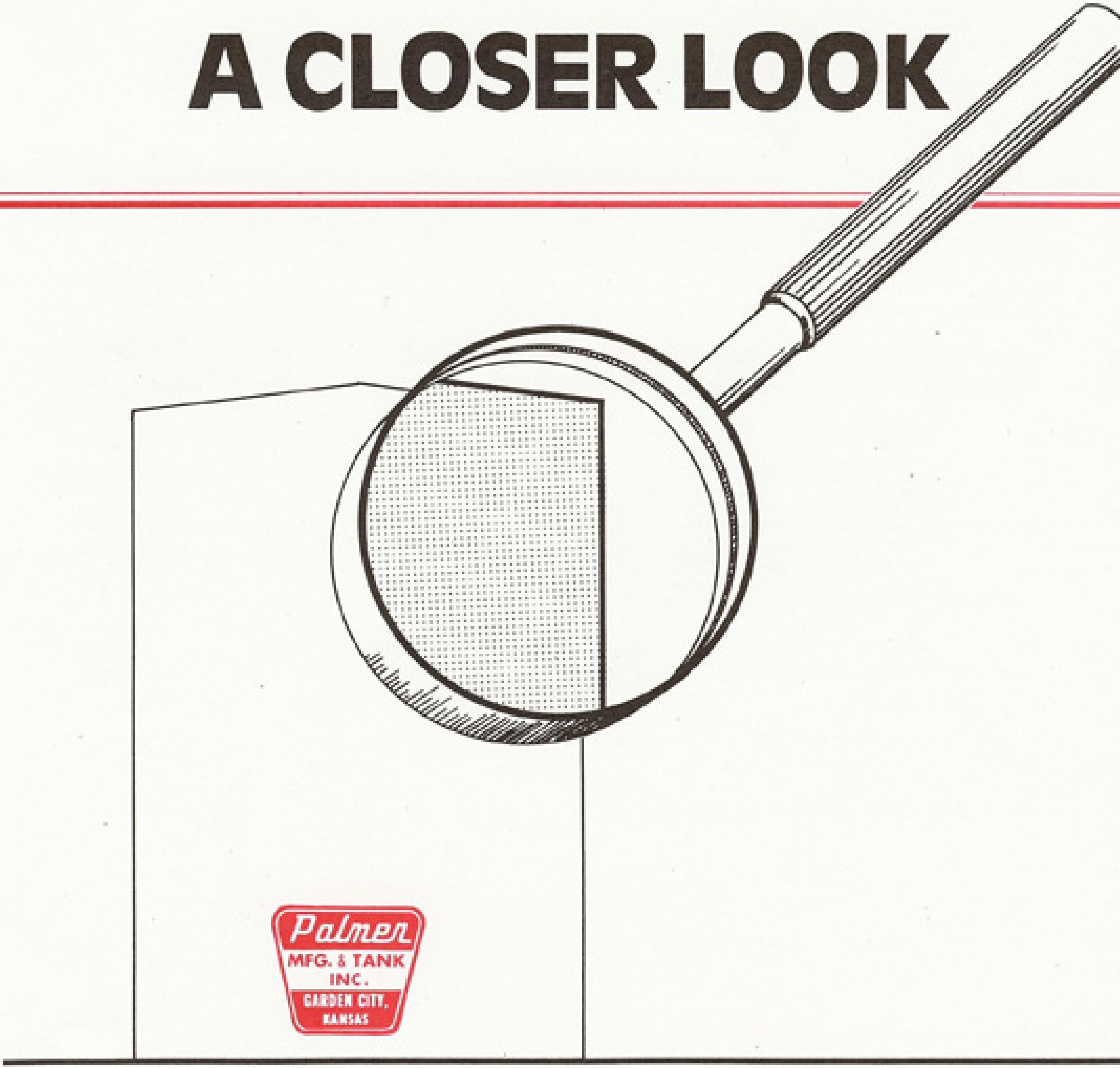
A CLOSER LOOK



at
Fiberglass Tank Specifications
and
Fabrication Techniques

Importance of Specifications

Palmer Manufacturing is providing the following information because we strongly feel specifications for fiberglass tanks are as important and perhaps even more important than specifications for steel tanks. We say this for many reasons. Unlike steel tanks, where it is fairly easy to determine if the welding of joints and fittings has been performed properly and where the quality of the steel can be verified, fiberglass tanks present unique challenges to both the manufacturer and the purchaser. For example there are basically four different types of fiberglass, all offering numerous fiber orientations, diameters, finishes and resistance to corrosion. As with fiberglass there are many different kinds and qualities of resins offering various degrees of corrosion resistance, price, fiberglass compatability and ease of fabrication. This coupled with the knowledge that there are numerous manufacturers of both fiberglass and resin, as well as 3 different fabrication techniques, results in literally hundreds of choices in the manufacture of fiberglass tanks. Therefore we think you will agree that specifications are indeed important because of the many variables involved.

Fabrication Techniques:

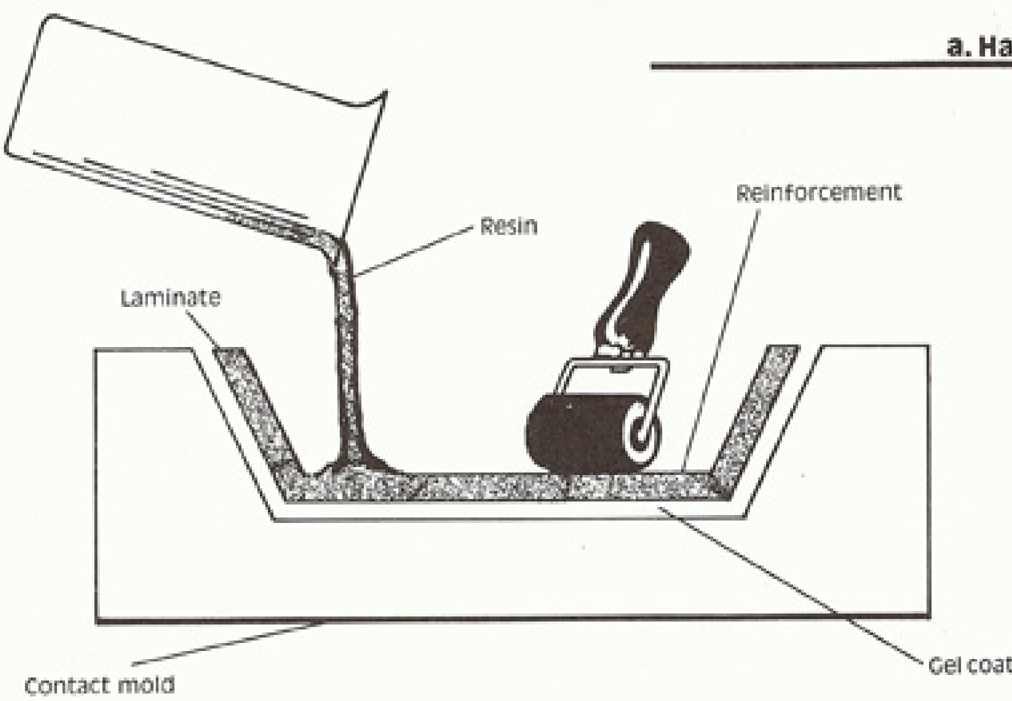
As mentioned above there are three fabrication techniques currently in use—hand lay up, chop spray, and filament winding, each of which is described below.

1. Contact molding is actually a term which applies to two different fabrication processes, hand lay up and sprayup.

Hand lay up is exactly as its name infers, a process which is perfomed entirely by hand. This is a low to medium volume method and is well suited for making boats, small tanks, housing and building panels and other large products.

This process involves manually placing fiberglass material on a mold and applying resin by pouring, brushing or spraying. The resin is then forced into the fiberglass material with specifically designed rollers. Thickness and added strength is obtained simply by increasing the number of layers of fiberglass. The use of thermosetting polyester resins allows the finished product to be cured at room temperature.

a. Hand layup

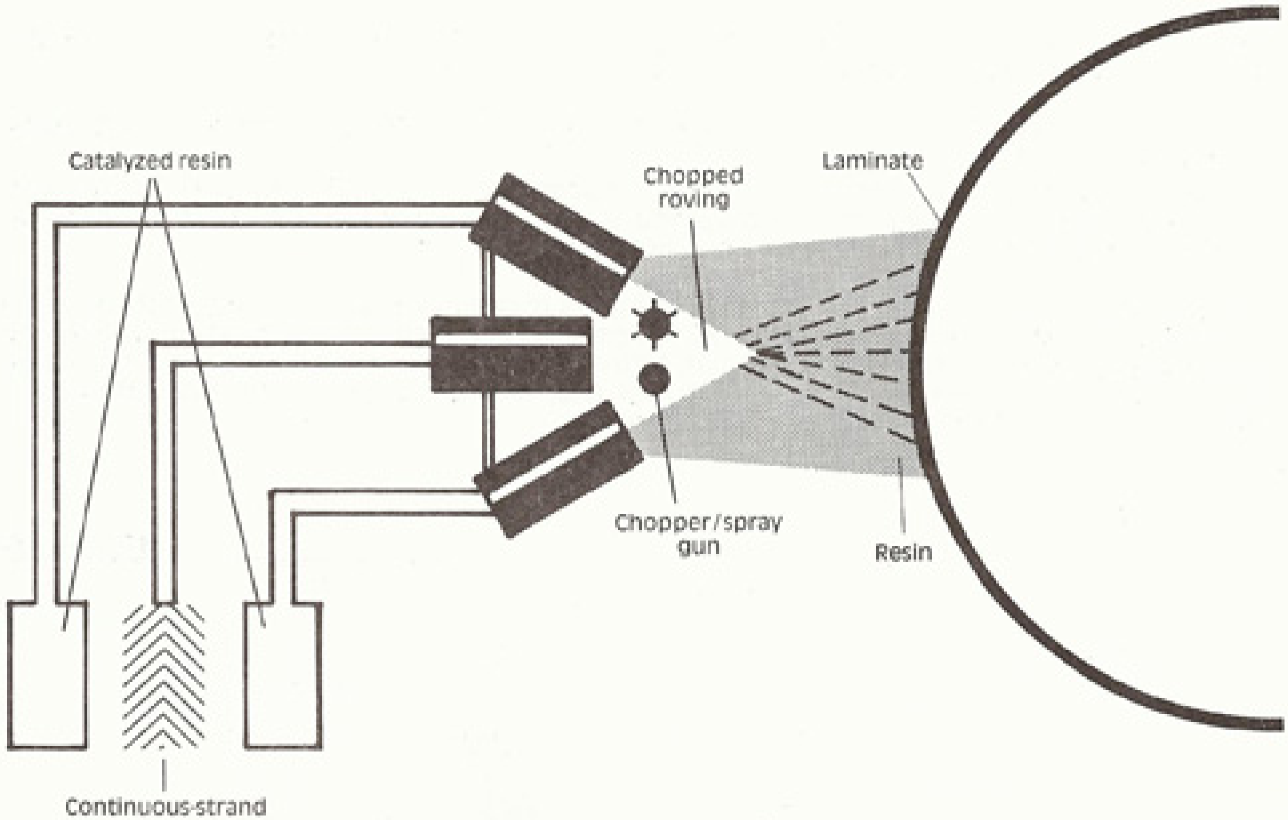


Advantages of this process include: Low initial investment in tooling and equipment, it is a simple process to learn, and it affords a wide range of part sizes.

Disadvantages include: The process is extremely dependent on the ability and experience of the fabricator. This means that the quality of the finished product is totally dependent on individual expertise. Also from a production cost standpoint, since this is a manual process, fabrication of large pieces tends to be very slow.

2. Spray up, the other contact molding process, is a method whereby continuous strands of fiberglass are fed into a "chopper gun" which chops fiberglass (by means of a rotary blade inside the gun) into 1" to 2" long strands. These strands along with resin are then sprayed onto a mold. Again, as in the hand lay up process, a roller is used to encapsulate or force the resin into the fiberglass.

This is a low to medium volume process and is suitable for making boats, small tanks, shower stalls and other small and large products. Resin systems primarily used in spray up are similar to hand lay up and can be cured at room temperature.



b. Sprayup

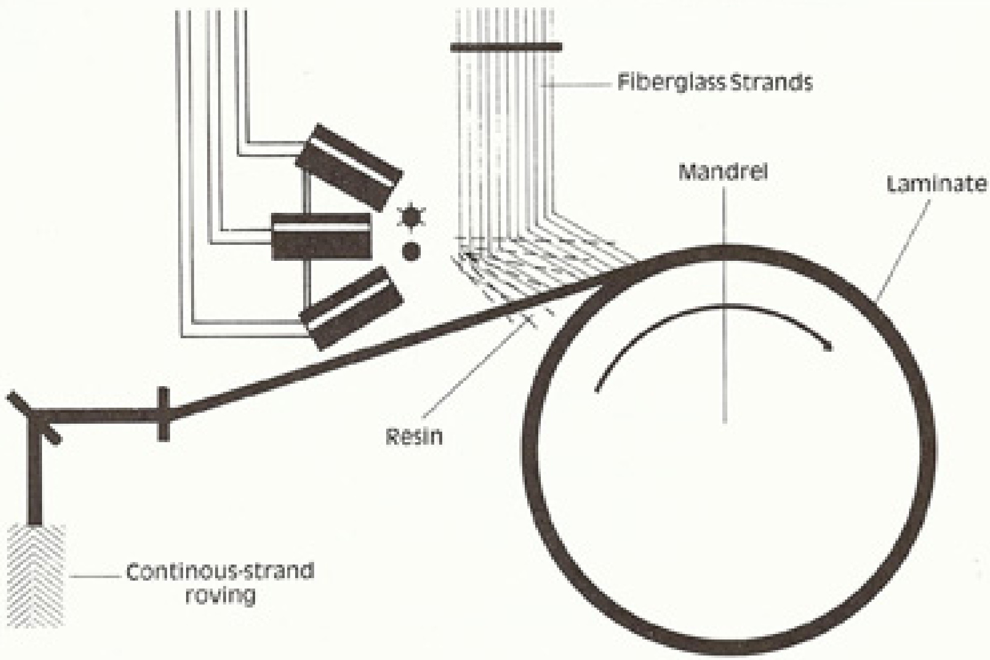
Advantages of this system include: Low initial investment in tooling and equipment, can be used in combination with hand lay up, offers greater versatility than hand lay up in part complexity, affords a wide variety of part sizes and is easy to learn.

Disadvantages are similar to hand lay up in that again quality is dependent on the individual producing the piece. Both hand lay up and spray up produce laminates that are 70% resin and approximately 30% fiberglass. While this is excellent for liquid retention, the strength of a laminate is derived from the amount of fiberglass contained in it.

The applicable specification for both of the two processes described is PS 15-69 published by the National Bureau of Standards (NBS).

3. Filament winding is the third fabrication method. This process involves wrapping multiple, continuous strands of fiberglass onto a rotation mandrel or drum. Resin is applied either by spraying or by pulling the strands through a resin bath. Special winding machines are capable of laying down strands in predetermined patterns anywhere from 54° to 90° to the axis. Therefore strength can be built into the structure in the direction where greatest stress will be experienced. For example high pressure filament wound pipe is commonly wound at a 54° angle. Tanks are most often wound at an angle of 90° to the axis, (commonly referred to as hoop winding) however some manufacturers offer tanks with windings in a helical pattern or a combination of helical and hoop winding is also available. This combination will result in a tank wall stronger than is possible by utilizing only one or the other winding patterns.

c. Filament winding



Filament winding can be and is commonly combined with the chop spray method. By combining the two processes a monolythic tank wall with superior strength and liquid retention capabilities can be produced.

Advantages of the filament winding process include: The greatest fiberglass to resin ratio, which gives the highest weight to strength ratio of any fiberglass-reinforced manufacturing process, it provides the highest degree of control over uniformity of thickness and fiber orientation, the process is highly automated and particularly suited for the manufacture of cylindrical products such as tanks and piping. This process also facilitates the construction of a monolithic wall.

Perhaps the single biggest disadvantage of filement winding is a high initial investment in equipment and tooling. This is especially true if a wide range of sizes in tanks or piping is offered. However, the degree of automation, quality control and strength of the finished product are making filament wound products preferred by many engineers.

The applicable specification for filament wound tank is D-3299-81 of the American Society for Testing and Materials (ASTM).

Resins:

In the production of fiberglass products, fiberglass provides strength to the structure while resin bonds the fiberglass together and keeps the liquid inside. If a mismatch between the resin and the product being stored occurs, the resin will soften and breakdown because of chemical attack or from high heat inside the tank. Therefore it is very important the fabricator know exactly what will be stored, at what concentrations or percentages and the maximum heat expected.

The most widely used resins in the production of storage tanks are known as polyesters, (a few specialty resins such as furans and epoxies are available but will not be discussed.) There are basically 4 different types of polyester resins now being used. Orthophthalics, Isophthalics, Bisphenol A Fumarates and Vinyl Esters.

Orthophthalic or general purpose resins are the least expensive and are therefore widely used in the production of bath tubs, shower stalls, boats and have some applicability in the production of storage tanks. These resins should not be used where temperatures above 150° F will be experienced or where resistance to chemical attack is important, (such as acid storage.) Isophathalic (Iso) resins, though slightly more expensive than Orthophthalic (Ortho) resins, are preferred in the manufacture of storage tanks because of better chemical resistance and higher heat tolerance, 170° - 210° F depending on the chemical stored.

Where increased chemical resistance or even higher heat tolerance is necessary Bisphenol A Fumarates or Vinyl Ester, resins are used. Again both are polyester resins but differ from Ortho and Iso resins in their chemical make up, even though they are considerably more expensive, there are very few chemicals Bisphenols and Vinyl Ester resins are incapable of storing.

Characteristics of each of the polyester resins can be changed by the use of additives, fillers and pigments. Antimony can be added to increase the nonflammability of resins, a colloidal silica is often used as a Thixotropic agent to increase viscosity and where static electricity build up is a problem the addition of certain types of graphite, carbon black, graphite fibers or metal coated fiberglass fibers will increase conductivity. Fillers are sometimes added to reduce production costs . The most often used fillers are ground limestone, talc, koalin clay and sand. However, the use of fillers is often prohibited by companies purchasing fiberglass tanks as fillers may reduce the corrosion resistance of the resin.

Because ultraviolet light tends to deteriorate polyesters, pigments can be added to a resin to improve its weatherability. Pigmented resins or surface coatings effectively block ultraviolet rays and therefore keep the exterior resin rich surface intact. Where little or no protection is provided exterior fiberglass fibers will become exposed, (a phenomenon known as blooming) and can have a detrimental effect on the tank, especially where spillage of corrosive liquids occurs.

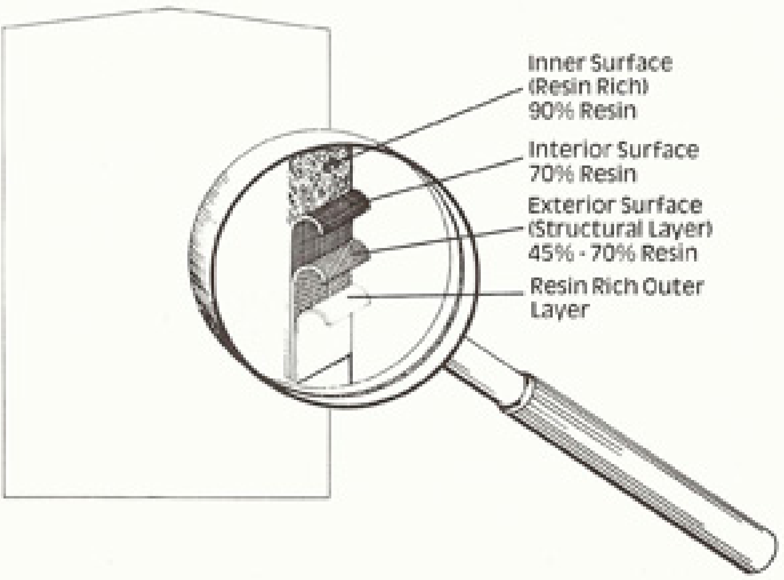
Specifications:

As mentioned, there now exists specifications for both contact molding and filament winding. However, both specifications are voluntary and it is therefore up to the individual manufacturer to comply.

As is the case with most specifications, the NBS and ASTM specifications are somewhat difficult to follow for persons not familiar with the process being described. Even though each area of the specifications is important, we have chosen a few areas for a more detailed discussion. We hope that this information will make the specifications more meaningful and easier to follow.

Both specifications talk about the fiberglass laminate as consisting of three distinct layers, an inner surface, an interior layer, and an exterior layer. The inner surface is the layer which is in direct contact with the liquid being stored. It is very important this layer be resin rich (a ratio of 90% resin to 10% reinforcing material is desirable) since the resin actually holds the liquid in the tank. Both specifications say this layer shall be from .010 to .020 inches thick and shall be reinforced with glass surfacing mat (C-Veil) or with an organic surfacing material (Nexus). Nexus is an organic surfacing mat commonly used when the liquid being stored would actually attack the fiberglass fibers in C-Veil.

It is very easy to determine if a tank has a good inner surface by simply looking at the interior of the tank. This surface should be very smooth and slick with a minimum of pits, or air bubbles and no exposed fibers. NBS states that, "There shall be an average of no more than 2 pits per square foot, providing the pits are less than 1/8 inch diameter and not over 1/32 inch deep and are covered with sufficient resin to avoid exposure of inner surface fabric." When the inner surface of a tank is not slick or has a multitude of pits or air bubbles it is very likely the tank will begin to leak sometime during its life. It is not uncommon for fabricators that don't follow the NBS or ASTM specification to leave the inner surface out entirely, as a cost savings of from 10% - 15% can be realized this way. Problems of weeping or leaks may not appear immediately but will start showing up perhaps a year or two after the tank is put in service. Small weeps may not be of great concern where the stored liquid is not hazardous, but in those instances where the liquid is flammable, extremely corrosive, or actually attacks glass fiber, the inner surface becomes one of the most important parts of the tank.



The interior layer comes next and is included to back-up and reinforce the inner surface. A ratio of 70% resin to 30% fiberglass is desirable and is most commonly applied using the chop spray method. This layer should be applied in two or more passes and in combination with the inner liner, be a minimum of .100 inches thick. Unlike the C-Veil or Nexus inner liner, it is difficult to determine if a good interior layer has been applied, unless sophisticated equipment is available for testing.

The final portion of the laminate is the exterior layer which makes up the structural portion of the tank. This layer will contain the highest concentration of fiberglass and will consist of many different layers and types of fiberglass. As mentioned earlier filament winding will produce the strongest laminate possible because the glass fibers are oriented in specific directions. Hand lay up tanks gain strength by using multiple layers of glass rovings which contain fibers oriented in one or two directions. The structural layer is primarily added for strength and therefore, is not designed to contain the liquid, should it pass through the two inner surfaces.

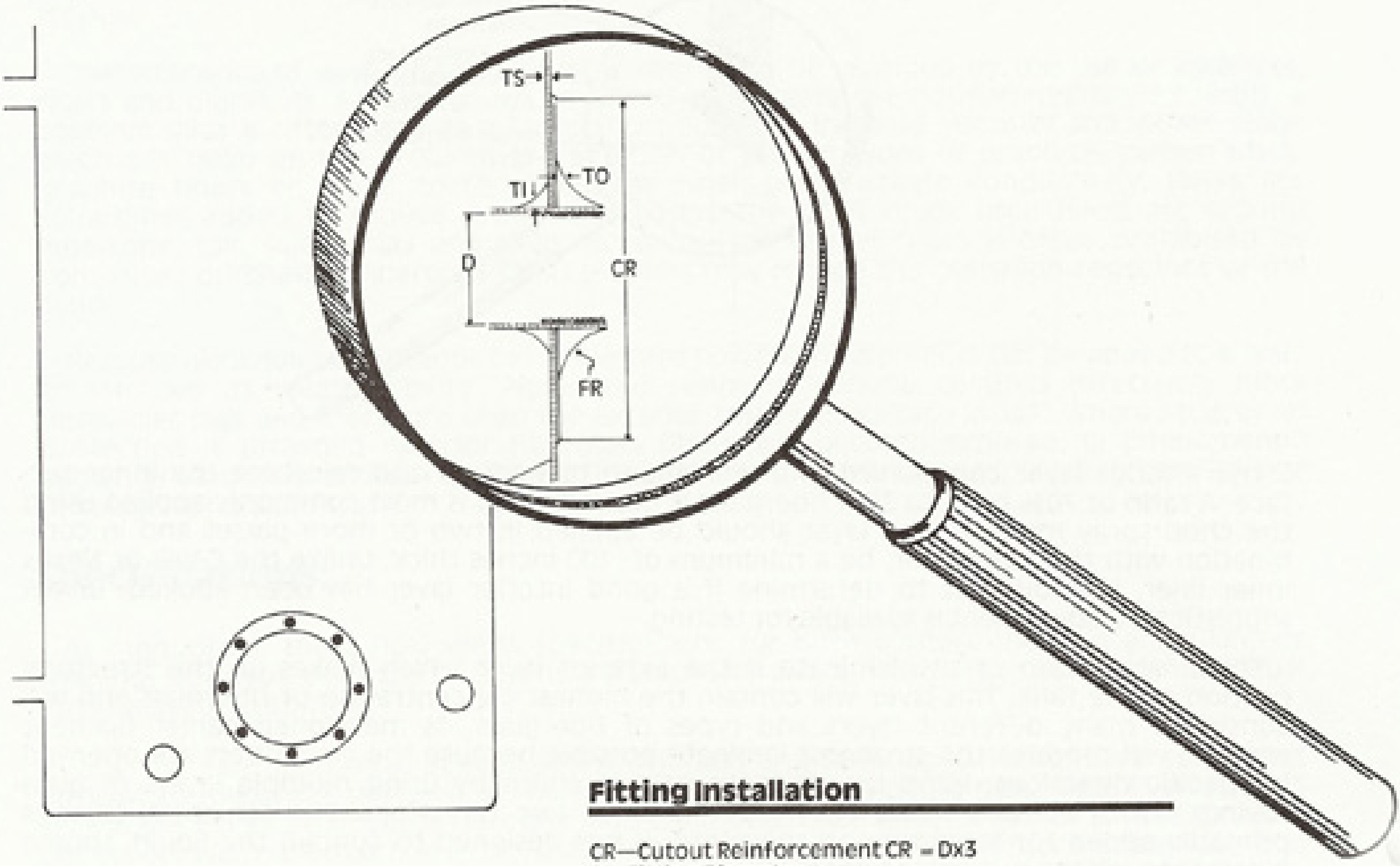
One other layer which many manufacturers include is a final coat of resin or gel coat sprayed over the exterior layer. This gives the tank a maintenance free exterior surface, and is very important when spillage of the stored liquid occurs.

There are applications where it is advantageous to fabricate tanks using two different types of resin. In these instances the inner liner would be fabricated with a higher grade resin than the exterior layer. Advantages would be that chemical resistance of the tank can be improved somewhat. However, where highly corrosive liquids are stored problems can arise from spillage or if the stored chemical passes through the inner liner the integrity and strength of the tank may suffer.

Another critical area is fitting and manway installation. Both NBS and ASTM refer to this in some detail but since the ASTM is somewhat easier to follow, all references to fitting installation will be taken from the ASTM specifications.

Specifications on steel pressure vessels point out that when material from a tank is removed (such as when fitting cutouts are made) material shall be replaced in order to bring that area back to a level of strength similar to what it was before the cutout was made. This is accomplished by welding material in around the cutout, and will look something like a donut at the fitting location.

Likewise, the ASTM states that "When a vessel shell or head is cut in an area bearing Hydrostatic pressure, the cutout shall be reinforced on a circular area concentric with the cutout." It goes on to describe the manner in which the fitting is to be secured, how much area is to be reinforced around the fitting, and how thick the reinforced area is to be. It describes the type of laminate to be used on the inside of the tank and the lengths of the interior and exterior laminates around the fitting. From all of this you can see that fitting and manway installation is very important to ASTM. Nowhere in the specifications does it mention that bolted or bulkhead type fittings are acceptable, or that rectangular manways are permitted.



Fitting Installation

CR—Cutout Reinforcement CR = Dx3
D—Fitting Diameter
TS—Tank Shell Thickness
FR—Fillet Radius 3/8" min.
TO—Outside Installation Laminate Thickness
TI—Inside Installation Laminate Thickness

Another area of interest is the minimum physical property requirements for fiberglass laminates at various thicknesses. The following table gives minimum acceptable physical properties in three important areas.

TABLE 1 Typical Contact-Molded Laminate Physical Properties[A]
Based on use of woven roving in thickness 1/4 in. and above.

Property	Thickness, in. (mm)			
	1/8 to 3/16 (3.2 to 4.8)	1/4 (6.4)	5/16 (7.9)	3/8 & up (9.5 & up)
Ultimate tensile strength, min. psi	9,000	12,000	13,500	15,000
Flexural strength, min, psi	16,000	19,000	20,000	22,000
Flexural modulous of elasticity (tangent), min psi	700,000	800,000	900,000	1,000,000

[A] Laminates that do not meet the minimum values of Table 1 are considered acceptable, provided they are made to afford the same overall strength that would be obtained with a laminate meeting the specified thickness.

Areas of general interest in the ASTM specifications are: tanks over 500 lbs. are to have lifting lugs, the top head shall be capable of supporting a single 250 lb. load on a 4x4 area without damage, the minimum thickness shall be 3/16", the minimum knuckle radius shall be 1.5", the resin shall be commercial grade ... that has been determined by previous documented service to be acceptable for the service conditions.

Obviously, both ASTM and NBS are more detailed and specific than what you have just read. However, our intent here is not to give you the technical details but rather give you enough information to look at a fiberglass tank and decide if it is a quality tank.

Sidewall Test Results as Reported by U.S. Testing

6-27-83 For Filament Wound Fiberglass Tanks,
Manufactured by Palmer Mfg., at the
Garden City, Kansas, Plant

Thickness	ASTM D-3299* & NBS PS-15-69** Requirements	FTMA Req. #1	Palmer Test Results
Tensil Strength			
.125-.188	9,000 PSI	6,300	(No sample tested at this thickness)
.25	12,000	8,400	23,466 (sample thickness—.289)**
.3125	13,500	9,500	35,499 (sample thickness—.36)***
.375	15,000	10,500	(No sample tested at this thickness)
Flexural Strength			
1/8 - 3/16	16,000	11,000	(No sample tested at this thickness)
1/4	19,000	13,000	(No sample tested at this thickness)
5/16	20,000	14,000	20,744***
3/8	22,000	15,500	37,384**
Flexural Modulas of Elasticity			
1/8 - 3/16	700,000	490,000	(No sample tested at this thickness)
1/4	800,000	560,000	(No sample tested at this thickness)
5/16	900,000	630,000	904,098***
3/8	1,000,000	700,000	

Fiberglass Content of 10 Sidewall Samples submitted from the Garden City Plant averaged 42.005%. Minimum Fiberglass Content requirements for the entire Laminate (a combination of Inner Surface, Interior Layer and Structural Layer) is not addressed in the ASTM.

Knuckle Radius from both Plants was shown as 2.2 inches. A Radius not less than 1.5 inches is required by ASTM and FTMA.

*—FTMA stands for "Fiberglass Tank Manufacturers Association"

***—GCP = Garden City Plant

WARRANTY

Limitation: This warranty is limited to new products manufactured and sold by warrantor. **The Warrantor:** Palmer Mfg. and Tank, Inc. West Hiway 50, P.O. Box 1195, Garden City, Kansas 67846, Ph. 316-275-7461.
Duration: Two (2) year from the date of purchase of this product.

The warrantor warrants its Fiberglass and Steel products to be free from defects in manufacture, materials, or workmanship, under normal and designated use and service to the original purchaser or user. All specifications and materials are approximate, and may vary slightly due to manufacturing techniques by either the Warrantor or by suppliers furnishing raw materials in the manufacturing process.

Specifically in regards to Fiberglass tanks the normal use and service requires:

a. That the tanks be installed according to manufacturers recommendations and according to the nature of its originally intended purpose.
b. That chemicals stored therein must be of the nature and percentage of solution designated on the tank and on the invoice.
c. That excessive weight due to valves, heavy pipes or strainers, etc. must not be carried by outlets.

Normal use and service EXCLUDES damage due to breakage during shipment, vandalism, flood, fire or other acts of God.
Any noncompliance with the above mentioned requirements shall cause this warranty to become VOID.

Warrantor's liability shall not exceed the purchase price of the products sold individually, F.O.B. point of delivery, and at the option of the warrantor, repair or replacement may be initiated or an allowance of credit may be granted the buyer. In the event remedy is sought for defect, notification in writing must be given the WARRANTOR within two [**2**] year after the date of purchase in order for warranty to be valid. Reasonable time must be allowed for replacement or repair of any product.

Products of a nature that can be easily transported, must be shipped prepaid to Manufacturer. Any repair to warranteed products must be performed by authorized personnel of WARRANTOR or by an authorized representative thereof.

This warranty is expressly in lieu of any other warranty expressed or implied, including any implied warranty of merchantability of fitness for a particular purpose.

The WARRANTOR SHALL NOT BE liable for any direct or consequential damages, including materials lost, labor or installed cost, injury, or property damage caused by any defect in any product sold by it. There are no warranties which extend beyond the description on the face hereof.

GALLONS IN ROUND TANKS—for one foot in depth

An easy method of computing the gallonage of any round, vertical or upright tank.

Dia. of Tanks Ft.	In.	No. U.S. Gals.	Cu. Ft. and Area in Sq. Ft.	Dia. of Tanks Ft.	In.	No. U.S. Gals.	Cu. Ft. and Area in Sq. Ft.	Dia. of Tanks Ft.	In.	No. U.S. Gals.	Cu. Ft. and Area in Sq. Ft.
1		5.87	.785	5	8	188.66	25.22	19		2120.90	283.53
1	1	6.89	.922	5	9	194.25	25.97	19	3	2177.10	291.04
1	2	8.	1.069	5	10	199.92	26.73	19	6	2234.	298.65
1	3	9.18	1.227	5	11	205.67	27.49	19	9	2291.70	306.35
1	4	10.44	1.396	6		211.51	28.27	20		2350.10	314.16
1	5	11.79	1.576	6	3	229.50	30.68	20	3	2409.20	322.06
1	6	13.22	1.767	6	6	248.23	33.18	20	6	2469.10	330.06
1	7	14.73	1.969	6	9	267.69	35.78	20	9	2529.60	338.16
1	8	16.32	2.182	7		287.88	38.48	21		2591.	346.36
1	9	17.99	2.405	7	3	308.81	41.28	21	3	2653.	354.66
1	10	19.75	2.640	7	6	330.48	44.18	21	6	2715.80	363.05
1	11	21.58	2.885	7	9	352.88	47.17	21	9	2779.30	371.54
2		23.50	3.142	8		376.01	50.27	22		2843.60	380.13
2	1	25.50	3.409	8	3	399.88	53.46	22	3	2908.60	388.82
2	2	27.58	3.687	8	6	424.48	56.75	22	6	2974.30	397.61
2	3	29.74	3.976	8	9	449.82	60.13	22	9	3040.80	406.49
2	4	31.99	4.276	9		475.89	63.62	23		3108.	415.48
2	5	34.31	4.587	9	3	502.70	67.20	23	3	3175.90	424.56
2	6	36.72	4.909	9	6	530.24	70.88	23	6	3244.60	433.74
2	7	39.21	5.241	9	9	558.51	74.66	23	9	3314.	443.01
2	8	41.78	5.585	10		587.52	78.54	24		3384.10	452.39
2	9	44.43	5.940	10	3	617.26	82.52	24	3	3455.	461.86
2	10	47.16	6.305	10	6	647.74	86.59	24	6	3526.60	471.44
2	11	49.98	6.681	10	9	678.95	90.76	24	9	3598.90	481.11
3		52.88	7.069	11		710.90	95.03	25		3672.	490.87
3	1	55.86	7.467	11	3	743.58	99.40	25	3	3745.80	500.74
3	2	58.92	7.876	11	6	776.99	103.87	25	6	3820.30	510.71
3	3	62.06	8.296	11	9	811.14	108.43	25	9	3895.60	520.77
3	4	65.28	8.727	12		846.03	113.10	26		3971.60	530.93
3	5	68.58	9.168	12	3	881.65	117.86	26	3	4048.40	541.19
3	6	71.97	9.621	12	6	918.	122.72	26	6	4125.90	551.55
3	7	75.44	10.085	12	9	955.09	127.68	26	9	4204.10	562.
3	8	78.99	10.559	13		992.91	132.73	27		4283.	572.66
3	9	82.62	11.045	13	3	1031.50	137.89	27	3	4362.70	583.21
3	10	86.33	11.541	13	6	1070.80	143.14	27	6	4443.10	593.96
3	11	90.13	12.048	13	9	1110.80	148.49	27	9	4524.30	604.81
4		94.	12.566	14		1151.50	153.94	28		4606.20	615.75
4	1	97.96	13.095	14	3	1193.	159.48	28	3	4688.80	626.80
4	2	102.	13.635	14	6	1235.30	165.13	28	6	4772.10	637.94
4	3	106.12	14.186	14	9	1278.20	170.87	28	9	4856.20	649.18
4	4	110.32	14.748	15		1321.90	176.71	29		4941.	660.52
4	5	114.61	15.321	15	3	1366.40	182.65	29	3	5026.60	671.96
4	6	118.97	15.90	15	6	1411.50	188.69	29	6	5112.90	683.49
4	7	123.42	16.50	15	9	1457.40	194.83	29	9	5199.90	695.13
4	8	127.96	17.10	16		1504.10	201.06	30		5287.70	706.86
4	9	132.56	17.72	16	3	1551.40	207.39	30	3	5376.20	718.69
4	10	137.25	18.35	16	6	1599.50	213.82	30	6	5465.40	730.62
4	11	142.02	18.99	16	9	1648.40	220.35	30	9	5555.40	742.64
5		146.88	19.63	17		1697.90	226.98	31		5646.10	754.77
5	1	151.82	20.29	17	3	1748.20	233.71	31	3	5737.50	766.99
5	2	156.83	20.97	17	6	1799.30	240.53	31	6	5829.70	779.31
5	3	161.93	21.65	17	9	1851.10	247.45	31	9	5922.60	791.73
5	4	167.12	22.34	18		1903.60	254.47	32		6016.20	804.25
5	5	172.38	23.04	18	3	1956.80	261.59	32	3	6110.60	816.86
5	6	177.72	23.76	18	6	2010.80	268.80	32	6	6205.70	829.58
5	7	183.15	24.48	18	9	2065.50	276.12	32	9	6301.50	842.39

To find the capacity of tanks greater than the largest given in the table, look in the Table for a Tank of one-half of the given size and multiply its capacity by 4; or one of one-third its size and multiply its capacity by 9, etc.

Useful Facts and Figures

Linear Measurement

1 foot (ft.)	= 12 inches (in.)	1 centimeter (cm)	= 10 millimeters (mm)
1 yard (yd.)	= 3 ft. = 36 in.	1 meter (m)	= 100 cm = 1000 mm
1 mile (statute)	= 5,280 ft.	1 kilometer (km)	= 1000 meters

To convert	into	Multiply by	To convert	into	Multiply by
inches	centimeters	2.5400	centimeters	inches	0.3937
inches	millimeters	25.4000	millimeters	inches	0.0394
feet	meters	0.3048	meters	feet	3.2808
feet	millimeters	304.8000	millimeters	feet	0.0033
yards	meters	0.9144	meters	yards	1.0936
miles	kilometers	1.6093	kilometers	miles	0.6214

Area Measurement

1 square foot (sq. ft.)	= 144 square inches (sq. in.)	1 sq. centimeter (cm_2)	= 100 sq. millimeters (mm_2)
1 square yard (sq. yd.)	= 9 square feet	1 sq. meter (m_2)	= 10,000 cm_2
1 acre	= 4,840 sq. yds.	1 acre (a)	= 100 m_2
1 square mile	= 640 acres	1 sq. kilometer (km_2)	= 1,000,000 m_2

To Convert	into	Multiply by	To convert	into	Multiply by
square inches	sq. centimeters	6.4516	sq. centimeters	sq. inches	0.1550
square feet	sq. meters	0.0929	sq. meters	sq. feet	10.7639
square yards	sq. meters	0.8361	sq. meters	sq. yards	1.1960
acres	sq. meters	4,047.0	sq. meters	acres	0.0002
square miles	sq. kilometers	2.5900	sq. kilometers	sq. miles	0.3861

Cubic Measurement (Volume)

1 cubic foot (cu. ft.)	= 1,728 cubic inches (cu. in.)	1 cu. centimeter (cm_3)	= 1000 cu. millimeters (mm_3)
1 cubic yard (cu. yd.)	= 27 cubic feet (cu. ft.)	1 cubic meter (m_3)	= 1,000,000 cm_3

To convert	into	Multiple by	To convert	into	Multiply by
cubic inches	cu. centimeters	16.3872	cu. centimeters	cubic inches	0.0610
cubic feet	cubic meters	0.0283	cubic meters	cubic feet	35.3145
cubic yards	cubic meters	0.7646	cubic meters	cubic yards	1.3079

Liquid Measurement (Capacity)

1 pint (pt.)	= 28.875 cubic inches	1 centiliter (cl.)	= 10 milliliters (ml.)
1 quart (qt.)	= 2 pints = 57.75 cu. in.	1 liter (l)	= 100 cl. = 1000 ml.
1 gallon (gal.)	= 4 qts. = 231 cu. in.	1 kiloliter (kl)	= 1000 liters

To convert	into	Multiply by	To convert	into	Multiply by
cubic inches	liters	0.0164	liters	cubic inches	61.0250
pints	liters	2.1132	liters	pints	0.4732
quarts	liters	0.9463	liters	quarts	1.0566
gallons	liters	3.7853	liters	gallons	0.2642
cubic feet	liters	28.3162	liters	cubic feet	0.0353

Weight Measurement

1 ounce (oz.)	= 16 drams	1 centigram (cg.)	= 10 milligrams (mg.)
1 pound (lb.)	= 16 ounces	1 gram (g.)	= 10 cg. = 1000 mg.
1 short ton	= 2000 pounds	1 kilogram (kg.)	= 1000 grams
1 long ton	= 2240 pounds	1 metric ton (t.)	= 1000 kg.

To convert	into	Multiply by	To convert	into	Multiply by
drams	grams	1.7718	grams	drams	0.5644
ounces	grams	28.3495	grans	ounces	0.0353
pounds	kilograms	0.4536	kilograms	pounds	2.2046
tons (short)	tons (metric)	0.9072	tons (metric)	tons (short)	1.1023

Power Measurement

1 horsepower (hp.) = 746 watts = .7457 kilowatts (kw)

To convert	into	Multiply by	To convert	into	Multiply by
horsepower (U.S.)	horsepower (met.)	1.0139	horsepower (met.)	horsepower (U.S.)	0.9863
horsepower (U.S.)	kilowatts	0.7457	kilowatts	horsepower (met.)	0.7355
kilowatts	horsepower (U.S.)	1.3405	horsepower (met.)	Kilowatts	1.3596

Useful Information

TO FIND:

The circumference of a circle, multiply diameter by 3.1416.
The diameter of a circle, multiply circumference by .31831.
The area of a circle, multiply square of diameter by .7854.
The area of a triangle, multiply base by 1/2 perpendicular height.
The surface of a ball, multiply square of diameter by 3.1416.
The solidity of a sphere, multiply cube of diameter by .5236.
The side of an equal square, multiply diameter by .8862.
The cubic inches in a ball, multiply cube of diameter by .5236
The cubic contents of a cone, multiply area of base by 1/3 the altitude.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

To find the capacity of tanks any size: given dimensions of a cylinder in inches, to find its capacity in U.S. gallons, square the diameter, multiply by the length and by .0034.

To ascertain heating surface in tubular boilers multiply 2/3 the circumference of boiler by length of boiler in inches and add to it the area of all the tubes.

SOME FACTS:

Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (U.S. standard) weighs 8 1/2 lbs. and contains 231 cubic inches.

A cubic foot of water contains 7 1/2 gallons, 1728 cubic inches and weighs 62 1/2 lbs.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

Steam rising from water at its boiling point (212 degrees) has a pressure equal to the atmosphere (14.7 lbs. to the square inch).

A standard horsepower: The evaporation of 30 lbs. of water per hour from a feed water temperature of 100 degrees F into steam at 70 lbs. gauge pressure.

NOTES

Palmer

MFG. & TANK COMPANY

GARDEN CITY, KANSAS

P.O. BOX 1195 2814 W. JONES AVE. (620) 275-7461
GARDEN CITY, KANSAS 67846

TOLL FREE 1-800-835-9136

HIGH PLAINS PUBLISHERS, INC., DODGE CITY