

## 2. THE PLAYING FIELD

### 2.1 Playing Field Description

The playing field is a carpeted, hexagon-shaped area with a freely rotating central goal. Around the perimeter of the field are three stations for human players, and three stations for drivers and coaches. At the start of each match, inner tubes are placed in various starting locations around the playing field and at the player stations, as shown in Figures 1.1 and 1.2.

### 2.2 Playing Field Construction

Section 2.2 presents the information necessary to replicate the playing field and tubes.

#### Border

The perimeter of the field is defined by three sections of a curb of 4x4 lumber, resting directly on the carpet, and three barriers which join these sections.

#### Player Stations

There are three player stations located outside the perimeter of the playing field. The stations are centered on three adjacent sides of the hexagonal field border. There are breaks in the usual 4x4 border of the playing field at the interfaces between the field and the player stations. A special barrier, designed to allow tubes to be pushed into the player station without allowing robots in, is used at these interfaces. Aside from these barriers, the player stations have no physical structure. Player station borders are represented by tape on the floor.

Each player station is 5 feet wide (parallel to the field border), and 6 feet long (extending out perpendicular to the field border). Each station is divided into two areas, an area where the player can sit/stand/kneel/etc., and the interaction zone. The interaction zone extends outward from the playing field border for a distance of 3 feet. The remaining area extends a further 3 feet from the interaction zone. The exact dimensions and locations of the player stations are indicated on the Playing Field blueprint provided by FIRST.

The special barrier is constructed from 2"Ø metal pipe and fittings, and is mounted to the tops of the 4x4 border by pipe flanges. Small sections of 2x4 are mounted to the outside of the 4x4 border to provide sufficient width to mount the pipe flanges. In addition, an oak 1x4, which rests on top of the playing field rug, is used to provide a rigid connection for the sections of 4x4 that make up the field border. This board is attached to recesses in the bottom of the 4x4 border such that it does not raise the 4x4s off the rug. The exact dimensions of the barrier are indicated on the blueprint.

#### Driver Stations

The driver stations are located outside the playing field to the right of the player stations. Driver stations have no physical structure other than a shelf on which the Transmitter and associated control system equipment can be placed. The

borders of the driver stations are represented by tape on the floor. The exact dimensions and locations of the driver stations are indicated on the blueprint.

### **Goal Assembly Procedure:**

The goal consists of a triangular wooden base upon which is bolted a pyramid shaped vertical structure fabricated from steel pipe, metal castings, and a connecting bracket at its top called an apex bracket. The entire unit is mounted on three, fixed caster wheels which allow the goal to rotate as a unit about its vertical centroidal axis. A short vertical, central steel stub shaft and ball bearing assembly, bolted to a large plywood disk that rests on the playing field floor (floor disk mount) keeps the goal located in the center of the playing field while allowing it to rotate due to moments it may be subject to by robots and inner tubes touching it during a competition round.

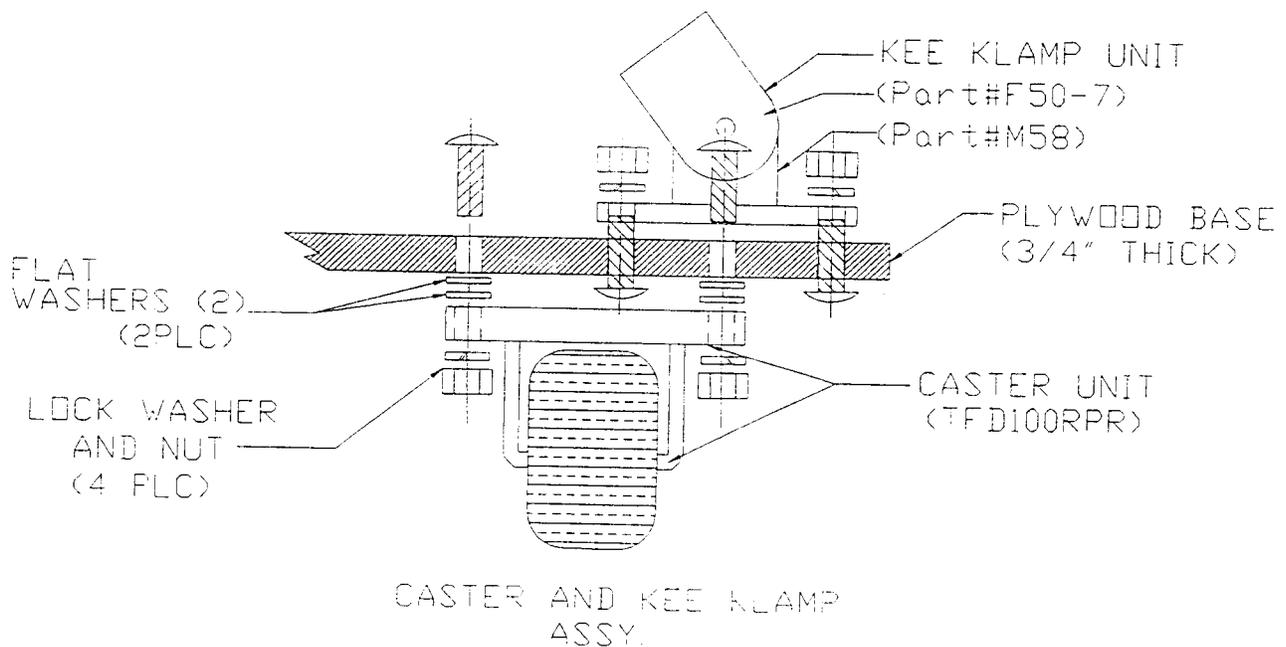
It is important that this procedure be carefully followed when fabricating the goal base and assembling the metal parts to it. **Read through this procedure in its entirety and plan it out before starting the assembly process.** Carry out the steps in numerical order, and carefully measure and lay out all dimensions as indicated. The various metal fittings used in this year's game design have been sourced from the Kee Industrial Products Co. Refer to the Playing Field blueprint provided by FIRST and the drawings herein, and review to the KEE KLAMP fittings catalog provided in the kit of parts.

- 1) Begin fabricating the triangular base by cutting out an equilateral triangle from a sheet of 3/4" thick plywood, the triangle being exactly 48" on each side.
- 2) Locate the exact center of the triangle as follows: bisect each side of the triangle, and pencil in a line from each side's center point to its opposite apex. All three lines should cross exactly at the geometric center point of the plywood base. Drill a small hole (1/16" diameter bit) through this center point. Be sure that the drill is perfectly normal (perpendicular) to the surface of the plywood. Flip the base over, and pencil in reference lines on the bottom surface from each triangle vertex to the drilled center hole. You now have established the important references from which all other measurements will be made when assembling the goal.
- 3) Fabricate a protective skirt for the base by measuring and cutting three appropriate lengths of standard stock 2"x4" lumber (actual dimensions are 1-1/2" x 3-1/2"), and attach the narrow (2") edges of the 2x4s to the plywood base thus forming a protective skirt around it. Use both wood glue and screws, driving 4 evenly spaced 2" long wood screws down through the top of the plywood into the narrow edge of each of the 2x4s, keeping the outer edges of the 2x4s aligned with the vertical edges of the triangular base. Also screw the butt ends of the 2x4s together, while keeping the screws away from the tip areas that will be removed when the triangle's points are cut off. Once the glue has set, saw off the three sharp points of the triangle thus creating a 1" flat on each one. Sandpaper the resulting base to remove any splinters and sharp edges.

- 4) On the top surface of the wooden base, carefully measure and mark the positions of the cast base plate fittings (KEE P.N. M58) at each vertex of the triangle. Mark the locations of the two bolt drill holes of each fitting on the lines previously penciled in step 2) above.
- 5) Flip the base over and carefully measure and lightly mark the four mounting hole locations for each of the three supporting fixed casters. Temporarily position the fixed casters on the bottom surface of the wood base over the mounting hole marks such that the wheel axles are directly over and parallel to the radial reference lines previously marked between the triangle apexes and base's geometric center. Carefully measure and verify the specified distance from the center of the plywood base to the center of each wheel's footprint. Check that there is no interference between the inner edges of the 2x4 skirts and the casters' mounting flanges. Check the positioning of the casters relative to the KEE cast base plate fittings on the top surface of the base. With the **exception of the inner bolt holes** of the KEE base plates fittings, there should be no overlap between bolt holes and mounting brackets of the casters and those of the base plates. Mark the final locations of the center of each of the mounting bolt holes, and using the caster mounting brackets as templates, pencil the outline of the bracket on the plywood at each apex
- 6) With the base still inverted, mark the locations of the two attachment bolt holes for the self-aligning 1" I.D. bearing at the center of the wood base. These are for the bolts that anchor the flange units (between which the bearing is clamped) that forms the central, vertical pivot of the goal proper.
- 7) Drill all mounting bolt holes in the base. Be sure the drill bits are precisely placed on the hole center marks. Use a 3/8" Ø drill bit for all the casters and center bearing bolt holes, and a 13/32" Ø bit for the KEE base plate bolts. Complete the goal base drilling procedure by cutting out the 2 1/2" diameter hole to accept the center bearing.
- 8) Assemble the goal's hardware to the plywood base as follows (see Figure 2.1):
  - a) Starting at one of the triangle apexes, insert the mounting bolts for the KEE base plate through the plywood base from **below** using two 3/8" dia x 2" carriage bolts.
  - b) Insert four 5/16" dia. x 1-1/2" carriage bolts through the plywood from **above** at the caster's position.
  - c) Place the KEE base plate on the top surface of the plywood base over the upward protruding bolt ends. Add a locking washer to each bolt, then screw on the nuts and tighten the bracket down onto the plywood. Check to be sure that the heads of the bolts have been

drawn up tightly against the underside surface of the plywood base. Repeat this procedure for the other two KEE base plates.

- d) Invert the base and place **two flat washers** over each of the four protruding wheel mounting bolts. Next, slip the three casters down over the protruding bolts (the flat washers are located **between** the plywood and the mounting brackets of the casters). Place locking washers over the bolt ends and screw a nut onto each one. Carefully adjust the casters such that their wheel axles are aligned directly over and parallel to the radial lines penciled in step 2) above. This will ensure that the wheels will be exactly tangent to the radius line from the vertical centroidal axis of the goal.
- e) Mount the central bearing onto the **bottom surface** of the plywood base by clamping the bearing between its two holding flanges, and bolt it into position from underneath using two 5/16" x 1-1/2" carriage bolts. Place a flat washer and a lock washer over the protruding bolt ends, screw on nuts and tighten the assembly.
- f) Mount the three Female Single Sockets (KEE P.N. F50-7) onto the KEE Base Plates as follows: Insert one or more washers as needed in the clearance space between the sides of the Single Sockets and the vertical tab of the Base Plates to achieve a snug fit between them. Bolt each joint together with a 5/16" dia. bolt and nut, and lightly tighten the bolts. We will hereafter refer to this Single Socket / Base Plate assembly as a swivel mount.



- 9) Prepare the pipe segments and assemble the vertical structure of the goal as follows:
  - a) The pipe used for the upper structure is standard iron pipe schedule 40 with an I.D. of 1-1/4", obtainable from most plumbing supply houses. Cut three pieces each 7' 6" long for the canted vertical posts, and nine pieces exactly 2' long for the canted horizontal arms.
  - b) Slip three of the cast iron Tees over each of the 7' 6" lengths, and carefully determine the positions of the Tees by measuring the specified distances from the top end of the vertical posts. Clearly mark their positions on the pipes for future reference. Place the Tees in their approximate positions on the pipes, and lightly tighten their set screws to temporarily hold them.
  - c) Place the goal base on a level floor and support it so that its wheels are slightly off of the floor. Place wooden blocks or their equivalent under the 2x4 skirt so that the base will not move. Using a carpenter's level and some wedges as necessary, accurately level the base in both the E-W and N-S directions.
  - d) Place a stepladder next to the base, and with someone on the ladder to hold the pipes, carefully insert the three long pipe sections into the pipe swivel mounts on the base. Be sure that the pipes are fully seated into the mounts, then tighten the set screws on the Single Sockets to securely anchor the bottom ends of the pipe sections.
  - e) Move the top ends of the pipes so that they come together approximately over the vertical center of the base forming a pyramid. Sufficiently tighten the bolt and nut fasteners at the base on the pipe swivel mounts (paragraph. 8f above) so that the pipes will remain in their canted positions without being supported at the top.
  - f) Attach the goal's top triangular shaped Apex Bracket supplied by FIRST. The Bracket consists of three aluminum plates welded into a triangular, Y shaped structure. Each plate has two bolt holes drilled near its outer end, with the holes near the top edge slightly closer to the triangular center than the holes near the bottom edge.
  - g) Position the Bracket at the top of the vertical pipes such that the top ends of the pipes are approximately aligned with the top edges of the Bracket. The pipes should be positioned such that they lie against the vertical faces of the Bracket **on the same sides as the weld beads**, with the two drilled holes in each plate falling approximately in the center of the side wall of each pipe. Using three, 6" C-clamps, temporarily clamp each pipe to the Apex Bracket. Place the clamps at the very top of the Bracket so that they are not close to the lower of the two bolt holes in the Bracket's plates.
  - h) Using a plumb bob on a length of string, drop a plumb line from the exact center of the Bracket down to the center of the vertical bearing

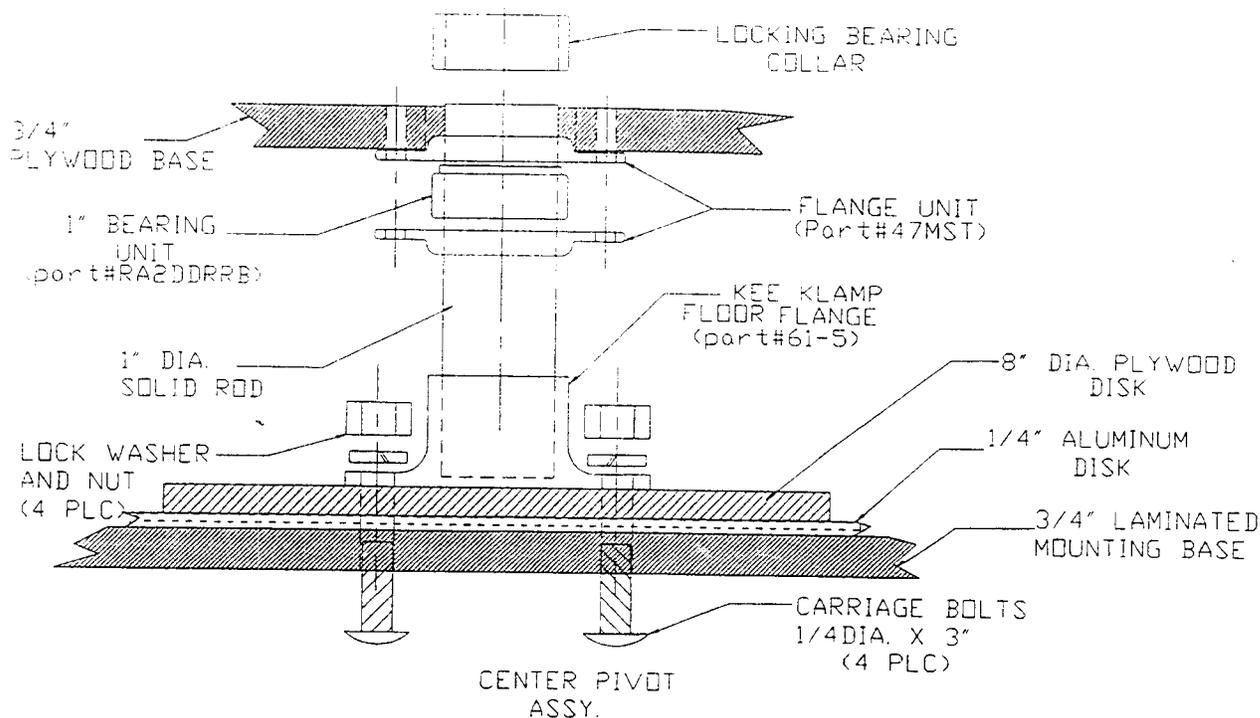
in the goal's base. Working with the Bracket and clamps at the top while observing the plumb bob, carefully adjust the Bracket until it is centered over the bearing, and its top surface is horizontal (not cocked - check it with a small level). This procedure requires a little trial and error, don't rush it!

- i) Once the Bracket is properly positioned, securely tighten the bolt and nut fasteners on the pipe swivel mounts at the goal's base.
  - j) Drill a 17/64"  $\varnothing$  hole through one of the three vertical pipes using the lower hole in the apex bracket-bracket plate as your guide. Run the drill through the hole and penetrate the adjacent pipe wall. **Note**, it is not necessary to drill into the opposite wall of the pipe. Carefully remove the C-clamp from the just drilled pipe, and holding a matching 1/4" nut with your fingers, slide the nut down into the pipe until it aligns with the just drilled hole. Now thread a 1" long x 1/4"  $\varnothing$  hex headed bolt through the plate and drilled hole, into the nut held inside the pipe. While now holding the nut inside the pipe with a small wrench, tighten the bolt securely. This will anchor the top end of the first pipe.
  - k) Repeat the above procedure at each of the other two pipe / Bracket lower hole connections.
  - l) Finally, using the same procedure as above, drill through each top Bracket bolt hole through the pipe inner wall, and place and tighten the second bolt and nut fastener on each pipe. At this point, the basic structure of the goal should form a rigid, strong pyramid structure.
- 10) Assemble the canted horizontal members to the vertical posts:
- a) Rotate the three Tees on each vertical pipe until they are roughly pointing radially outward from the center line of the goal. Lightly tighten the dual set screws to temporarily hold the Tees in place. Insert the 2' long horizontal pipe segments into each of the nine Tees, then securely tighten the single set screws that hold the short pipe segments in the Tees.
  - b) Working with each horizontal member individually, loosen the two vertical pipe set screws on the Tee, and make final adjustments to the members until each is at its specified vertical position and pointed exactly radially outward from the center of the goal. This can be done by having someone stand behind the goal, and using the vertical plumb bob line as a reference, sight back through the plumb line to the Tee and instruct another team member to rotate the Tee until the horizontal pipe is properly aligned. Give a final alignment check of all parts of the goal and securely tighten all set screws.
- 11) Assemble the flanges to the horizontal pipe segments:
- a) From a sheet of 1/4" plywood, cut out nine disks that are exactly 3 15/16" in diameter. Using one of the round Kee Klamp cast iron

flanges as a template, center it over each disk and mark the centers of two (opposite each other) flange mounting holes onto the disks. Using a 3/16" Ø bit, drill the two screw holes where marked through each disk. Chamfer (one surface only) each hole to accept a flat headed screw such that the surface of the heads will lie even with the surface of the disk. Attach one disk to the flat mounting surface of each flange using two 1/2" x 10/32" Ø flat headed screws and nuts, placing the screws through the chamfered side of the disks, then the flanges, and thread on the nuts from behind the flange.

- b) Mount the flanges on their respective horizontal posts. This completes the fabrication of the rotatable upper portion of the goal.
- 12). Fabricate the circular, laminated floor disk mount assembly (see Figure 2.2):
- a) From 3/8" thick sheets of plywood, cut four semicircular segments each having a radius of 2 1/2'. Identify the smoothest two segments (which will be used for the top surface), and set them aside. Place the remaining two segments on a flat horizontal surface with their diameters butted together so as to form a 5' diameter disk. Place and glue the other two semicircle segments on top of the bottom disk (smooth surface up), aligning the top butted diameters at 90 degrees to the seam of the bottom pair. This forms a 3/4" thick laminated floor base upon which the goal proper will ride.. Be sure that this laminated structure is perfectly flat and not warped. It will help to place weights (such as bricks) on the base until the glue has set.
  - b) Fabricate the track that the caster wheels will ride on: **Note:** for the official competition, FIRST will use a 1/4" thick disk of aluminum as the surface upon which the wheels will ride. The full weight of the goal will be carried by the three caster wheels riding on this disk which will be subject to wear with repeated use over the many competition rounds. (For their test purposes, teams fabricating goals may wish to use some other less expensive material such as 1/4" hard board (Masonite)). Cut out a 42" Ø disk from a sheet of 1/4" thick aluminum
  - c) Center and glue the disk to the top surface of the laminated floor disk mount
  - d) Cut an 8" diameter disk from a scrap of the plywood and glue it to the center of the top surface of the laminated floor disk mount. (This smaller disk functions both as a support base for the stub shaft and a reinforcement to the floor mount).
  - e) Position the small Kee Flange (P.N. 61-5, 3/4"Round Flange) at the center of the 8" plywood disk and mark the position of the four mounting holes of the flange. Using a 17/64" drill bit, drill each of the holes all the way through the entire base assembly.

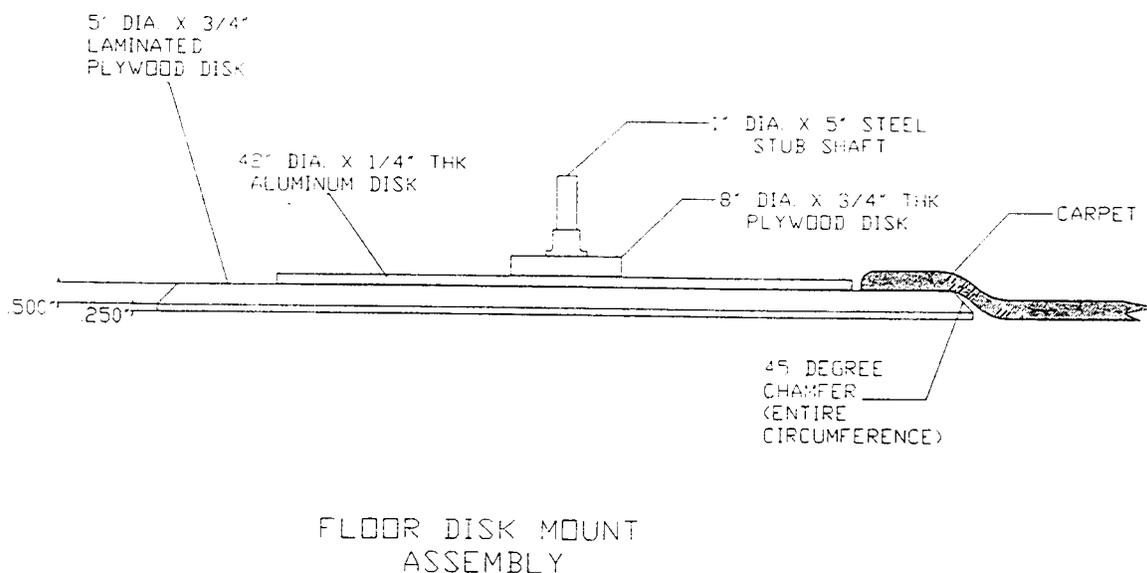
- f) Take the 1" dia. x 5" long steel stub shaft provided in the kit and check its fit with the 1"  $\varnothing$  goal center bearing. The stub shaft should easily slip into the inner bore of the bearing. If it is tight, use some fine emery cloth and light oil, and polish the surface of the shaft until it easily slides in and out of the bearing.
- g) Insert the 1"  $\varnothing$  stub shaft into the small Kee Klamp flange. Securely tighten the set screw on the flange to hold the stub shaft in place. Next place the flange on the center of the 8" plywood disk and floor mount. Check to see that the upward pointing stub shaft is perfectly perpendicular to the surface of the aluminum disk. Place flat washers as shims under the flange if needed to achieve an accurate alignment. Using four, 1/4" x 3"  $\varnothing$  carriage bolts, lock washers and nuts, fasten the flange and 8" disk securely down onto the mount by inserting the bolts from underneath the floor mount and drawing their heads up tightly into the laminated base.



13). Complete the goal assembly and mating with the playing field carpet (see Figure 2.3):

- Cut a 44" diameter hole in the center of the playing field carpet, and position the carpet on the competition playing field.
- Lift up one edge of the carpet, slide the laminated base assembly under it and center the base in the carpet opening. Check the level of the base and place thin shims under it if needed.

- c) Lift the upper portion of the goal, align it over the center of the floor mount, and lower it over the stub shaft to engage the shaft into the bearing on the base. Spin the upper portion to check for any binding of the wheels and vertical shaft bearing. The structure should rotate easily.
- d) Slip the locking collar down the protruding end of the stub shaft until it contacts the bearing, then raise it up 1/16" and securely lock it in place. Check to see that there is no binding against the collar when the goal is rotated.
- e) Finally, give the entire structure a quality assurance check for alignment, and recheck the tightening of all accessible fasteners.
- f) Using a staple gun, staple the edge of the circular opening in the carpet to the laminated base. (If the carpet has been rolled up, let it lay flat for a day or two before stapling it to the base).



### **Inner tube preparation:**

Each team will use nine, type KR 14 /15 rubber automobile inner tubes painted the color of the assigned team position. These are standard inner tubes, and are available at most automotive supply stores. For practice purposes, teams should procure only the above type inner tubes designed for use in radial tires. The inner tubes must be prepared for use as indicated below.

- 1) Before painting, the inner tubes must be cleaned to ensure good paint adhesion. The following cleaning procedure is recommended:  

Bring four gallons of water to a boil, remove it from the heat and pour it into a five gallon plastic bucket. Dissolve one cup of TSP cleaner (available at most paint and hardware stores) in the hot water and place three uninflated inner tubes into the solution. Using a long handled brush, agitate the tubes, turning and scrubbing them for several minutes. Repeat this process several times until the tubes have been in the solution for a total of 15 minutes. Remove them from the solution, thoroughly rinse in cool water and let dry. Repeat this procedure with the rest of the tubes. It will be necessary to use a fresh TSP solution for each batch of tubes as the cleaner will quickly darken with material dissolved from the rubber.
- 2) Inflate the tubes before painting them. Fill them with air until they reach 25 3/4" in (outer) diameter measured as follows: Lay the tube to be measured on a horizontal surface. Locate the diameter line that runs across the tube and passes directly over the tube's air filler stem. Locate the two vertical lines that just touch the outer edges of the tube where the diameter line intersects them. The distance between these points is the officially recognized inner tube diameter. A simple jig can be built that will easily indicate this measurement while the tube is being inflated.
- 3) Paint the inner tubes. Because of the flexing of the tubes, we are employing latex paints. The official paints that will be used during the competition will be Satin Breakthrough Paint manufactured by Vanex Coatings, 1700 South Shawnee Street, Mount Vernon, IL. Their phone numbers are: (618)-244-1414 and (800)-851-7390. Vanex will advise teams of the name and address of their nearest distributor. Apply a prime coat of latex primer followed by two coats of the color.

**Notes on Playing Field Construction**

- F1. All field dimensions listed in Section 2 are  $\pm 1$ " non-cumulative.
- F2. Tubes will be inflated to size, not pressure. All tube dimensions listed in Section 2 are  $\pm 1$ ".
- F3. The playing field carpet will rest directly on the floor except where otherwise noted.
- F4. The central goal will rest directly on the floor. The carpet will overlap the circular disk by three inches, and will be attached to the disk via heavy duty staples.