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The COMPETITION
1997

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The RULES

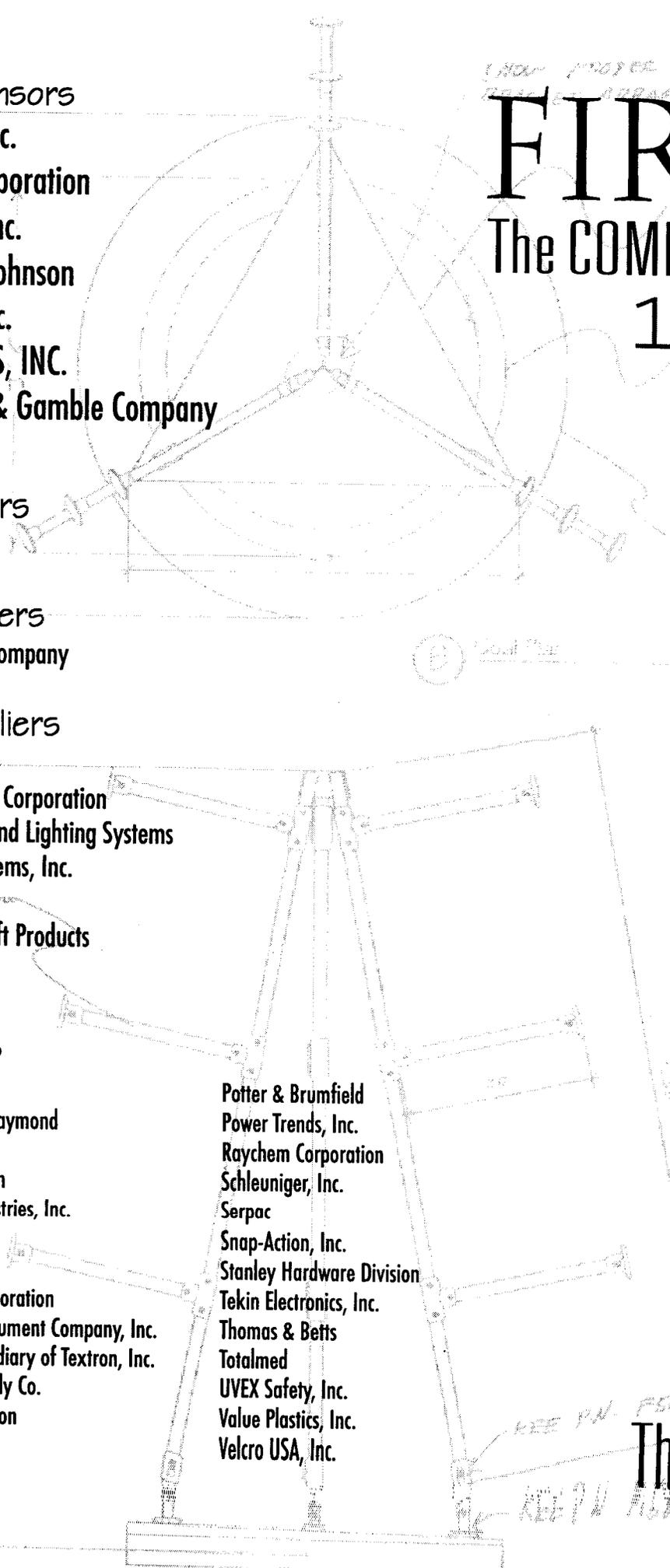


TABLE OF CONTENTS

1. THE GAME

- 1.1 Game Description1
- 1.2 General Tournament Rules4
- 1.4 Game Specific Rules6

2. THE PLAYING FIELD

- 2.1 Playing Field Description10
- 2.2 Playing Field Construction10
 - Field Border.....10
 - Player Stations10
 - Driver Stations10
 - Goal Assembly Procedure
 - Inner tube preparation
 - Notes on Playing Field Construction19

3. ROBOT DESIGN, CONSTRUCTION & OPERATION

- 3.1 Safety Rules20
- 3.2 Design & Operation Rules20
- 3.3 Control System Rules22
- 3.4 Materials Usage & Limitations24
 - Outside Sources - Small Parts, Inc. Catalog25
 - Outside Sources - Additional Hardware List25
 - Unlimited Quantity Items26
- 3.5 Kit of Parts28
- 3.6 Additional Hardware List35
- 3.7 FIRST Policy on Repair and Replacement of Non-functional Control System Components36
 - Transmitter Box or Receiver Box.....36
 - Speed Controllers.....36
 - RNets.....37
 - Servos & Servo Cables.....37
 - Joysticks.....37
 - Drill Motors and Gearboxes.....37
 - Seat Motors and Tape Drive Window Mechanisms.....38

THE COMPETITION-1997 RULES

4. CONTROL SYSTEM MANUAL

4.1 Introduction & General Description.....	39
4.2 Control System Components.....	40
4.3 Power Distribution	41
4.4 Transmitter	44
4.5 Receiver	46
Programming the Receiver.....	48
RNets and Tether Adapter.....	49
PWM Outputs.....	49
Relay Outputs.....	50
Sensor Inputs.....	50
4.6 Output Devices.....	52
Skil Gearmotors and Tekin Speed Controllers.....	52
Seat and Window Motors.....	52
Mechanical Power Transmission.....	53
4.7 Batteries & Chargers.....	53

5. ADMINISTRATIVE DETAILS

5.1 How to contact FIRST	55
5.2 FIRST Web Site	55
5.3 Motorola Midwest Regional.....	56
5.4 New England Regional.....	57
5.5 Johnson & Johnson Mid-Atlantic Regional.....	58
5.6 National Championship.....	59
5.7 Schedule of Events	59
5.8 Shipping & Transportation of Machines.....	61
5.9 Submission Deadlines	63
5.10 Before You Come to The Competition	64
Pit Area.....	64
Warm Clothing.....	64
5.11 Before You Leave The Competition.....	64
Return Unused Kit Parts and the Kit Container.....	64
Take your Machine home.....	65
Return the Control System.....	65

THE COMPETITION-1997 RULES

6. AWARDS	
6.1 Chairman's Award.....	66
6.2 Founder's Award.....	67
6.3 Judges' Awards.....	67
6.4 Autodesk Excellence in Engineering Creativity and Communications Award.....	68
6.5 WPI Design Innovation Scholarship	68
APPENDIX A - COMPLETE LIST OF RULES.....	69
Outside Sources - Small Parts, Inc. Catalog	78
Outside Sources - Additional Hardware List	79
Unlimited Quantity Items	79
APPENDIX B - TEAM CONTACT INFO	82
APPENDIX C - SUPPLIER CONTACT INFO	107
APPENDIX D - ORDERING FROM SMALL PARTS.....	110
APPENDIX E - AUTODESK ANIMATION COMPETITION.....	114
APPENDIX F - WPI DESIGN INNOVATION SCHOLARSHIP.....	121
APPENDIX G - CALENDAR OF EVENTS AND DEADLINES.....	124
APPENDIX H - SHIPPING INFORMATION.....	126
APPENDIX I - NATIONAL CHAMPIONSHIP ACCOMMODATIONS..	136
APPENDIX J - DEFAULT RECEIVER PROGRAM.....	148
APPENDIX K - MANUFACTURERS' SPECIFICATIONS.....	152

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Teams are hereby permitted to make an unlimited number of reproductions of this manual for team use only. This manual is not to be distributed to the public. Teams wishing to describe the game design, field design, or other aspects of The Competition in press releases, web pages, etc. are welcome to do so as long as the description is not detailed enough that The Competition could easily be duplicated.

1. THE GAME

1.1 Game Description

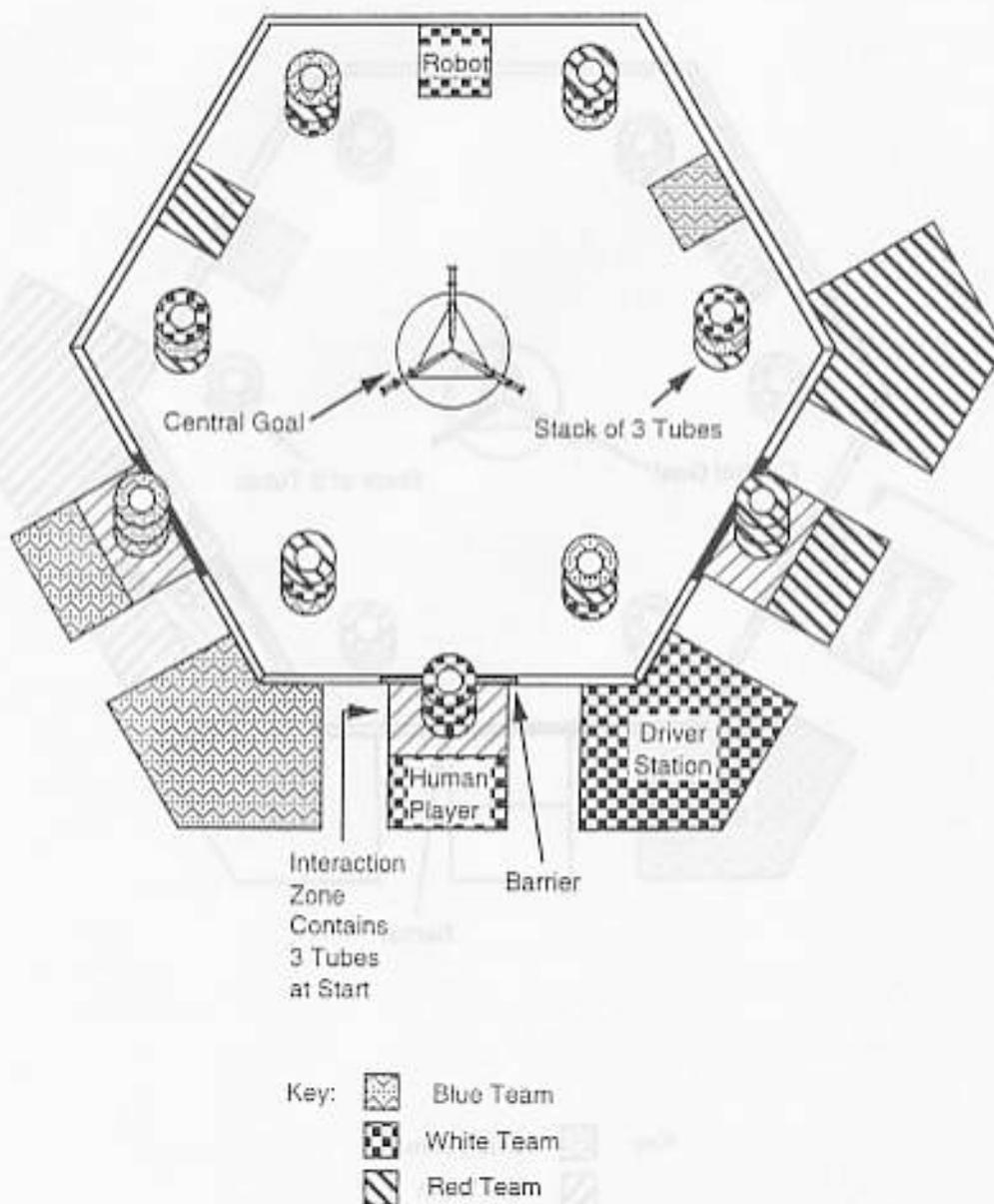
Teams must design and built robots to collect, transport, and lift inner tubes. In addition to a robot, each team will be allowed to use a human player to interact with the tubes. The robots will compete within a hexagon-shaped playing field with an 8 foot tall, freely-rotating central goal, while the players will be located at stations just outside the playing field. Starting locations of the tubes, robots, and players are shown in Figures 1.1 & 1.2. The goal will be given a spin by hand in a random direction at the start of each match.

Each team will have 9 tubes which can be placed on pegs on the central goal, or on or over the top of the central goal, to score points. The tubes will be color-coded to identify team ownership. Points will be awarded to teams with tubes located on pegs or on top of the goal at the conclusion of each two minute match.

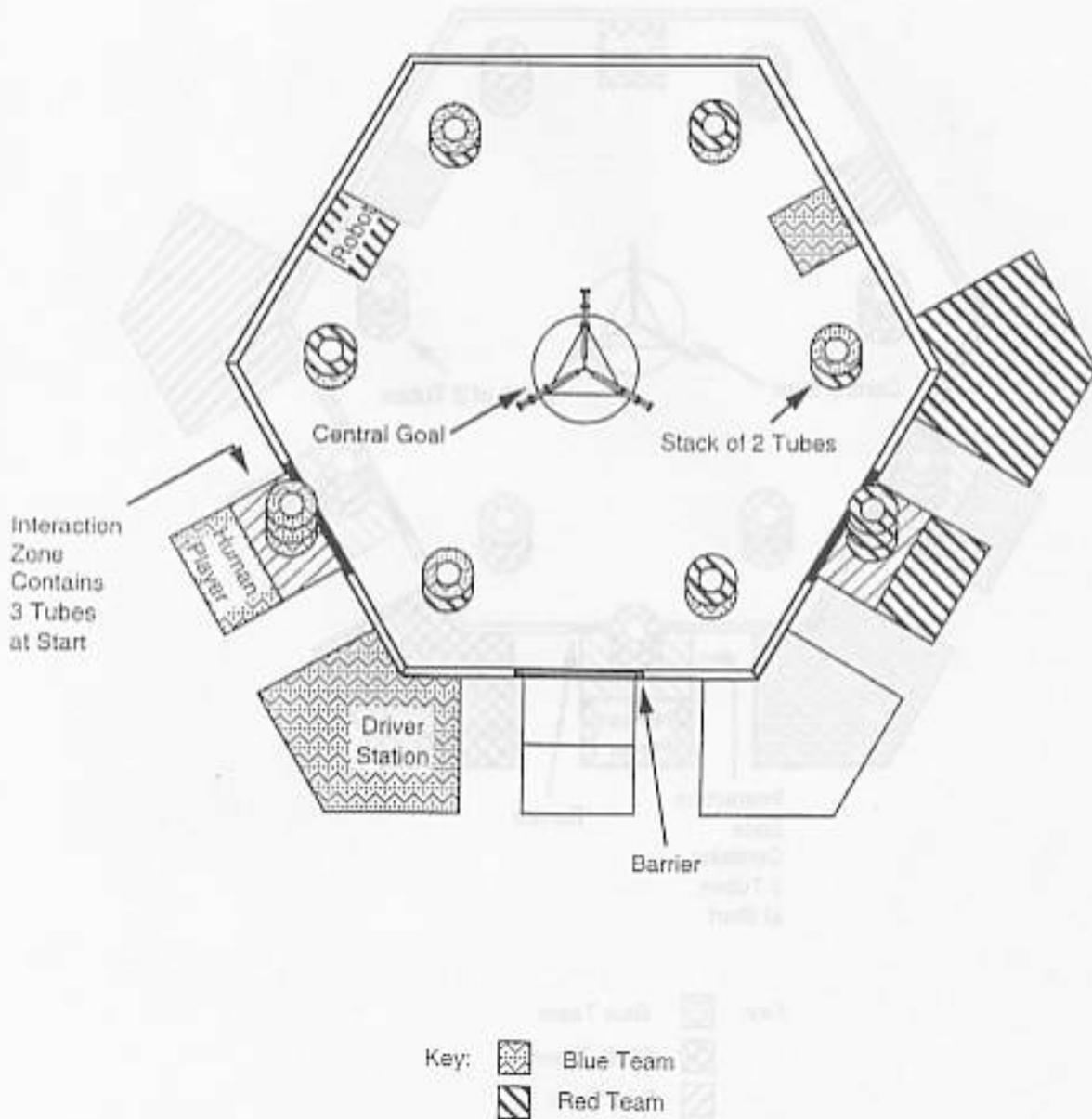
Each tube in a scoring position will be worth 1 point. In addition, certain configurations of tubes will double the score. Each tube on or over the top of the goal will double the score. For each set of 3 tubes that forms a vertical row on the pegs on a corner of the goal, the score will double. It is possible to have more than one row per corner, and rows on more than one corner.

The winner of a match is the team with the highest score. In the event of a tie, the team with the highest tube in a non-scoring position breaks the tie. If no non-scoring tubes are above the surface of the playing field, the non-scoring tube closest to the center of the base of the goal wins. If there are still any unresolved ties, the referees will flip a coin.

Playing Field - Top View
 Seeding/Double Elimination Rounds
 Figure 1.1



Playing Field - Top View
 Seeding/Double Elimination Rounds
 Figure 1.2



1.2 General Tournament Rules

(see complete list of rules in Appendix A)

- T1. Referees have ultimate authority during The Competition--their rulings are final.
- T2. If a team is disqualified by a referee, their robot is turned off for the remainder of the match, the human player must cease interacting with tubes at the player station, and any points scored during that match will be forfeited.
- T3. If a robot is disabled by a referee, the robot is turned off for the remainder of the match, and any points scored during that match will count. The human player may continue to interact with tubes at the player station.
- T4. A team may not win a match through an advantage gained by breaking a rule, even accidentally. The effect of the infraction on the outcome will be decided by the referees.
- T5. Strategies aimed solely at the destruction, damage, or entanglement of opponents' robots are not in the spirit of The Competition and will not be allowed. Turning over an opponent's robot is not considered damaging and will be allowed, but stabbing, cutting, etc., is illegal. If a breach of this rule occurs the contestant's control system may be disabled by the referees.
- T6. Robot shoving will be allowed and is expected to be quite common; however, if you damage opponents' robots, referees may take action against your team. Possible actions include, but are not limited to: stopping the match to allow the damaged robot to be repaired before resuming play, a complete rematch after repairs have been made, or disqualification of your team and forfeiture of any points scored.
- T7. If a team's robot is damaged to the point that it cannot complete a round on a fair basis, that team may be eligible for a rematch. This decision will be up to the referees.
- T8. If one team intentionally damages another team's robot, it may result in disqualification. However, if the damaged team's robot is considered too flimsy to begin with, the other team may not be disqualified. The ultimate determination will be with the referees.
- T9. Deliberately damaging the playing field, controls, or tubes (using spiked wheels, for example) is strictly illegal and may result in disqualification.
- T10. If a robot damages the playing field, barriers, tubes, or another robot, even inadvertently, and the referees feel that further damage is likely to occur, the referees may decide that corrective measures (such as eliminating a sharp edge) are required to allow the robot to continue competing.
- T11. A robot may not intentionally contaminate the playing field, tubes, goal, or another robot with lubricants.

- T12. After a match, team members are not allowed on the playing field until referees have completed the scoring procedure.
- T13. The barriers in front of the player stations are safety features, not part of the playing field. Robots should not be designed to react against them. Incidental contact with the barriers is acceptable. Pushing a tube against a barrier to allow pickup of the tube is acceptable if the forces applied are not sufficient to damage the barrier or otherwise deform the playing field.
- T14. Robots which become entangled in the barriers or goal will not be freed until after the match has finished, unless the entanglement represents a safety hazard.
- T15. If a robot goes out-of-bounds to the point that it has to apply force to any out-of-bounds surface to rejoin play, its control system will be disabled.
- T16. If one team intentionally moves another robot out-of-bounds, the robot out-of-bounds will be disabled for the remainder of the match.
- T17. Tubes which are knocked out-of-bounds will be placed back into play next to the field border near the exit point without undue delay. Tubes returned to play will not be fed directly to a robot or human player.
- T18. Tubes which are popped will be replaced without undue delay. If a tube pops while being held by a robot, the referees may opt to pause the match and place the replacement tube in the hold of the robot.
- T19. It is not the responsibility of the referees if they damage trapping devices while attempting to retrieve tubes. Please design your robot so that tubes may be retrieved quickly and easily after a match is over.
- T20. No remote communication devices, such as air phones, walkie-talkies, cellular phones, etc., may be used by teams during a match. The wireless communications systems used by FIRST staff have been carefully checked to insure that they do not interfere with the robot control systems.
- T21. During The Competition, teams will be notified of their field positions at least two minutes prior to the start of their match in the staging area. Teams will be allowed a maximum of one minute to set up their robots on the field and a maximum of one minute to remove all robot parts from the playing field following a match. You will have at least 4 minutes before your next scheduled match.
- T22. If a team is not ready to setup their robot on the field, and the two minute notification period is about to expire, and they do not wish to forfeit the match, then they must inform the field coordinator that they are invoking a time-out. Each team may take up to 10 minutes (cumulative) of time-outs during the double-elimination rounds. The duration of a single time-out may not exceed 5 minutes. If a robot is still not ready at the end of the time-out period, the team will forfeit the match.
- T23. During the finals matches (quarter-finals on), each team may take up to 10 minutes (cumulative) of time-outs which can be used to delay the start of

a match if their robot is not ready. The duration of a single time-out may not exceed 5 minutes. Unused time-out time from the double elimination matches is lost.

- T24. We strongly encourage you to develop and wear team uniforms, including identifying hats and t-shirts that display company and high school team names and/or logos. This will help the audience, announcers, judges and spectators identify you and your robot.

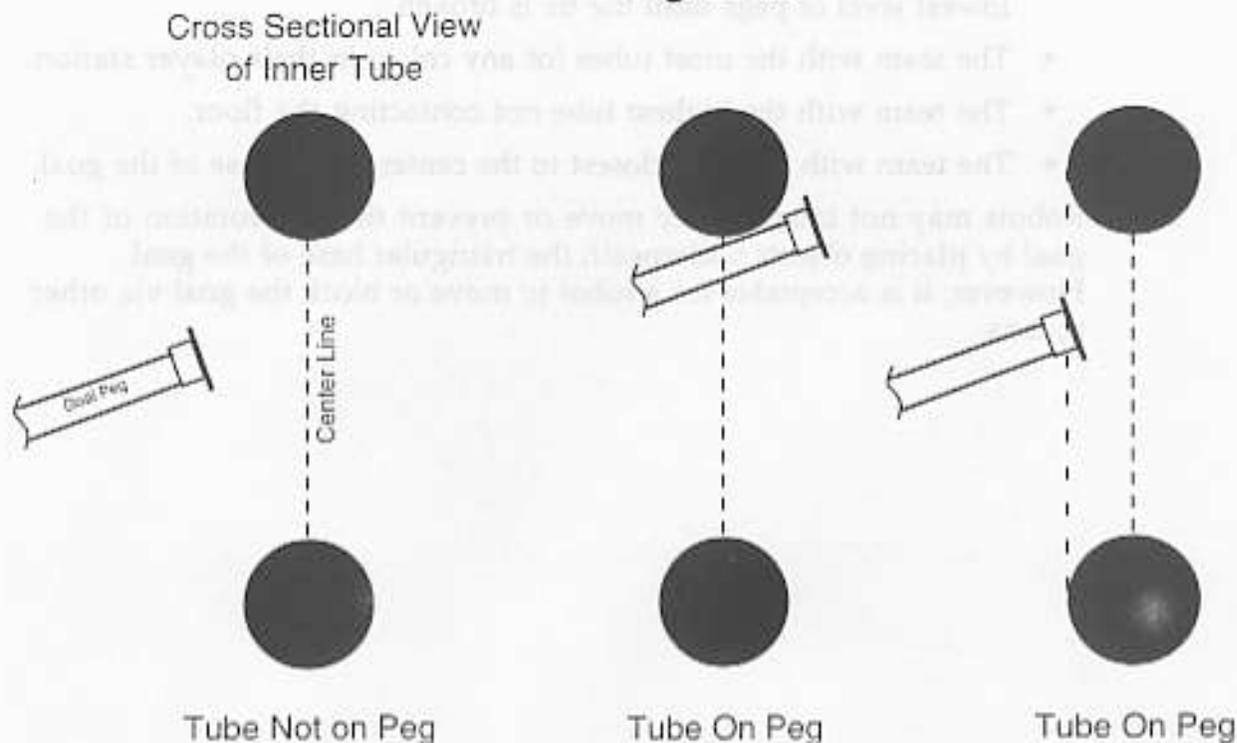
1.4 Game Specific Rules

(see complete list of rules in Appendix A)

- P1. Prior to the start of each match, teams will be assigned a color: Red, White, or Blue. This color will be used to determine the placement of the robot, human player, and drivers & coaches around the playing field. Figures 1.1 & 1.2 show the color-based layout of the playing field.
- P2. During setup for each match, robots may be placed in any orientation within the designated starting area, but may not touch the 4x4 boundary.
- P3. During a match, five members per team (two "drivers", two "coaches", and one "player") are allowed in the designated areas next to the field. Operator badges will be supplied by FIRST at each event and must be worn by these team members for field access.
- P4. The two drivers and human player must be students from a pre-college team partner school.
- P5. During a match, the robots may only be operated the drivers and/or by software running in the on-board control system.
- P6. The drivers and coaches must remain at the driver stations during the match, and may not reach over the playing field or player stations.
- P7. Human players must remain at the player stations during a match, and may not reach over the playing field or team operator areas.
- P8. Inside the player station, adjacent to the playing field, is a three foot interaction zone. Although this is part of the player station, players may not apply weight (stand, sit, kneel, etc.) to this portion of the player station during a match. Reaching and/or leaning over the interaction zone, such as to grab or throw tubes, is ok.
- The interaction zone is intended as a safety feature to help prevent potentially dangerous contact between robots and humans. Please exercise caution when reaching into the interaction zone.
- P9. The player stations are not considered part of the playing field, and are thus off limits to the robots. *(See rule T15.)*
- P10. For safety reasons, no part of a robot may touch the human players. If this occurs due to an intentional act, the team causing the safety hazard will be disqualified. If this occurs by accident, the robot causing the safety hazard

- will be disabled. The referees will decide whether the violation was intentional or an accident.
- P11. For safety reasons, no robot may launch a projectile of any sort, including tubes, toward the player stations or driver stations, with the one exception noted below. If this occurs due to an intentional act, the team causing the safety hazard will be disqualified. If this occurs by accident, the robot causing the safety hazard will be disabled. The referees will decide whether the violation was intentional or an accident.
- It is acceptable for a robot to launch tubes, but no other types of projectiles, toward the player station assigned to the same team as the robot.
- P12. During a match, no team member may intentionally touch any robot, except for reasons of personal safety. If this happens, the team will be disqualified.
- P13. During a match, no driver or coach may intentionally touch a tube, except for reasons of personal safety. If this happens, the team will be disqualified.
- P14. A human player may choose not to return tubes to the playing field. However, any tubes which leave the player's station, such as by rolling or being pushed out of the boundaries, will be returned to the playing field near the player's station without undue delay.
- P15. Human players may use only their bodies to interact with the tubes. Special clothing and/or equipment will only be allowed for those who demonstrate a need based on a physical disability.
- P16. Each team will start with 3 tubes in the interaction zone at their player station, and 6 tubes on the playing field. The tubes on the playing field will be arranged in stacks as shown in Figures 1.1 & 1.2.
- P17. Each match will last for two minutes. It will begin when the control system is enabled and end when it is disabled, unless whistled dead by the referees.
- P18. Final scoring will begin when all tubes come to rest or upon a referees' decision. Team members will not be allowed onto the field until all scoring is complete.
- P19. Final Scoring - Phase I
- Each tube on any peg is worth 1 point. A tube will count as "on a peg" if any part of the peg, including the end flange, passes through the hole at the center of the peg. See Figure 1.3 for an example.
 - Each tube on or above the center of the top of the goal is worth 1 point. A tube will be considered "on or above the center of the top of the goal" if the rotational axis of the goal passes through the open middle of the tube, and the tube is above the bottom of the apex bracket.

Figure 1.3



P20. Final Scoring - Phase II

- Each tube on or above the center of the top of the goal doubles the score.
- Each vertical row of tubes doubles the score. A "vertical row" occurs when a team has at least one tube on every peg on one corner of the goal. Separate vertical rows may be achieved on separate corners. Alternately, if a team has at least two or three tubes on every peg on one corner of the goal, they will achieve two or three vertical rows, respectively.

P21. All decisions regarding scoring will be made by the referees.

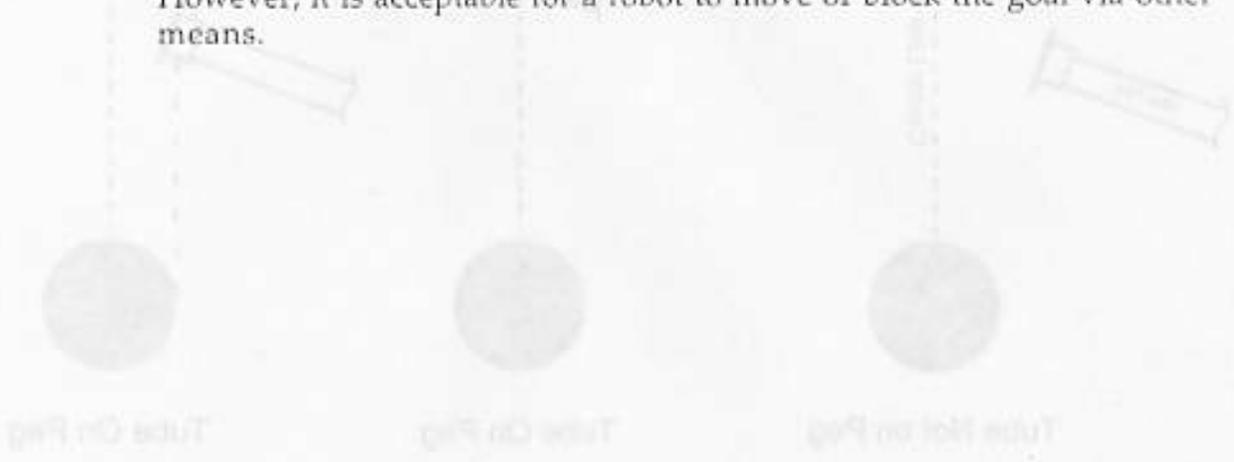
P22. The winner of a match is the team with the highest score.

P23. In the event of a tied score the following tie breaking conditions will be applied in the order below until the tie is won:

- The team with the highest tube in a scoring position wins the tie. To be considered highest, it must be the highest tube on or above the center of the top of the goal. If no tubes are in that position, it is the tube on the highest level of pegs. Subtle variations in height for a given level of pegs will not be considered.

- The team with the most tubes in scoring position in the highest level of the goal. This starts at the top level of pegs and progresses to the lowest level of pegs until the tie is broken.
- The team with the most tubes (of any color) in their player station.
- The team with the highest tube not contacting the floor.
- The team with the tube closest to the center of the base of the goal.

P24. Robots may not intentionally move or prevent the free rotation of the goal by placing objects underneath the triangular base of the goal. However, it is acceptable for a robot to move or block the goal via other means.



121. Each tube on or above the center of the top of the goal doubles the score.

122. Each vertical row of tubes doubles the score. A "vertical row" occurs when a team has at least one tube on every peg on one corner of the goal. Separate vertical rows may be achieved on separate corners. Alternatively, if a team has at least two or three tubes on every peg on one corner of the goal, they will achieve two or three vertical rows respectively.

123. All decisions regarding scoring will be made by the referee.

124. The winner of a match is the team with the highest score.

125. In the event of a tied score the following tie-breaking conditions will be applied in the order below until the tie is won:

- The team with the highest tube in a scoring position wins the tie. To be considered highest, it must be the highest tube on or above the corner of the top of the goal. If no tubes are in that position, it is the tube on the highest level of pegs. Slight variations in height for a given level of pegs will not be considered.

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

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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.

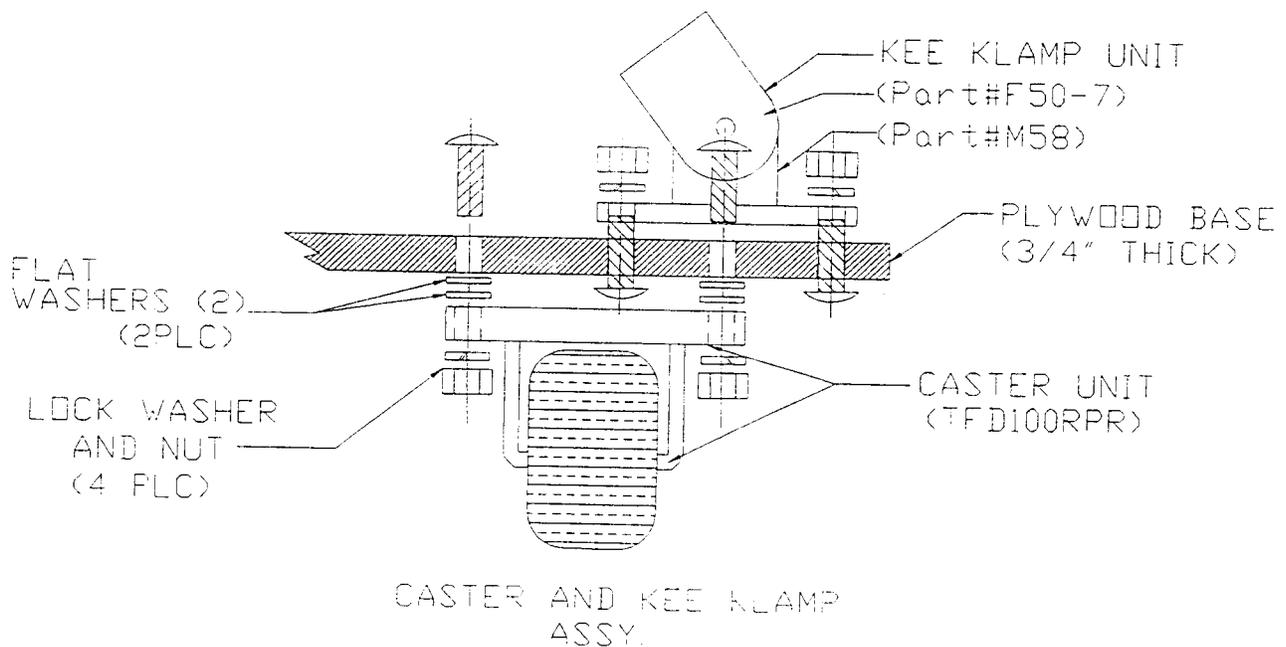
It is important that this procedure be carefully followed when fabricating the goal base and assembling the metal parts to it. **Read through this procedure in its entirety and plan it out before starting the assembly process.** Carry out the steps in numerical order, and carefully measure and lay out 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

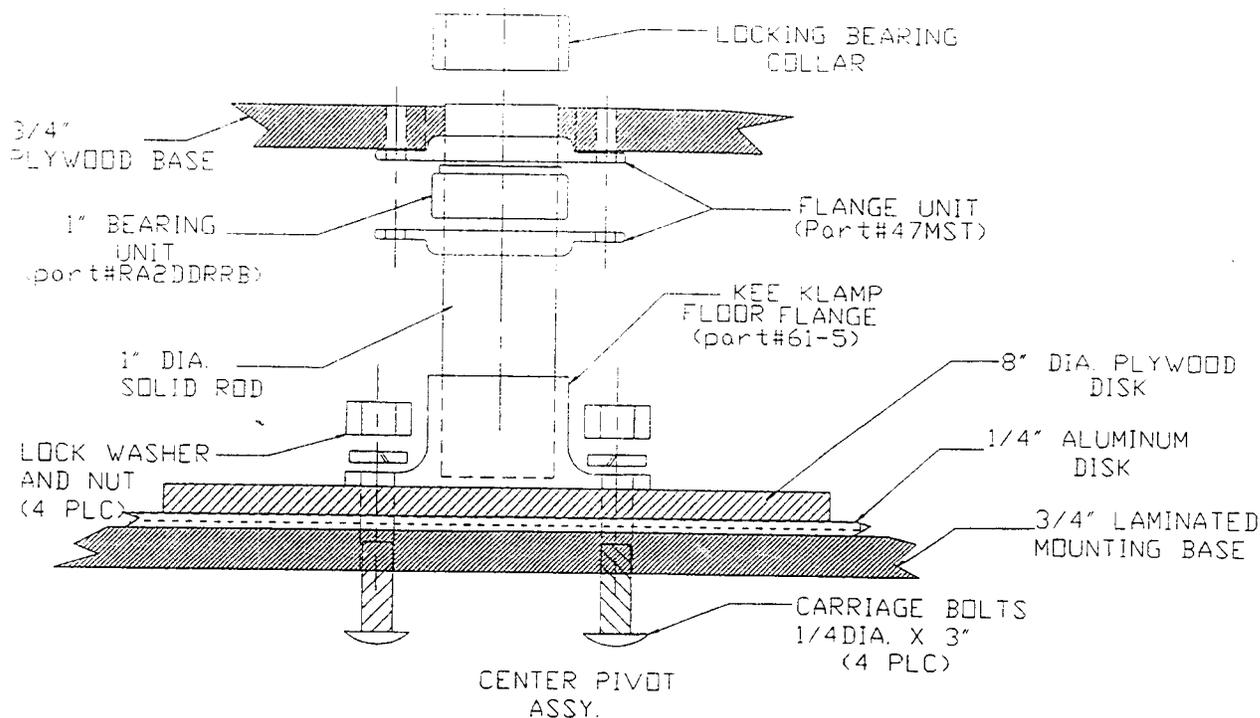
in the goal's base. Working with the Bracket and clamps at the top while observing the plumb bob, carefully adjust the Bracket until it is centered over the bearing, and its top surface is horizontal (not cocked - check it with a small level). This procedure requires a little trial and error, don't rush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

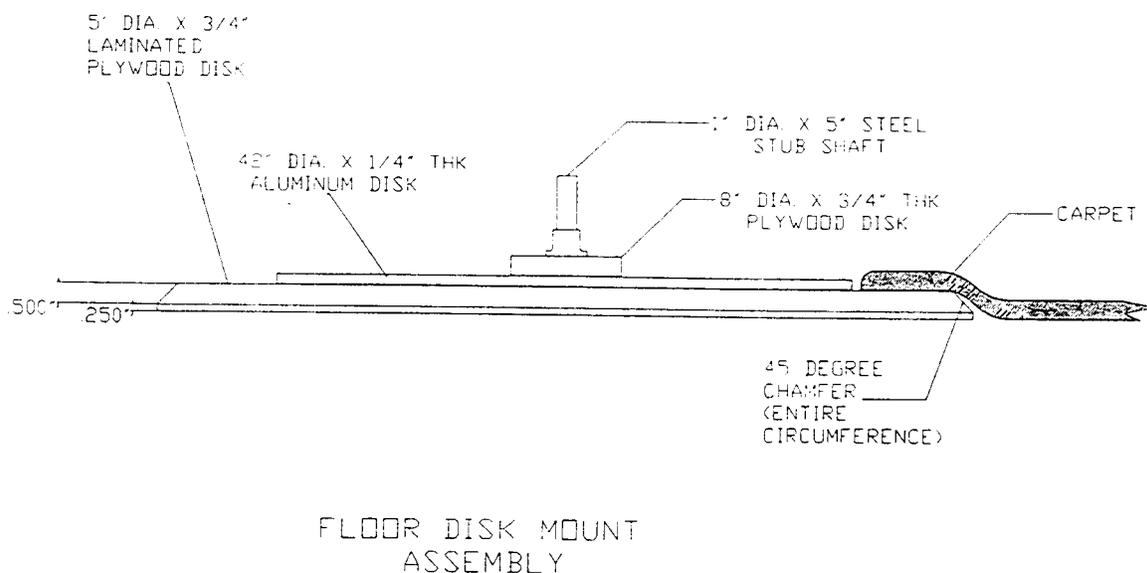
- f) Take the 1" dia. x 5" long steel stub shaft provided in the kit and check its fit with the 1" \varnothing goal center bearing. The stub shaft should easily slip into the inner bore of the bearing. If it is tight, use some fine emery cloth and light oil, and polish the surface of the shaft until 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 ± 1 " non-cumulative.
- F2. Tubes will be inflated to size, not pressure. All tube dimensions listed in Section 2 are ± 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.

3. ROBOT DESIGN, CONSTRUCTION & OPERATION

3.1 Safety Rules

(see complete list of rules in Appendix A)

- S1. Safety first. Due to the nature of the event in which electrical equipment, springs and tools are used, safety will not be compromised.
- S2. Safety glasses must be worn by all team members in the driver stations and player stations during matches, and in the pit area when working on robots. They are also highly recommended if your neighbor(s) in the pit are working on their robot.
- S3. Any robot which causes a safety hazard during a match will be disabled.
- S4. If at any time the referees determine that a robot is likely to cause safety hazards in future matches, the robot must be modified to the referees' satisfaction or it will not be allowed to compete.
- S5. No energy stored in a rubber band may be used to launch any projectile. This does not apply to the latex tubing provided in the Kit. However, the inner tubes are the only projectiles the latex tubing may be used to launch.
- S6. Projectiles must have a frontal area greater than or equal to 10 square inches and be shaped to avoid eye injury.
- S7. **Do not tamper with the power supply, batteries, chargers, speed controllers, joysticks, or any other control system component except as noted in the control system rules.** Tampering could result in failure or malfunction of the control system, and lead to a safety hazard or damage to the robot.
- S8. Remove batteries from the robot while making adjustments to your robot. Due to the strength of the motors in the Kit, it is important to keep fingers away from the gears while your robot is connected to a power supply.
- S9. The batteries may deliver more than 100 Amperes. Do not let the wires come into contact with any metal surfaces. Route wires carefully to avoid damage and short circuits, which may cause serious burns, fire, and/or permanent destruction of the batteries.

3.2 Design & Operation Rules

(see complete list of rules in Appendix A)

- M1. The energy used by the robots in The Competition must come solely from:
 - electrical energy derived from the onboard battery packs
 - storage achieved by deformation of springs or the latex tubing provided in the Kit
 - compressed air (or vacuum) stored in the air accumulator

- a change in the altitude of the device's center of gravity.
 - storage achieved by deformation of springs purchased from Small Parts, Inc. (SPI) Latex tubing from SPI may not be used as a spring.
- M2. Robots must sit, unconstrained, inside a 36" square footprint and be no more than 48" high at the start of a match. The weight of the robot, including batteries and control system, may not exceed 120.0 pounds.
- Size \leq 36" long x 36" wide x 48" high; Weight \leq 120.0 pounds**
- Keep in mind that these are maximum dimensions. It is recommended that robots be designed for slightly smaller dimensions and weights in order to allow a degree of tolerance for oversized/overweight mechanisms and differences in measurement between the team and the official inspection. Many teams have discovered the hard way that reducing size and weight while preserving functionality is no easy task after the robot has been constructed.*
- Also, many shippers such as UPS will not ship packages as large as a full robot. Many teams have found it helpful to make ease of disassembly and reassembly one of the design goals.*
- M3. All robots will be weighed and measured during the practice day at each Competition event and may be re-inspected anytime during an event. If modifications to your robot are necessary to meet the above requirements, they must be completed before seeding matches begin.
- M4. **Teams are expected to design and build robots to withstand vigorous amounts of interaction with other robots.** (See also rules T6-8.)
- M5. Until the controls are enabled at the beginning of each match, robots and any appendages, extensions or projectiles must remain unconstrained within the 36"x36"x48" starting size. Once a match begins, robots may extend beyond that limit under their own power.
- M6. Robots must be designed to operate by reacting against the surface of the playing field, the innermost face of the 4x4 field border, the goal, the tubes, the other robots, and the air. (See Section 2.2 for Field Diagrams.)
- M7. **Robots must display their team company and school names and/or logos. The judges, referees, and announcers must be able to easily identify them by name. In addition, team numbers must be displayed on at least two opposite sides (180 degrees apart) of the robot. Numbers should be at least 3 inches high and clearly visible from a distance of not less than 50 feet.**
- M8. During a match, robots may be manipulated only by the normal operation of the wireless programmable control system.
- M9. Gaining traction by using adhesives or by damaging the surface of the playing field or the tubes is not allowed. (See also Rules T9-10.)
- M10. During any Competition event, any mechanism which will alter the operation of the robot may not be added or removed after the first match of the seeding rounds unless mandated by the judges for rule compliance reasons. However, mechanisms existing on the robot may be reconfigured

between matches. Also, the control system may be reprogrammed as described in the control system rules between matches.

- M11. No substitute robots are permitted; however, functionally identical replacement parts are allowed.
- M12. Only items listed under the PNEUMATICS section of the Kit list may be used to store, generate, or transmit compressed air or vacuum, with the following exceptions:
- Suction cups may be fabricated from legal Kit parts, as defined in rule K1 below.
 - Pneumatic fittings from Small Parts, Inc. may be used.

Custom-made pneumatic fittings, air cylinders, pumps, air accumulators, and so forth are not allowed, even if they are created from components included in the kits. Also, valves, syringes, tubing, and so forth from SPI or outside sources may not be used for pneumatics.

3.3 Control System Rules

(see complete list of rules in Appendix A)

- C1. The control system is provided to allow wireless control of the robots. The Transmitter box, Receiver box, servos, speed controllers, RNETs, antennas, batteries, battery chargers, power supply and joysticks may not be tampered with, modified, adjusted or marked in any way, with the following exceptions:
- the dip switches on the Transmitter and Receiver may be set for custom operation.
 - the user programmable code in the Receiver may be customized.
 - the speed controllers may be calibrated as described in the Tekin REBEL Owner's Manual.
 - The connectors on the ends of the 12 AWG wires on the Tekin REBEL Speed Controllers must be removed. Do not remove the connector on the 24 AWG, 3 wire PWM cable.

Tampering includes drilling, cutting, machining, gluing, rewiring, etc. All items listed in Rule C1 must be mounted without alteration. Do not write on or otherwise mark control system components.

- C2. Do not attach tape, stick-on hook & loop fasteners, glue, or other adhesives to control system components. We will re-use many of these components, and these items can be difficult to remove. Instead, use clamps, straps, or existing holes for mounting. The only exceptions to this rule are:
- Tape may be used to secure the position of the trimmers on the Joysticks in order to prevent accidental changes in calibration.
 - Stick-on hook & loop fasteners may be used to attach the speed controllers.

For mounting control system components, use mechanical fasteners, such as cable ties, straps, or brackets. Do not use tape, stick-on hook & loop fasteners, glue, or other adhesives.

- C3. The black/almond project box is intended to serve as a mounting point for the rocker switches and potentiometers and to enclose the associated wiring. You may modify the project box in any manner to accommodate your needs. It may not be used on the vehicle.
- C4. **Only the wire supplied in the Kit may be used to conduct electricity.** Additional wire is not permitted.
- C5. Electrical devices may only be wired as described in Section 4. Some important facts are listed here in Section 3.3.
- C6. The 12 gauge wire must be used for connections from the batteries to the speed controllers, from the speed controllers to any motors, and from the batteries to the Receiver box.
- C7. The 16 gauge jacketed cable must be used for any device connected to a relay output.
- C8. The 22 and 24 gauge wire may only be used for connecting sensors (limit switches, reed switches, rocker switches, air pressure switches, potentiometers) to inputs or for extending the PWM cables.
- C9. **Relay outputs may not power more than one device per output.** (The double-solenoid valve is considered one device, because the diodes may be used to route power to only one solenoid at a time.)
- C10. **Only the Receiver, speed controllers, and muffin fan may be connected directly to the battery outputs.**
- C11. The battery contacts inside the Skil drill shells must be used to draw power from the batteries. If the handle part of a drill shell is cut away from the main body, the wire side of the contacts must be insulated with heat shrink tubing or electrical tape to prevent short circuits.
- It is strongly recommended that the contacts be used in conjunction with the handle of the drill shell and the battery clip at the end, as they are designed to hold the battery snugly yet allow for easy changeover of batteries.*
- C12. The Skil drill motors may be powered only by the Tekin speed controllers.
Do not connect the drill motors to the relay outputs.
- C13. No more than one motor may be powered by each Tekin speed controller.
- C14. The Delco seat motors and Delphi tape drives may be powered by the Tekin speed controllers or the relay outputs.
- C15. Two 0.1 μ F capacitors, included with each speed controller, must be installed on each motor connected to a speed controller, as described in the Tekin REBEL Owner's Manual.

- C16. One 20A circuit breaker (provided in the Kit) must be installed in series with each drill motor. The circuit breaker must be accessible for inspection at each Competition event.
- C17. One 30A circuit breaker (provided in the Kit) must be installed in series with the positive terminal on each battery contact, such that all battery output flows through this breaker before being distributed to the Receiver, speed controllers, fan, or other battery. The circuit breaker must be accessible for inspection at each Competition event.
- C18. Only the 9 volt power supply included with the Kit should be used to power the Transmitter box. Use of an alternate power supply could damage the Transmitter box or RNet and is therefore prohibited.
- C19. Do not connect 12 volt power or ground wires to the relay outputs. Doing so will cause a short circuit and may damage the Receiver.
- C20. Do not connect power or other outputs to the sensor port on the Receiver. Power for sensors is available from the sensor port.
- C21. Any sensors used on the robot must be connected directly to the sensor port on the Receiver, and may not be wired in series with the motors, pumps, or valves.
- C22. R Nets may not be used in the Pit Area at any Competition event. A tether must be used for bench testing.
- C23. If the control system is damaged due to improper wiring or misuse, FIRST will charge for repair or replacement of the affected items. (*See Section 3.7 for details.*)
- C24. Robots must only be operated with both batteries present and wired in parallel.
- Operating a robot with only one battery can permanently destroy the battery. Don't do it!**
- C25. All wires distributing power with a constant polarity (i.e. not a relay or speed controller output) must be color coded as follows:
- Use Red 12 AWG or White 16 AWG wire for +12Vdc.
 - Use Black 12 or 16 AWG wire for GND.
- C26. **Teams are responsible for any software bugs introduced into the Receiver's control program when using a custom program. If a software bug negatively impacts the performance of a robot during a competition match, it will not be grounds for a rematch or even a pause in the match.**

3.4 Materials Usage & Limitations

(see complete list of rules in Appendix A)

- K1. Each robot must be constructed exclusively from materials provided in the Kit of Parts ("the Kit") supplied by FIRST, with the following additions and exceptions:

- 2' x 4' x 1" ROHACELL™ P170 structural foam shipped to each team from FIRST.
- Material available from outside sources, as explained below.
- Material satisfying the unlimited quantity criteria, as explained below.
- The Kit container, part packaging, and any documentation in the Kit container may not be used to build the device.
- Adhesive tape may not be used except as an electrical insulator.
- Lubricants may not be used except to reduce friction within your own robot.

Outside Sources - Small Parts, Inc. Catalog

Each team receives an account with a \$425 credit balance which will be debited for the actual purchases you make. You may go beyond this dollar limitation for prototyping or to purchase spare parts, but your team is responsible for paying the balance on the account. See Appendix D for more details on accounting and ordering.

Up to \$425 worth of materials purchased from Small Parts, Inc. may appear on your final robot. Items which appear below in the unlimited quantity category do not count against the \$425 limit when used as described.

It has been brought to our attention that the actual prices of components purchased from Small Parts, Inc. may not match the prices printed in the catalog. Please use the catalog prices when calculating the cost of robot components from SPI for compliance with the \$425 limit.

If you use only a portion of what you buy from Small Parts, you may prorate the dollar amount used to the smallest quantity listed for purchase in the catalog. For example, if you buy 5' of rod which could have been purchased by the foot, but end up using only 6", you may calculate the amount used as the purchase price for one foot.

Outside Sources - Additional Hardware List

Materials on the Additional Hardware List may be obtained from any supplier, but in limited quantity. A specific list of materials and maximum quantities/dimensions is provided in Section 3.6. Cost is not considered.

If an item on the Additional Hardware List is available from Small Parts, Inc., then it may be purchased from SPI without being counted against the \$425 limit on materials purchased from SPI. However, any amount of the item purchased from SPI above and beyond the quantity allowed in the Additional Hardware List will count against the \$425 limit. Obviously, any item purchased from SPI will count against your credit limit, regardless of whether or not it is listed in the Additional Hardware List.

Unlimited Quantity Items

The following items may be used in unlimited quantity subject to the following criteria. (See rule K9)

- Fasteners, washers and adhesives -- if used for joining and fastening purposes only.
- Fasteners -- if used as pins in a linkage or as hinge pins.
- Crimp-on spade connectors -- if used to conduct electricity, used with the proper gauge wire, crimped properly, and fully insulated, such as the Thomas & Betts units provided in the kits.
- Adhesive tape -- if used as an electrical insulator.
- Lubricants -- if used to reduce friction within your own device.
- Teflon tape -- if used around the threads of pneumatic fittings to prevent leaks.
- Shrink wrap tubing of any diameter -- if used for electrical insulation.
- Pipe fittings (tees, reducers, elbows, and angles) -- if used to join sections of pipe
- Endcaps -- if used to cap pipe.

K2. Many of the materials in the Kit are raw materials. They are intended to be used for manufacturing structural or mechanical parts for your robot.

K3. There is no restriction on the total quantity of sprockets/pulleys and chain/belt that can appear on your robot. However, there is a restriction on the amount which can be obtained from outside sources other than SPI. (See the *Additional Hardware List and Rule K4* .) Any quantity above the amount listed on the Additional Hardware List must therefore be purchased from SPI, or manufactured from raw materials available from either the Kit, the Additional Hardware List, or SPI.

K4. As denoted in the Additional Hardware List, each team may purchase from an outside source sprockets (not gears) and/or pulleys and additional chain and/or belt, with the following conditions:

- On your final robot, you may use no more than a combined total of 4 sprockets and/or pulleys from outside sources other than SPI.
- On your final robot, you may use no more than a combined total of 10' of chain and/or belt from outside sources other than SPI. There are no restrictions regarding pitch or width of chain and/or belt. However, you may not purchase a wide belt, slice it lengthwise, and use more than a 10' length in the final robot.
- These components must be "commercially available," strictly *off-the-shelf* only. No custom or special orders.
- A double-sprocket or double-pulley assembly counts as two sprockets or pulleys, respectively.

- K5. Gears (not sprockets) must be purchased from SPI, or manufactured from raw materials available from either the Kit, the Additional Hardware List, or SPI.
- K6. The dimensions for sheets and boards listed in the Additional Hardware List represent the maximum length and maximum width which may be purchased, not the total area. The thickness represents a fixed quantity, not a maximum.
- K7. The dimensions for rods and shafts listed in the Additional Hardware List represent the maximum length that may be purchased for a given diameter of rod/shaft.
- K8. You may purchase only one of the three types of 1/2" or thicker wood listed in the Additional Hardware List; Plywood, Chipboard, or Particleboard.
- K9. Items listed as unlimited quantity items, when used without satisfying the criteria for unlimited use, must be purchased from SPI against the \$425 limit or manufactured from raw materials available in the Kit, from the Additional Hardware List, or from SPI.
- K10. Net material is allowed; however, if it is used to entangle opponents' robots, the referees may disallow it.
- K11. For safety reasons, you may not fabricate your own springs. However, it is acceptable to elastically deform and relax materials not designated as springs as long as the rate at which the energy is released does not exceed the rate at which the energy was stored. This is intended to allow reasonable use of the elastic properties of materials without creating unsafe conditions caused by sudden the release of stored energy in materials not designed to act as springs. Materials which are designated as springs include: All items listed in the Springs section of the Kit List, and compression, tension, torsion, constant force, and washer springs available from Small Parts, Inc. Latex tubing from SPI is not considered a spring.
- K12. A limited number of replacement parts will be made available by FIRST upon justified request. Otherwise, lost or damaged Kit materials may be replaced only with identical components of the same material, dimensions and treatment at the team's cost.
- K13. Materials in the Kit may not be changed chemically with the following exceptions:
- rope ends may be singed to prevent loose ends or to bind them together
 - resin and hardener may be mixed to produce epoxy.
 - metal may be heat treated in order to improve surface hardness
 - metal may be anodized to improve appearance

Completely melting and recasting a material is considered a chemical change. However, merely heating a material, such as a sheet of polycarbonate or ROHACELL™, in order to bend it into a new shape without cracking is not considered a chemical change.

- K14. The mailing tubes provided in the Kit are considered packaging material and may not be used during any Competition event.
- K15. All unused parts and materials must be returned to FIRST for proper recycling.
- K16. The control system is the property of FIRST and certain components must be returned at the conclusion of The Competition. The control system is not for sale. Teams wishing to borrow the control system for a limited amount of time after The Competition may do so by following the procedures outlined in Section 5.5. For teams that wish to operate their robots after this period, FIRST can provide basic instructions on how to refit the robots to use off-the-shelf remote control systems.

3.5 Kit of Parts

The following pages are a detailed packing list for all Components which make up the official Kit of Parts. A checklist has been included in your Kit which you should use as you go through the Kit to be sure you have received all parts. This checklist should be signed by a team member and returned to a FIRST staff member as you leave the Kickoff Workshop. Any materials you did not receive will be shipped to you as soon as possible.

List of Components

Bearings

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
2 Bolt Self-Aligning Flange	fits 1" bearing	Gray Container	2	The Torrington Company
2 Bolt Self-Aligning Flange	fits 1/2" bearing	Gray Container	8	The Torrington Company
Radial Ball Bearing w/Spherical OD	1/2" i.d., self locking collar	Gray Container	4	The Torrington Company
Radial Ball Bearing w/Spherical OD - for	1" i.d., self locking collar	Gray Container	1	The Torrington Company
Single Row Radial Flanged Ball Bearing	1/4" i.d.	Gray Container	4	The Torrington Company
Single Row Radial Flanged Ball Bearing	3/8" i.d.	Gray Container	4	The Torrington Company

Control System

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
2 Conductor Jacketed Wire	15', #16 AWG	Gray Container	1	General Cable
2 Conductor Jacketed Wire	20', #24 AWG	Gray Container	1	General Cable
2 Pin Power Connector	Black, European style header	Gray Container	1	Augat RDI
25 Pin Cable	DB25 Male to Female, 6' ,	Green	1	Brevan Electronics
25 Pin Connector	DB25, solder cup, male	Gray Container	2	Brevan Electronics
3 Conductor Shielded Wire	20', #24 AWG	Gray Container	1	General Cable
3 Headed Cable	DB9 F, DB9 M, High Density	Green	1	Brevan Electronics
8 Pin Connector	European style header	Gray Container	2	Augat RDI
9 Pin Cable	DB9 Male to Female, 6' ,	Green	2	Brevan Electronics
Battery Charger		Green	2	Emerson Electric
Battery, rechargeable	12 Vdc	Green	4	Emerson Electric
Circuit Breaker for Batteries	12 volt, 30 Amp, auto-resetting	Gray Container	2	Snap-Action, Inc.
Circuit Breaker for Drill Motors	12 volt, 20 Amp, auto-resetting	Gray Container	2	Snap-Action, Inc.
Crimping Tool for Spade Connectors		Green	1	Thomas & Betts Corp.
Diode	1 Amp max	Gray Container	2	Brevan Electronics
Dongle	DB9 Female, #1-8	Kick Off Check	1	Brevan Electronics
Flightstick Joystick	7 ft cable with Male DB15	Green	2	CH Products
Heat Shrink Tubing	3/4"Ø x 1', Black, 2:1 Shrink	Green	1	Raychem Corporation
Heat Shrink Tubing	3/8"Ø x 2', Black, 2:1 Shrink	Green	1	Raychem Corporation
Knob for Potentiometer		Shipped to	2	FIRST
Limit Switch		Gray Container	10	Honeywell - Microswitch Division
Muffin Fan	12 Vdc	Green	1	PAR Associates
Plastic Hood for 25 Pin Connector	fits DB25	Gray Container	1	Brevan Electronics
Potentiometer	50KΩ, linear	Shipped to	4	FIRST

List of Components

Power Connector for Valves	12 Vdc, Gray	Green	3	Numatics, Inc.
Power Supply	9 Vdc, 1.0 Amp max	Green	1	Golden Pacific Electronics, Inc.
Programming Software for Control	3.5" HD Floppy	Shipped to	1	FIRST / Parallax, Inc.
Project Box	Black or Almond	Green	1	Serpac
Receiver Box		Shipped to	1	FIRST
Reed Switch	Normally open, magnet	Gray Container	4	CP Clare
RNET 9600slm + Antenna (for	DB9 female	Shipped to	1	Motorola
RNET 9600slms + Antenna (for	High Density DB15 female	Shipped to	1	Motorola
Rocker Switch		Shipped to	8	Honeywell - Microswitch Division
Rocker Switch Cover	Black	Shipped to	1	Honeywell - Microswitch Division
Rocker Switch Cover	Blue	Shipped to	2	Honeywell - Microswitch Division
Rocker Switch Cover	Green	Shipped to	1	Honeywell - Microswitch Division
Rocker Switch Cover	Red	Shipped to	2	Honeywell - Microswitch Division
Rocker Switch Cover	White	Shipped to	1	Honeywell - Microswitch Division
Rocker Switch Cover	Yellow	Shipped to	1	Honeywell - Microswitch Division
Servo	Hitec/JR-style connector, 42	Green	2	Hitec RCD, Inc.
Servo Extension Cable	Hitec/JR-style, 36" long	Green	2	Hitec RCD, Inc.
Servo Y Cable	Hitec/JR-style, 24" long	Green	2	Hitec RCD, Inc.
Spade Connector	female, 12-10 AWG	Shipped to	20	Thomas & Betts Corp.
Spade Connector	female, 16-14 AWG	Shipped to	20	Thomas & Betts Corp.
Spade Connector	female, 22-18 AWG	Green	20	Thomas & Betts Corp.
Spade Connector	male, 12-10 AWG	Green	20	Thomas & Betts Corp.
Spade Connector	male, 16-14 AWG	Shipped to	20	Thomas & Betts Corp.
Spade Connector	male, 22-18 AWG	Green	20	Thomas & Betts Corp.
Speed Controller	7.2 - 12 Vdc, Reversing	Green	4	Tekin Electronics, Inc.
Terminal Strip	6 channel, tubular screw contact	Shipped to	2	Thomas & Betts Corp.
Tether Adapter	DB9 F-F, pins: 2->3, 3->2, 5->5	Green	1	Brevan Electronics
Transmitter Box		Shipped to	1	FIRST
Wire	16', #12 AWG, Black	Gray Container	1	General Cable
Wire	16', #12 AWG, Red	Gray Container	1	General Cable
Wire Nut	for 12 AWG wire	Gray Container	10	Home Depot
Wiring Harness for Air Pumps	fits Textron pumps, 6" leads	Green	2	McCord Winn Textron
Wiring Harness for Seat Motor	5', #16 AWG	Gray Container	4	Nova Biomedical

List of Components

Flexible Shaft Coupling	Black	Gray Container	4	FIRST
Folding Table Brace	9-1/2"	Green	4	Stanley Hardware
Hinged Hasp	3" Strap	Green	1	Stanley Hardware
Magnet	1/4-20 Plastic Thread	Gray Container	1	Honeywell - Microswitch Division
Magnet	8-32 Thread Mount	Gray Container	3	Honeywell - Microswitch Division
Pivot for Steel Track		Green	2	Stanley Hardware
Roller Guide for Steel Track	7/8" Ø x 1/4" wheel	Green	4	Stanley Hardware
Sash Guide w/Triangular Mount (LH)		Gray Container	1	Delphi Interior and Lighting
Sash Guide w/Triangular Mount (RH)		Gray Container	1	Delphi Interior and Lighting
Side Release Buckle	Fits 3/4" Strap	Gray Container	1	McMaster-Carr Supply Company
Steel Hinge w/ screws	3-1/2" x 3-1/2"	Green	2	Stanley Hardware
Steel Track w/Endstop	2'	Green	2	Stanley Hardware
Tape for Window Actuator (additional)	16'	Gray Container	1	Delphi Interior and Lighting
Trantorque Coupling	3/8" i.d, 3/4" o.d.	Gray Container	2	Small Parts, Inc.
Utility Draw Pull Latch	1-3/4" high x 3-9/32" wide,	Gray Container	1	McMaster-Carr Supply Company
Wheelchair Wheel	6" Ø, 5/16" i.d. bearings,	Gray Container	2	Skyway Recreation Products
Wheelchair Wheel	8" Ø, 5/16" i.d. bearings,	Gray Container	2	Skyway Recreation Products

Springs

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
Compression Spring	0.600" o.d. x 3" long x 0.059"	Gray Container	1	Associated Spring Raymond
Constant Force Spring, Large	1.02" i.d.	Gray Container	2	Associated Spring Raymond
Constant Force Spring, Medium	0.85" i.d.	Gray Container	1	Associated Spring Raymond
Constant Force Spring, Small	0.51" i.d.	Gray Container	2	Associated Spring Raymond
Latex Tubing	1/4" i.d., 3/8" o.d., 5'	Green	1	Totalmed
Small Tension Spring	0.650" o.d. x 2.875-3.000" long	Gray Container	1	Associated Spring Raymond
Snugger (Spring for Steel Track)		Green	4	Stanley Hardware
Spring Loaded Hinge	4" x 4", 30 in/lb max	Green	1	Stanley Hardware

Sprockets & Pulleys

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
Pulley with Fixed Eye	1 1/2" Ø, for 5/8" Rope	Green	2	Stanley Hardware
Pulley with Fixed Eye	1" Ø, for 5/16" Rope	Green	1	Stanley Hardware

Tools

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
5/32" Allen Wrench	comes with Spring Hinge	Green	1	Stanley Hardware

List of Components

Wiring Harness for Window Lift Motor	5', #16 AWG	Gray Container	2	Nova Biomedical
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Documentation

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
Kee Klamp Pipe Fitting Catalog + 2		Gray Container	1	Kee Industrial Products
Numacalc	manual and software for IBM	Green	1	Numatics, Inc.
Numatics Training Manual		Kick Off Check	1	Numatics, Inc.
Small Parts Catalog		Gray Container	2	Small Parts, Inc.

Fasteners

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
5 Minute Epoxy Gel	resealable 1 oz. dual syringe	Gray Container	1	McMaster-Carr Supply Company
Cable Tie	11.10" x 0.140"	Green	20	Thomas & Betts Corp.
Cable Tie	7.00" x 0.091"	Green	20	Thomas & Betts Corp.
Cable Tie Mounting Base	self-adhesive, holes for #8	Green	25	Thomas & Betts Corp.
Helical Plastic Wire Wrap	1/4" Ø x 24"	Gray Container	1	McMaster-Carr Supply Company
Hook & Loop Fastener	1" x 2', stick-on	Green	1	McMaster-Carr Supply Company
Rubber Band, Large	3-1/2" x 1/4" wide	Gray Container	5	Staples
Rubber Band, Small	3-1/2" x 1/8" wide	Gray Container	5	Staples
Velcro Stick Back Coins	5/8"Ø, 15 sets per pack	Green	1	Velcro USA, Inc.
Velcro Sticky back Hook & Loop Tape	3/4" x 18"	Green	1	Velcro USA, Inc.
Velcro Trunk Strap	5/8" x 15'	Green	1	Velcro USA, Inc.

Field Components

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
Apex Bracket for Game Goal	3 legged top joining bracket	Gray Container	1	Sylvester Sheet Metal
Rubber Inner Tube	KR14/15	Green	1	Carol Tire

Motors & Pumps

<u>Part Name/Description</u>	<u>Dimensions</u>	<u>Location</u>	<u>Qty /Kit</u>	<u>Product Supplier</u>
Battery Contact Assembly		Green	2	Emerson Electric
Battery Retaining Clip		Green	2	Emerson Electric
Drill Gear Shift Lever		Green	2	Emerson Electric
Drill Gearbox	1100/400 RPM, slip clutch	Green	2	Emerson Electric
Drill Housing, Right and Left Half	Holds motor, gearbox, battery	Gray Container	2	Emerson Electric
Drill Housing Screws	Torx Head T10 pan head	Green	14	Emerson Electric
Drill Motor	12 Vdc, with Metal Pinion	Green	2	Emerson Electric
High Output Lumbar Pump MWT Motor	12 vdc, 22 psi max, 3/16" o.d.	Green	1	McCord Winn Textron
Low Output Lumbar Pump Johnson Motor	12.vdc, 4 psi max, 3/16" o.d.	Green	1	McCord Winn Textron

List of Components

Seat Motor	12 Vdc	Gray Container	4	Delco Electronics Corporation
Window Lift Motor with Tape Drive	left hand side	Gray Container	1	Delphi Interior and Lighting
Window Lift Motor with Tape Drive	right hand side	Gray Container	1	Delphi Interior and Lighting

Other

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Carpet Sample	12" x 12", 20 oz., closed loop	Gray Container	1	FIRST
Co-Polymer Gutter Guard	6" x 24"	Gray Container	1	Home Depot

Pneumatics

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Adapter fitting for Pressure Switch	1/4" NPT female to 1/8" barb	Shipped to	2	Numatics, Inc.
Air Cylinder	1-1/16" bore, 4" stroke	Gray Container	1	Numatics, Inc.
Air Cylinder	7/16" bore, 12" stroke	Gray Container	1	Numatics, Inc.
Barbed Fitting	1/8" i.d. to 1/8 NPTF	Green	4	Numatics, Inc.
Barbed Fitting	1/8" i.d. to 10-32 UNF	Green	12	Numatics, Inc.
Barbed T-Connector	1/8" Ø barbs	Green	2	Value Plastics, Inc.
Check Valve	1/8" Ø barbs	Green	2	Air Logic
Detachable Barbed Connector	1/8"Ø to 1/8"Ø	Green	3	Value Plastics, Inc.
Detachable Barbed Reducing Connector	1/8"Ø barb to 1/4"Ø PTF	Green	1	Value Plastics, Inc.
Detachable Barbed Reducing Connector	3/16"Ø to 1/8"Ø	Green	1	Value Plastics, Inc.
Detachable Barbed Reducing Connector -	3/16"Ø to 1/8"Ø	Green	1	Value Plastics, Inc.
Detachable Rotating Barbed Connector	1/8"Ø to 1/8"Ø	Green	1	Value Plastics, Inc.
Double Solenoid Valve	12 VDC, 10-32 UNF-3B	Green	1	Numatics, Inc.
Numatrol Tubing	1/4" o.d., 1/8" i.d., 15'	Gray Container	1	Numatics, Inc.
Plug for Valves	10-32 UNF	Green	5	Numatics, Inc.
Plug for Volume Chamber	1/4"Ø PTF	Green	1	Value Plastics, Inc.
Polyurethane Tubing	3/16" i.d., 5/16"o.d. x 4'	Gray Container	1	Value Plastics, Inc.
Pressure Switch	1/4" NPT male thread	Green	2	Numatics, Inc.
Single Solenoid Valve	12 VDC, 10-32 UNF-3B	Green	1	Numatics, Inc.
Syringe	140 cc, Luer Lock Tip	Green	1	Lowell Medical Instrument
Volume Chamber	approx 1 liter, 1/4NPTF ports	Gray Container	1	Numatics, Inc.

Rods & Shafts

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Aluminum Rod	1/2" Ø x 24"	Gray Container	2	McMaster-Carr Supply Company
Brazing Rod	1/16" Ø x 18"	Gray Container	6	McMaster-Carr Supply Company
Brazing Rod	1/8" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company

List of Components

Delrin (Acetal) Rod	1/4" Ø x 24"	Gray Container	1	McMaster-Carr Supply Company
Drill Rod	1/2" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company
Drill Rod	1/4" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company
Drill Rod	3/8" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company
Drill Rod	5/16" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company
Drill Rod for Goal	1" Ø x 5"	Gray Container	1	McMaster-Carr Supply Company
Flexible Motor Shaft	13.5" long, Fits Seat Motor	Gray Container	4	Delco Electronics Corporation
LDPE Rod	1" Ø x 24"	Gray Container	1	McMaster-Carr Supply Company
Threaded Rod with 8 Hex Nuts	1/4" Ø x 24", 20 pitch coarse	Gray Container	1	McMaster-Carr Supply Company
Wooden Dowel	1/4" Ø x 18"	Gray Container	2	McMaster-Carr Supply Company

Sheets & Boards

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
Aluminum Plate	1/4" x 3" x 12"	Gray Container	1	McMaster-Carr Supply Company
Aluminum Sheet	1/16" x 12" x 18"	Gray Container	1	McMaster-Carr Supply Company
HDPE Block	1" x 2" x 6"	Gray Container	1	McMaster-Carr Supply Company
Masonite Board	1/4"x12" x 12"	Gray Container	1	Home Depot
Particle Board - Sample (see Add'l	5/8" x 6" x 12"	Gray Container	1	Home Depot
Pine Board	3/4" x 1-1/2" x 9"	Gray Container	1	Home Depot
Pine Board	3/4" x 2-1/2" x 9"	Gray Container	1	Home Depot
Pine Board - Sample (see Add'l Hardware	3/4" x 3-1/2" x 9"	Gray Container	1	Home Depot
Plywood	3/8" x 6" x 12"	Gray Container	1	Home Depot
Plywood - Sample (see Add'l Hardware	1/2" x 6" x 12"	Gray Container	1	Home Depot
Polycarbonate Sheet	1/16" x 12" x 12"	Gray Container	1	McMaster-Carr Supply Company
Rohacell© P170 Structural Foam	1" x 24" x 49"	Shipped to	1	Richmond Aircraft Products
Rubber Sheet, Black	3/32" x 6" x 18"	Gray Container	1	McMaster-Carr Supply Company
Rubber Sheet, Red	1/16" x 6" x 18"	Gray Container	1	McMaster-Carr Supply Company

Small Parts

Part Name/Description	Dimensions	Location	Qty /Kit	Product Supplier
4 - Tooth Tape Engaging Snap Clip		Gray Container	8	Delphi Interior and Lighting
Cabinet Catch Magnet w/ Plastic Case		Green	1	Stanley Hardware
Channel for Tape Drive	left hand side	Gray Container	1	Delphi Interior and Lighting
Channel for Tape Drive	right hand side	Gray Container	1	Delphi Interior and Lighting
Double Magnet Cabinet Catch		Green	1	Stanley Hardware
Flat Washers	1/4" i.d., 7/8" o.d.	Gray Container	4	McMaster-Carr Supply Company

3.6 Additional Hardware List

The parts listed on this page may be purchased from Small Parts, Inc. or other sources, and are subject to the limitations mentioned in Section 3.4.

Fasteners

Hose Clamp	up to 10 of any size
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Other

Fiberglass Matting	4' x 4' x up to 1/8"
Resin + Hardner	as needed for Fiberglass

Rods & Shafts

Closet Rod	1 1/4" Ø x 6'
Copper Water Pipe	1/2" Ø x 10'
Electrical Conduit Pipe (EMT)	1" Ø x 10'
Electrical Conduit Pipe (EMT)	1/2" Ø x 10'
Electrical Conduit Pipe (EMT)	3/4" Ø x 10'
Flexible Conduit (ENT)	1/2" Ø x 10', PVC
PVC Pipe	1" i.d. x 10', schedule 40
PVC Pipe	1-1/2" i.d. x 10', schedule 40
PVC Pipe	1/2" i.d. x 10', schedule 40
PVC Pipe	3/4" i.d. x 10', schedule 40

Rope, Belts, & Chain

Nylon Braided Rope	5/16"Ø x 20'
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Sheets & Boards

1/2" Plywood, 5/8" Chipboard OR 7/16" Particle Board	4' x 4'
Aluminum Plate	1' x 2' x 1/4"
Aluminum Plate	4' x 4' x 1/32"
Pine Board	3/4" x 3-1/2" x 10'
Polycarbonate Sheet	1/4" x 4' x 4'
Polycarbonate Sheet	3/8" x 2' x 4'

Sprockets & Pulleys

Chain/Belt to match Sprocket/Pulley	up to 10' total, any combo
Sprockets or Pulleys	up to 4 total, any size/combo

3.7 FIRST Policy on Repair and Replacement of Non-functional Control System Components

FIRST has developed the following policies on the repair and replacement of control system components.

If you experience a failure in any of your control system equipment, please call FIRST to insure that all components are correctly configured. If this does not resolve the problem, you will be instructed to follow the steps outlined below. Please note the differences in procedure based on the component that is determined to be non-functional.

- If, during examination of the failed components, the failure is determined to be due to misuse or mis-wiring, you will be charged according to the rates below.
- If the affected unit(s) failed due to a manufacturing defect, you will not be charged.
- Any team with an outstanding balance will not be allowed to register or compete at any Competition event until the balance is paid. Teams will be allowed to pay outstanding balances, by check only, at the registration desk at each Competition event.

Transmitter Box or Receiver Box

- 1) Ship the non-functional unit to FIRST.
- 2) Upon receipt of the unit, it will be examined to determine whether it can be repaired or must be replaced.
- 3) FIRST will ship the repaired or replacement unit to the team via 2nd day UPS shipment within 1 business day of receipt.
- 4) If the failure was determined to be a result of misuse or mis-wiring, the following charges will be assessed:

Replacement of Transmitter Board, or Receiver Board: \$150.00

Repair of Transmitter Board, or Receiver Board: \$50.00

Speed Controllers

The speed controllers have a 90 day warranty. Teams have the option of contacting Tekin for repair/replacement of defective units. Tekin estimates an approximate 3 day turnaround time from receipt of units to shipment of repaired/replacement units.

If teams wish to obtain a replacement speed controller through FIRST, we will provide a new unit, shipped via 2nd Day UPS, for the list price of \$205.00.

FIRST is able to provide these replacement speed controllers through a special arrangement with Tekin, and has only a limited number of speed controllers available. This policy is intended to provide teams with failed units a timely

method of obtaining replacements. Teams wishing to obtain spare speed controllers must go through regular retail channels.

If you do experience a failure, you should seriously consider the fact that if one speed controller failed with the current vehicle design, a replacement may also fail during The Competition. Carefully evaluate the abrupt startup and reversing loads on the motor, the interim and overall gear ratios, and the driving techniques used.

RNets

- 1) Ship both RNets to FIRST.
- 2) FIRST will ship a pair of replacement RNets via 2nd day UPS shipment within 1 business day of receipt.

Servos & Servo Cables

Replacements can be purchased from FIRST for \$15. These units will be shipped via 2nd day UPS air. As with speed controllers, FIRST has a limited number of servos available. Teams wishing to purchase spare servos may purchase equivalent models through regular retail channels.

Joysticks

The Flightstick joysticks have a 1 year warranty. Teams have the option of contacting CH Products for resolution of problems with defective units. Alternately, Flightstick joysticks are available in most computer stores.

Drill Motors and Gearboxes

There are only a limited number of replacement motors and gearboxes available.

If you have a burned out motor:

- 1) Ship the non-functional motor to FIRST.
- 2) FIRST will ship a replacement motor to the team via 2nd day UPS shipment within 1 business day of receipt.

If you have a non-functional gearbox:

- 1) Ship the gearbox to FIRST.
- 2) Seriously consider the fact that if a brand new gearbox failed with the current vehicle design, a replacement may also fail during The Competition. Carefully evaluate the shock loading of the gearbox, the interim and overall gear ratios, and the driving techniques used.
- 3) FIRST will ship a replacement gearbox to the team via 2nd day UPS shipment within 1 business day of receipt.

Note: If you modify the gearbox, and a failure occurs, FIRST will not provide a replacement.

Alternately, teams may purchase a new Skil 12 volt cordless drill from a standard retail outlet and use the motor and/or gearbox.

Seat Motors and Tape Drive Window Mechanisms

- 1) Ship the motor to FIRST.
- 2) FIRST will ship a replacement motor to the team via 2nd day UPS shipment within 1 business day of receipt.

As with other components, FIRST has a limited number of replacement motors available. Teams wishing to purchase spare motors may purchase equivalent models through General Motors parts distributors.

4. CONTROL SYSTEM MANUAL

4.1 Introduction & General Description

(see controls rules in section 3.3)

Please read the following section carefully. Failure to configure your control system properly could result in personal injury, damage to the control system, or damage to your robot. FIRST will not provide free replacement of control system parts damaged due to misuse or mis-wiring.

In this section you will find:

- Descriptions of the control system components
- Configuration options
- Wiring diagrams
- Hook-up instructions
- Rules for usage

If, after reading this section, you have problems configuring the control system, please contact FIRST for assistance. We will be happy to answer any questions you may have. See section 5.1 for information on how to contact FIRST.

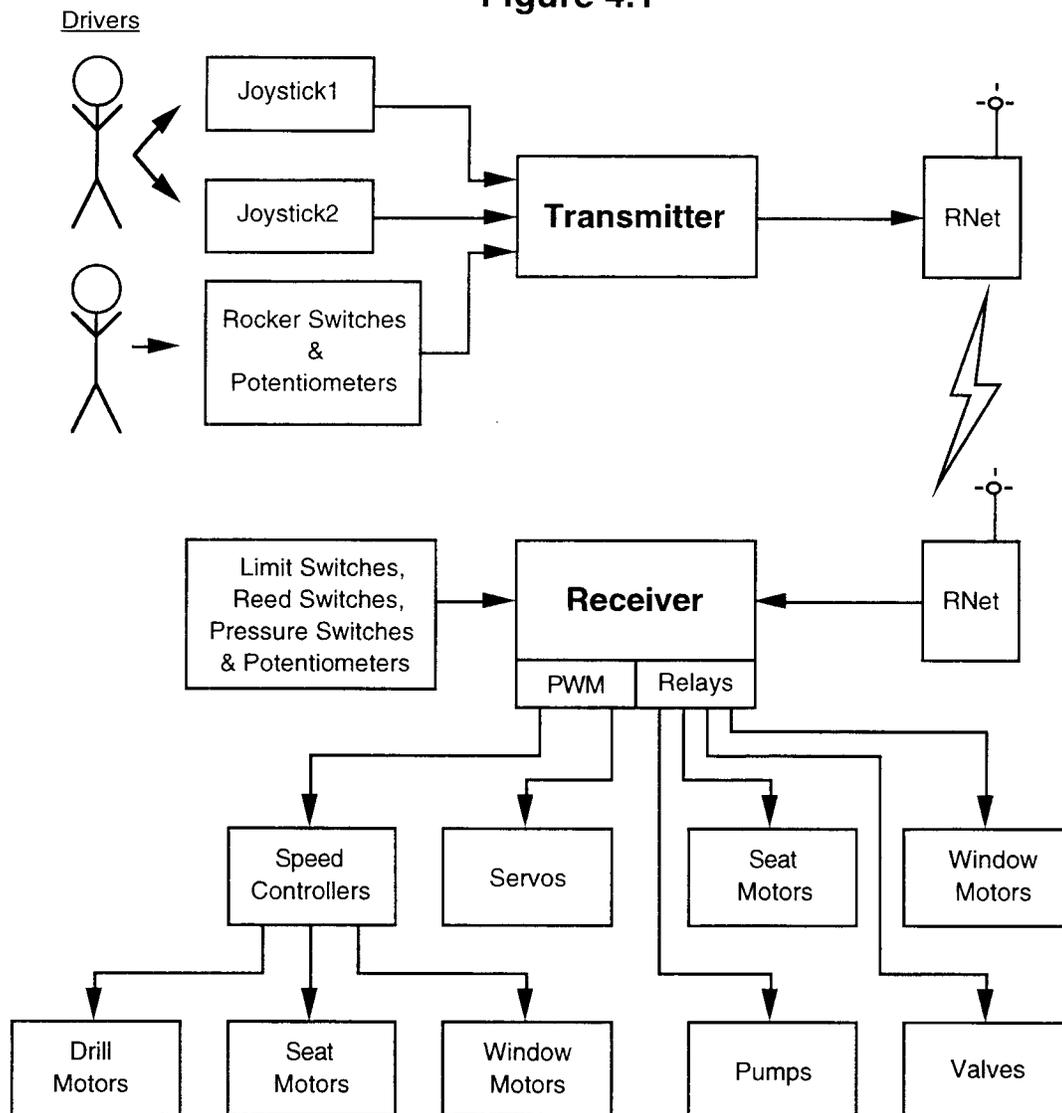
Before proceeding with a discussion of the individual components that make up the control system, it is helpful to understand the overall function of the control system.

The heart of the control system is comprised of two main units: the Transmitter, and the Receiver. Basically, the Transmitter takes input from the drivers and passes it along to the Receiver. The Receiver takes this information, gathers more information from sensors on-board the robot, figures out what to make the robot do, and makes the robot do it.

More specifically, the Transmitter reads the joystick, switch, and potentiometer inputs controlled by the drivers and relays this information to the Receiver via the RNet radio modems (or tether cable). The Receiver takes this information, verifies that it has been received correctly, and then hands it off to the user program. The user program, which runs on the receiver, takes the data from the Transmitter, reads the on-board sensor inputs, figures out what to do with the outputs to make the robot behave as desired, and sets the PWM and relay outputs to the appropriate states. Figure 4.1 shows a block diagram illustrating this concept.

The rest of this section will provide the details necessary to hook up the control system and make it work.

**Control System Block Diagram
Figure 4.1**



4.2 Control System Components

The Kit contains a variety of input devices:

- Two CH Products three-axis proportional joysticks with trigger and thumb switches
- Eight Honeywell Microswitch rocker switches
- Ten Honeywell Microswitch limit switches
- Four CP Clare reed switches.
- Two Numatics pressure switches
- Four potentiometers

The rocker switches are meant for use with the Transmitter to provide up to 16 switch inputs. In addition, there are two switch inputs on each joystick, which share input channels with 4 of the rocker switch inputs. If desired, the joystick switches can be disabled by setting some DIP switches inside the Transmitter.

Both joysticks and 2 of the potentiometers can be used with the Transmitter to provide up to 8 channels of proportional input.

The limit switches, reed switches, and pressure switches are intended for use as feedback sensors on your robots, but may also be used as part of the user interface on the Transmitter end. The Receiver can handle up to 16 switch inputs, so all of these switches can be used on the robot at once.

The remaining 2 potentiometers can be used with the Receiver to provide 2 channels of proportional input on-board the robot.

There are also a variety of output devices:

- Two Hitec servos
- Four Tekin reversing speed controllers
- Two Skil cordless drill motors
- Four Delco seat motors
- Two Delphi tape drive window mechanisms
- Two McCord-Winn Textron air pumps
- Two Numatics pneumatic valves.

The servos provide proportional position control, while the speed controllers provide proportional velocity control. Both the servos and speed controllers are controlled directly by the PWM outputs on the Receiver.

Due to their high current requirements, the drill motors may be driven only by the speed controllers. Also, no more than one motor may be powered by each speed controller. If proportional control of the seat or window motors is desired, they may also be driven by speed controllers.

Attempting to drive the drill motors directly with the Receiver relay outputs could damage the control system and is therefore prohibited.

All other output devices must be driven by the relay outputs on the Receiver. No more than one device may be powered by a single relay output.

4.3 Power Distribution

The Transmitter is powered by the 9Vdc power supply. In turn, the transmitting RNet receives power from the Transmitter.

On the Robot, power distribution is more complex. Power is provided by a pair of Skil rechargeable Ni-Cad batteries directly to the Receiver, speed controllers, and the muffin fan. All other devices receive power through the Receiver.

The batteries must be wired in parallel, such that the final output voltage is still 12Vdc, but the current capacity is doubled.

Do not wire the batteries in series. This will yield 24Vdc, and many components of the control system will be damaged.

Important: The Skil batteries are designed to be able to sustain an output current of 70 Amps each, but will blow an internal safety fuse in less than 3 seconds at 100 Amps. If this fuse blows, the battery is dead and cannot be repaired. When under heavy load, such as with both drill motors stalled, a robot can draw more than 100 Amps, which is enough to kill a single battery. Therefore, robots must only be operated with both batteries present and wired in parallel, which will halve the load on each battery. FIRST will not provide free replacement of batteries with blown fuses.

To provide a measure of protection, one 30A auto-resetting circuit breaker (provided in the Kit) must be installed in series with the positive terminal on each battery contact (one breaker/battery), such that all battery output flows through this breaker. These circuit breakers must be accessible for inspection at each Competition event.

Although not required, it is recommended that power from the batteries be distributed via the terminal strips, with one strip used for +12Vdc distribution, and the other strip used for GND. Also, if desired, the terminal strips may be rearranged into units with more or less channels and used to distribute power in multiple locations on the robot. This is not recommended, however, because each channel is designed to hold only one wire in each end.

With time, wires in terminal strips can become loose as the soft copper wire strands creep under the pressure of the screw. Also, normal operating vibration of a robot can loosen wires. Be sure to check the wires in the terminal strip on a periodic basis to prevent failures which could harm the control system or cause a robot to stop dead in the middle of a match.

In order to minimize mistakes and facilitate diagnosis of any problems, all wires distributing power with a constant polarity (i.e. not a relay or speed controller output) must be color coded as follows:

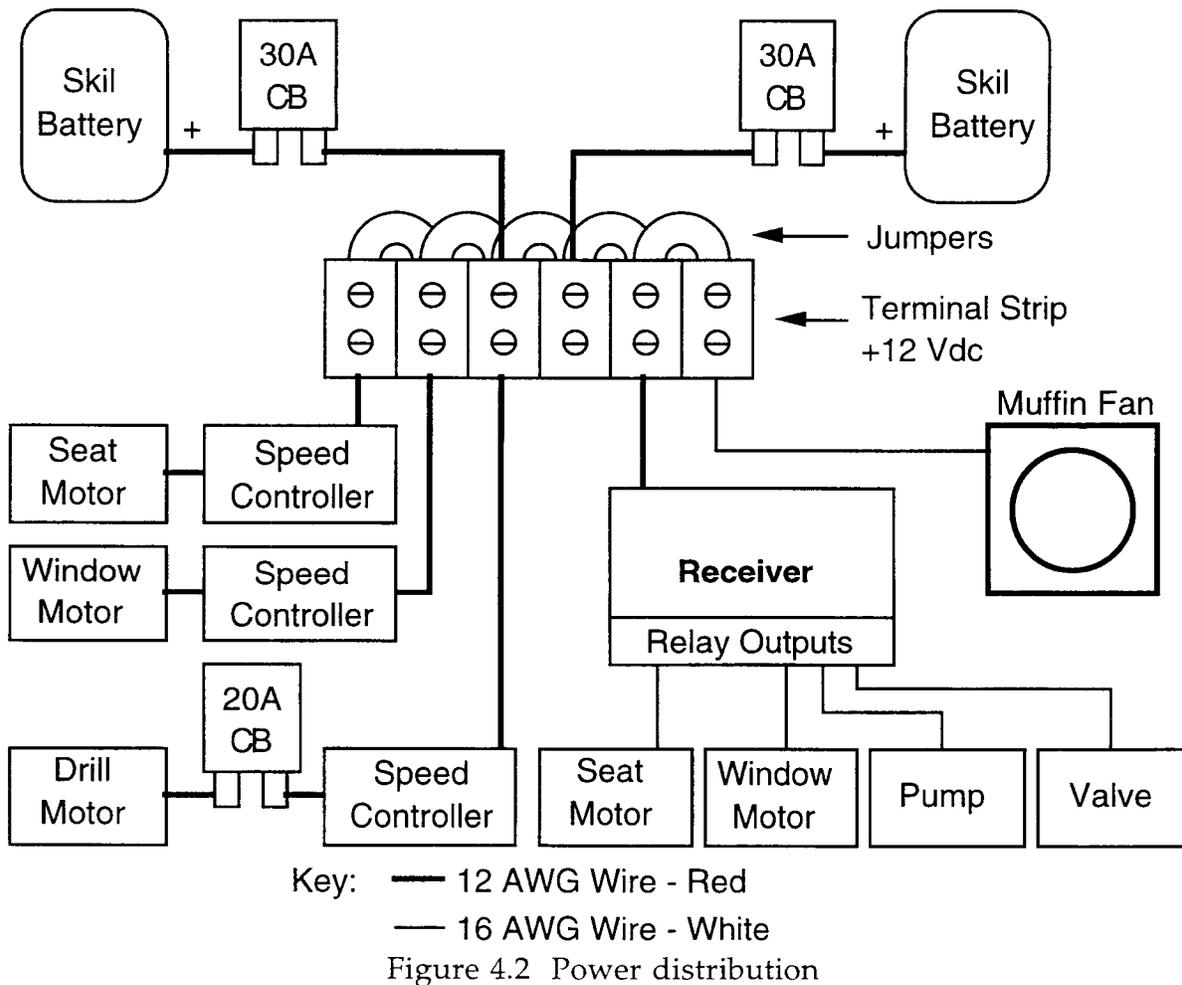
- Use Red 12 AWG or White 16 AWG wire for +12Vdc.
- Use Black 12 AWG or Black 16 AWG wire for GND.

The wires and cables included in the kits are intended for specific uses. Table 4.1 shows the minimum wire sizes allowed for hookup of the various control system devices.

Table 4.1: Minimum Wire Size by Device Type

Device	Wire Type
drill motors, speed controllers (power & motor leads), Receiver (power input)	12 AWG, red & black
Receiver (relay outputs), seat motors, window motors, pumps, valves, fan	16 AWG, 2 conductor
limit switches, reed switches, pressure switches, PWM cables, rocker switches	22 or 24 AWG, 2 or 3 conductor

Figure 4.2 shows a schematic for power distribution using the terminal strips.



Note that Figure 4.2 shows only the +12Vdc side of the power distribution. The GND side is identical except for the absence of the circuit breakers.

The control system cables containing 3 wires or less may be shortened or lengthened as needed as long as the following conditions are met:

- Proper insulation (electrical tape, wire nuts, or shrink wrap) must be used.
- Proper wire type, as specified above, must be used.

4.4 Transmitter

The Transmitter reads the joystick, switch, and potentiometer inputs controlled by the drivers. It relays this information to the Receiver via the RNet radio modems (or tether cable). This allows the drivers to tell the robot what to do, such as turn left or extend an arm.

The connection diagram for the Transmitter Box is shown in Figure 4.3.

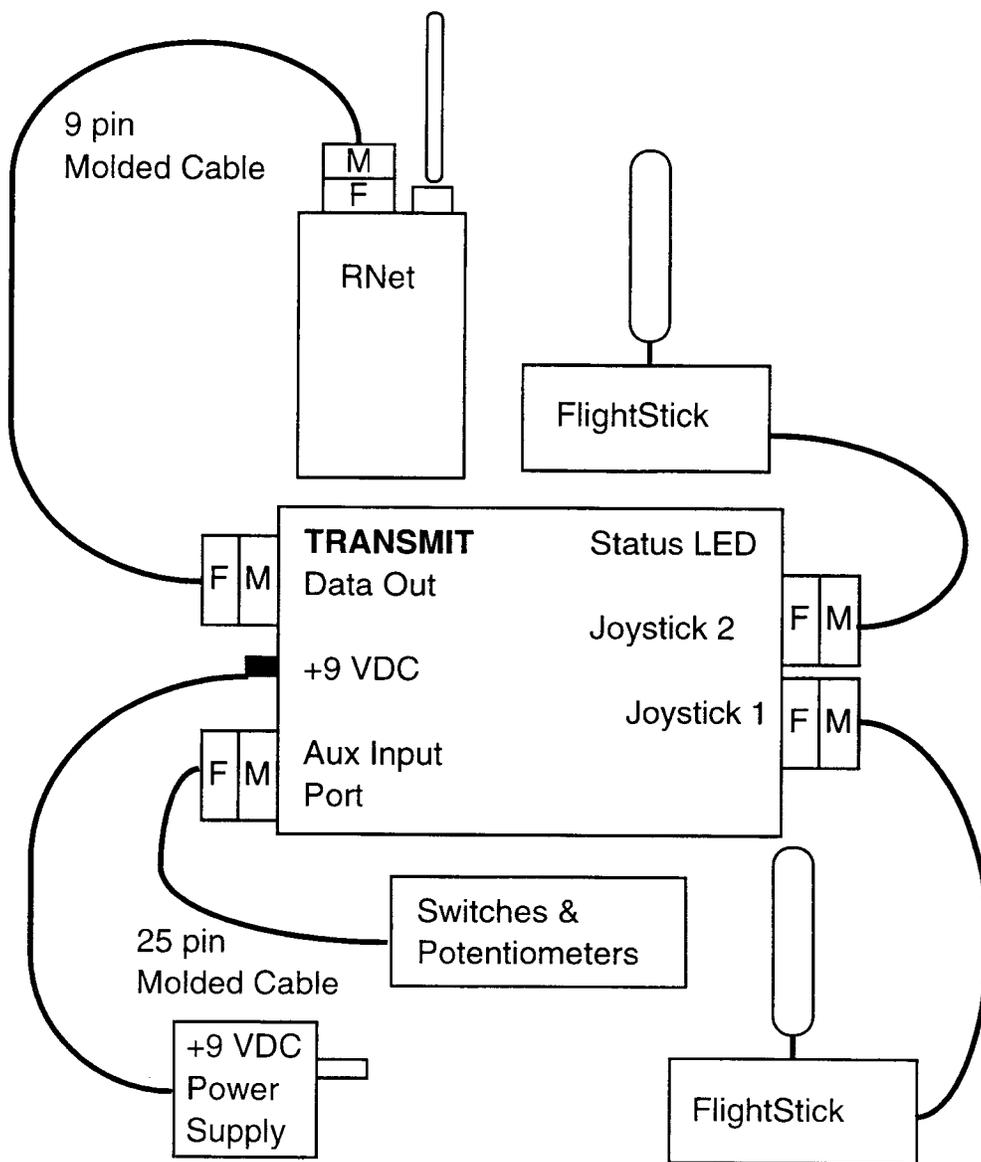


Figure 4.3 - Connection Diagram for Transmitter Box

Warning

Only the 9 volt power supply included with the Kit should be used to power the Transmitter box. If you experience any problems with the 9 volt power supply, contact FIRST for a replacement. Use of an alternate power supply could damage the Transmitter box or RNet and is therefore prohibited.

In order to connect the rocker switches and potentiometers to the Transmitter, they must be wired to the 25 pin male connector and mounted inside the black/almond project box. The 25 pin cable must then be used to make the connection from the 25 pin connector in the project box to the auxiliary input port on the Transmitter.

The exact wiring configuration for the switches and potentiometers inside the project box is not specified. Instead, teams may wire these devices as desired to work with the software and output devices connected to the Receiver. Table 4.2 shows the pin assignments for the auxiliary input port.

Table 4.2: Auxiliary Input Port Pin Assignments with Corresponding Control Program Variable Names

Pin Description	RX Variable	Pin Description	RX Variable
Pin 1: +5Vdc	-	Pin 14: +5Vdc	-
Pin 2: Switch Input 6	sw3_rev	Pin 15: Switch Input 5	sw3_fwd
Pin 3: Switch Input 2 (top button - Joystick 1)	sw1_rev	Pin 16: Switch Input 1 (trigger button - Joystick 1)	sw1_fwd
Pin 4: Analog Input 2	aux1	Pin 17: Switch Input 8	sw4_rev
Pin 5: Switch Input 7	sw4_fwd	Pin 18: Switch Input 4 (top button - Joystick 2)	sw2_rev
Pin 6: Switch Input 3 (trigger button - Joystick 2)	sw2_fwd	Pin 19: Analog Input 2	aux2
Pin 7: Ground	-	Pin 20: Ground	-
Pin 8: Ground	-	Pin 21: Switch Input 16	sw8_rev
Pin 9: Switch Input 15	sw8_fwd	Pin 22: Switch Input 14	sw7_rev
Pin 10: Switch Input 13	sw7_fwd	Pin 23: Switch Input 12	sw6_rev
Pin 11: Switch Input 11	sw6_fwd	Pin 24: Switch Input 10	sw5_rev
Pin 12: Switch Input 9	sw5_fwd	Pin 25: +5Vdc	-
Pin 13: +5Vdc	-		

Switch inputs should be closed to Ground or left open to achieve a 1 or 0 state, respectively, on the Receiver.

Do not connect switches to +5Vdc.

The analog input ports on the Transmitter read resistance, not voltage. To connect a potentiometer to the auxiliary input port, connect one of the outer

potentiometer connectors to +5Vdc and the middle connector (wiper) to the analog input pin of your choice.

Do not connect a potentiometer between +5Vdc and Ground on the Transmitter.

The switch inputs on the joysticks are wired in parallel with some of the switch inputs on the auxiliary input port, as indicated in Table 4.2. If desired, the switch inputs on the joysticks can be selectively disabled by changing the settings of DIP switches inside the Transmitter. To change the DIP switches, the Transmitter must be opened by removing the four screws on the bottom cover. Table 4.3 details the Transmitter DIP switch settings.

Attention: Before opening the Transmitter box, remember to disconnect the power supply. While the Transmitter box is open, be careful to avoid static discharges to the circuit board or connectors. Also, make sure not to let any foreign particles, especially metal fragments, get inside the enclosure or onto the circuit board. It is best to open the unit in a clean environment away from where your robot is being worked on. Never operate the Transmitter with the cover off.

Table 4.3: Transmitter DIP Switch Settings

Button	DIP Switch
Joystick 1 - Top	3
Joystick 1 - Trigger	4
Joystick 2 - Top	7
Joystick 2 - Trigger	8

Figure 4.4 shows the location of the DIP switches on inside the Transmitter box. To access the DIP switches, the cover of the Transmitter box must be removed. To remove the cover, unscrew the four Phillips head screws on the underside of the Transmitter box.

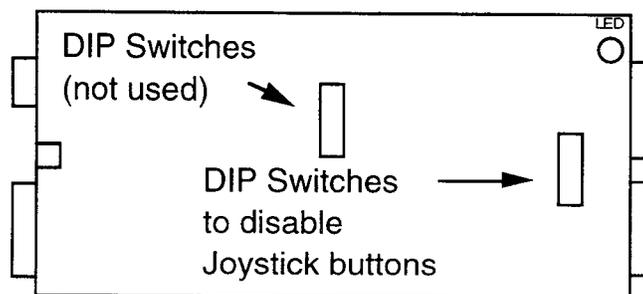


Figure 4.4: Location of DIP Switches Inside Transmitter Box

4.5 Receiver

The Receiver takes data from the Transmitter, verifies that it has been received correctly, and then hands it off to the control program. The default control program takes the data from the Transmitter, reads the on-board sensor inputs, and sets the PWM and relay outputs to the appropriate states. Table 4.4 shows

the mapping of Transmitter and Receiver inputs to Receiver outputs when the default program is running.

Table 4.4 - Input to Output Mapping of Default Receiver Program

Input	Output
Joystick 1 - X Axis	PWM1
Joystick 1 - Y Axis	PWM2
Joystick 2 - X Axis	PWM3
Joystick 2 - Y Axis	PWM4
Auxiliary Input Port - Analog #1	PWM5
Joystick 1 - Thumbwheel	PWM6
Auxiliary Input Port - Analog #2	PWM7
Joystick 2 - Thumbwheel	PWM8
TX Switch 1, (RX Switch 1 turns off)	Relay Output 1 (F)
TX Switch 2, (RX Switch 2 turns off)	Relay Output 1 (R)
TX Switch 3, (RX Switch 3 turns off)	Relay Output 2 (F)
TX Switch 4, (RX Switch 4 turns off)	Relay Output 2 (R)
TX Switch 5, (RX Switch 5 turns off)	Relay Output 3 (F)
TX Switch 6, (RX Switch 6 turns off)	Relay Output 3 (R)
TX Switch 7, (RX Switch 7 turns off)	Relay Output 4 (F)
TX Switch 8, (RX Switch 8 turns off)	Relay Output 4 (R)
TX Switch 9 or RX Switch 9	Relay Output 5 (F)
TX Switch 10 or RX Switch 10	Relay Output 5 (R)
TX Switch 11 or RX Switch 11	Relay Output 6 (F)
TX Switch 12 or RX Switch 12	Relay Output 6 (R)
TX Switch 13 or RX Switch 13	Relay Output 7 (F)
TX Switch 14 or RX Switch 14	Relay Output 7 (R)
TX Switch 15 or RX Switch 15	Relay Output 8 (F)
TX Switch 16 or RX Switch 16	Relay Output 8 (R)
RX Analog Input 1	Not Used
RX Analog Input 2	Not Used

If desired, a custom user control program can be loaded into the Receiver to provide more sophisticated control of the robot. Adding a user control program will not erase the default control program, so the Receiver can be changed back to use the default program quickly and easily in the event of problems with the custom program. DIP switches on the side of the Receiver are used to select which program (default or custom) is running, and to reset the Receiver in the event of a problem. Table 4.5 shows the Receiver DIP switch settings.

Table 4.5: Receiver DIP Switch Settings

DIP Switch	Setting
1	Default control program
2	User control program
3	Reset
4	Not Used
<p>Notes:</p> <p>To select an option, place the appropriate switch in the down position.</p> <p>Only one program (default or user) can run on the Receiver at once. If neither or both programs are selected, the Receiver will not function properly.</p> <p>In order to load a user control program into the Receiver, the DIP switches must be set for the user control program. The Receiver is designed to prevent the default control program from being overwritten.</p>	

Programming the Receiver

The control program running on the Receiver is written PBASIC, a dialect of the BASIC programming language. This language was selected because it is fairly easy to learn and debug in a short period of time. However, as with all programming languages, it is possible to create a program that does not behave as expected. If a custom control program is used, the team assumes full responsibility for insuring that the code works as expected.

It must be clearly understood that teams are responsible for any software bugs introduced into the control program when using a custom program. If a software bug negatively impacts the performance of a robot during a competition match, it will not be grounds for a rematch or even a pause in the match.

To program the Receiver, use the software included on the disk labeled "Programming Software for Control System". This disk contains a copy of the program editor/compiler/programming utility (STAMP2.EXE), the source code for the default control program (RXSLAVE.BS2), and complete documentation for the STAMP2 program and the PBASIC programming language (BS2BOOK.PDF & BS2APPS.PDF). With the exception of the source code for the default control program, these files can also be obtained via the Internet from Parallax, Inc. at <http://www.parallaxinc.com> or <ftp://ftp.parallaxinc.com>.

The documentation files are in Adobe's Portable Document Format (PDF). Programs to view these files are available over the Internet for free for most operating systems from Adobe at <http://www.adobe.com>.

The source code for the default control program is provided both as an example of how to write a program in PBASIC, and to provide a head start in writing a custom program. It is recommended that the RXSLAVE.BS2 file be copied, and that the copy be used to write any custom control software. This way, the original file will always be available as a backup. The source code for the default control program is also available in Appendix J.

In order to program the Receiver, the 9pin cable must be connected from the serial port of a PC to the Programming Port on the Receiver.

RNets and Tether Adapter

The Receiver gets data from the Transmitter either via the RNet radio modems or a direct connection via the tether adapter. The 2 ends of the 3-headed cable are used to connect the multi-frequency RNet to the Data In Port on the Receiver. The other end of this cable should be mounted in a position that is easy to access.

To operate the robot via wireless control, attach the dongle to the third end of the 3-headed cable. This will select the appropriate frequency and route data from the RNet to the Receiver.

To operate the robot with the tether adapter, remove the dongle, and connect the tether adapter to the third end of the 3-headed cable. Then, unplug the fixed-frequency RNet from the 9pin cable on the Transmitter, and plug this cable directly into the tether adapter.

Avoid bundling the 3-headed cable with the battery or motor wires. Locate the RNet so the antenna is not shielded by metal objects. The hook and loop fastener on the RNet provides an easy means of attachment to the robot. However, we recommend a secondary means of attachment because the RNets have broken loose in the past due to the serious impacts and vibrations the robots undergo during The Competition.

PWM Outputs

The PWM outputs are designed to drive the servos, and to provide a control signal to the speed controllers. The speed controllers and servos may be directly connected to the PWM outputs, or may be connected via the 36" servo extension cables and/or 24" servo Y cables. When plugging a PWM cable onto the output connectors, be sure to observe the orientation indicated on the label.

Some of the PWM cables in the kits have Hitec/JR style connectors while others have Futaba J-style connectors. The Hitec/JR style cables have yellow, red, and black wires, while the Futaba style cables have white, red, and black wires. These cables should be treated as equivalent. In order to use the Futaba style connectors, you may need to shave off the external tab to obtain a proper fit. See the figure 4.5 below for details.

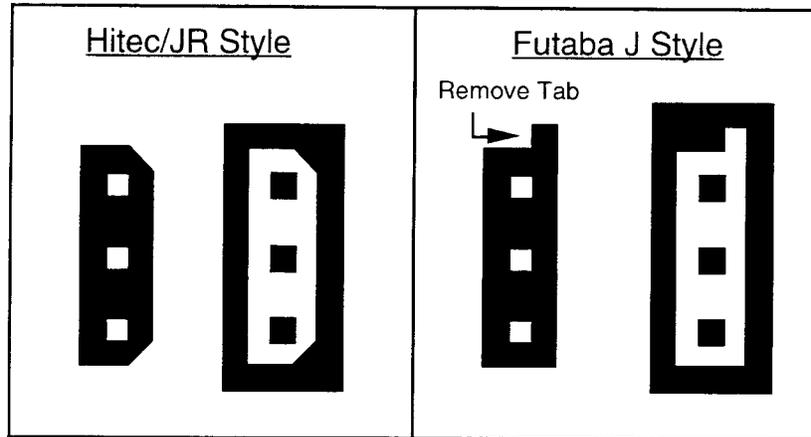


Figure 4.5: Hitec and Futaba-Style PWM Connectors

Relay Outputs

The relay outputs are designed to provide forward and reverse control of the seat motors, window motors, pumps, and valves. These outputs should be connected directly to the motor/pump/valve with the appropriate wire.

Do not run power from the batteries into the relay outputs. Doing so will damage the control system.

To achieve control of both solenoids on the double solenoid valve and use only one relay channel, use the diodes provided in the kit to route power to one solenoid at a time. Figure 4.6 shows the schematic for this arrangement.

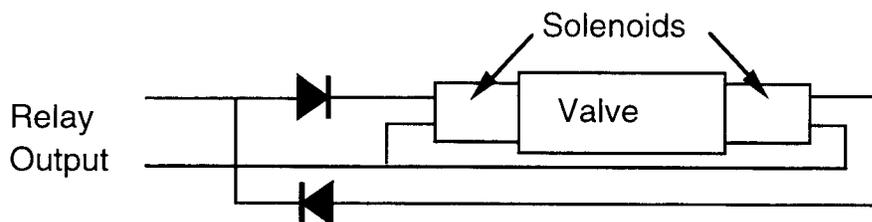


Figure 4.6: Use of Diodes with Double Solenoid Valve

Sensor Inputs

The sensor inputs on the Receiver can be used to measure various conditions on the robot and trigger automatic responses by the control software. For example, by mounting a limit switch in such a position that it is triggered when a mechanism reaches one of the ends of travel, the limit switch can be used to disable the motor from trying to travel further in that direction without preventing it from moving back in the other direction. This can prevent binding or damage to the mechanism, and can save energy by preventing the motor from operating in a stall condition.

There are 16 switch inputs and 2 analog inputs available. The limit switches, reed switches, and air pressure switches may be connected to the switch inputs. The potentiometers may be connected to the analog inputs. Use 2 or 3 conductor jacketed cable and a 25 pin male soldercup connector to connect sensors to the Sensor Port. Table 4.6 describes the pin assignments for the Sensor Port.

Do not connect power or any other signals to these switches or switch inputs. Be careful to observe the polarity of the power inputs when wiring the control system. You will be required to pay for replacement or repair of devices damaged due to improper wiring.

Table 4.6: Sensor Port Pin Assignments with Corresponding Control Program Variable Names

Pin Description	RX Variable
Pin 1: Switch Input 1	rx_sw1
Pin 2: Switch Input 2	rx_sw2
Pin 3: Switch Input 3	rx_sw3
Pin 4: Switch Input 4	rx_sw4
Pin 5: Switch Input 5	rx_sw5
Pin 6: Switch Input 6	rx_sw6
Pin 7: Switch Input 7	rx_sw7
Pin 8: Switch Input 8	rx_sw8
Pin 9: Ground	-
Pin 10: Ground	-
Pin 11: Ground	-
Pin 12: Ground	-
Pin 13: +5Vdc	-
Pin 14: Switch Input 9	rx_sw9
Pin 15: Switch Input 10	rx_sw10
Pin 16: Switch Input 11	rx_sw11
Pin 17: Switch Input 12	rx_sw12
Pin 18: Switch Input 13	rx_sw13
Pin 19: Switch Input 14	rx_sw14
Pin 20: Switch Input 15	rx_sw15
Pin 21: Switch Input 16	rx_sw16
Pin 22: Ground	-
Pin 23: Ground	-
Pin 24: Analog Input 1	sensor1
Pin 25: Analog Input 2	sensor2

Switch inputs should be closed to Ground or left open to achieve a 1 or 0 state, respectively.

Do not connect switches to +5Vdc.

The analog input ports on the Receiver read a voltage between 0 to +5Vdc. To connect a potentiometer to the auxiliary input port, connect one of the outer potentiometer connectors to +5Vdc, the other outer connector to Ground, and the middle connector (wiper) to the analog input pin of your choice.

Do not connect any voltages greater than +5Vdc to the analog input port. It will damage the Receiver.

4.6 Output Devices

Skil Gearmotors and Tekin Speed Controllers

Refer to the Tekin REBEL Owner's Manual for connection of the speed controller to the battery and motor. Two capacitors, included with each speed controller, should be installed on each drill motor as described in the Owner's Manual. Please secure the motor wires carefully to avoid breaking the capacitor leads.

One 20A circuit breaker must be installed in series with each drill motor to protect both the drill and the speed controller. Do not disable the circuit breaker by connecting its terminals together. Please insulate the terminals of this circuit breaker separately so inspectors at The Competition can verify correct installation. If the circuit breaker trips during use, you should use a higher gear reduction ratio. The circuit breaker usually resets in less than one second.

If the speed controller shuts off due to overheating during use, you may need to use a higher gear reduction ratio, or you may be running it continuously in reverse. The speed controller runs hotter in reverse than it does in forward. The speed controller usually takes 30 seconds or more to reset. An optional 12V muffin fan has been included in the Kit primarily for added protection against overheating of speed controllers and/or drill motors. You should install this fan to direct cooling air over the power components that run the hottest. You may provide power to the fan from the 12V power distribution terminal blocks directly. Note that the fan is not reversible.

The drill motors and gearboxes snap together for convenient handling during assembly of a drill; this motor-gearbox sub-assembly cannot support normal loads by itself. The gearshift lever on the gearbox and the gears actuated by it cannot withstand large gear-shifting forces, especially while operating. We recommend that you use the plastic drill shell to support the motor, gearbox and shift mechanism, and provide ample speed reduction between the drill and its load.

The drill components were designed for drilling holes and driving screws, not for propelling a 120 pound robot or launching huge tubes several feet into the air. Please remember this when designing and operating your robot. Align mechanical power transmission components accurately. If you couple the spindle to another shaft, support the shaft with two bearings and use a suitable flexible coupling. If you mount a gear, pulley, or sprocket to the gearbox spindle, use the largest pitch diameter possible to minimize side loads resulting from transmitting torque. Note the tradeoff between side loads and available gear ratio. A small pulley on the spindle allows a good gear ratio, but results in excessive side loads. Seriously consider the possible need for two stages of speed reduction between the drill and its load. If the drill shows signs of overloading, such as clutch disengagement, improve your design. When you get out on the playing field, failures will be far more likely than they were during practice.

Seat and Window Motors

The seat and window lift motors contain one worm gear reduction stage and a positive temperature coefficient (PTC) thermistor for overload protection. As the motor becomes warm from use, the resistance of the PTC device increases, thereby reducing the motor current and output torque. Operation at or near stall continuously will reduce the output torque to near zero until the motor has been allowed to cool. To prevent overheating, take care to couple the output shaft in a manner that does not impose large side loads, use an appropriate gear ratio, and minimize the internal friction of the mechanism driven.

Mechanical Power Transmission

One of the most common problems teams have experienced in past competitions is mechanical power transmission failure. Typical torques at the final stage of your propulsion power transmission assembly are large enough to cause serious problems for most conventional means of fixing gears, pulleys or sprockets to shafts. Set screws almost always fail. Pins offer better torque transmission, but can cost you valuable time if one breaks. Be careful not to use a pin so large that it occupies so much of the original shaft cross-section that the shaft breaks. Consider carefully the use of good clamping type couplings, even though they may be expensive. We have included two 3/8 in. bore Trantorque collet type couplings in the Kit, and recommend that you use them on the drill spindles. Although the Trantorque is intended for use on a smooth shaft, it has been used successfully on the threaded spindle. You should bore the component to be mounted a few thousandths of an inch smaller than the recommended 0.750 in. to compensate for the spindle diameter, which is slightly under 0.375 in. Be careful to avoid interference with other parts when installing the Trantorque coupling.

4.7 Batteries & Chargers

The battery chargers use a temperature sensor to terminate charging. A warm battery must be allowed to cool before the charger will begin charging. Please do not attempt to cool a battery by immersing it in ice, water, or snow. A battery that has been left out in cold weather must be allowed to reach room temperature before charging. Failure to do so will cause serious damage to the battery, which may leak toxic liquid as a result.

Be careful to avoid shorting the batteries. Short-circuit current exceeds 100A and can cause fire, serious injury, and leakage of toxic materials. If you have a battery that you know to be damaged, please do not put it in the trash. Turn it in to us and tell us that it is damaged, so we can recycle it properly.

Freshly charged batteries will be provided at The Competition for teams who have not had time to charge a pair fully for their next match. The best strategy when working in the pit is to trade one set of batteries at the FIRST charging station for a fresh set a few minutes prior to your next match and "top them off" with your own charger. Use the other set for testing in the pit.

Two batteries with an average load of 10A each will run for at least five minutes.

To plug batteries into the robot control system, use the handles of the drill shells in conjunction with the battery contacts. For convenience, the handles may be cut from the main body of the drill shell. It is recommended that the battery retaining clips also be used to provide an easy means of securing the batteries in the handles.

See Section 4.3 for information on acceptable wiring of the batteries.

5. ADMINISTRATIVE DETAILS

5.1 How to contact FIRST

FIRST Can be reached via phone, fax, mail, email, or on the web.

Mailing Address and Telephone/Fax Numbers

FIRST

200 Bedford Street

Manchester, NH 03101

800-871-8326

603-666-3907 (fax)

Technical And Judicial Hotline

If at any point in the design process you run into technical difficulties or need clarification of any of the rules, please contact:

For rules clarification:	For playing field specs:
Eric Rasmussen	Charlie Jost
ear@usfirst.org	chasjost@usfirst.org

All questions and answers about the rules will be made public in a periodic series of faxes to the teams, and on posts to the FIRST homepage. However, the identity of teams submitting the questions will not be made public unless they are posted by the team on the web.

Administrative Questions or Concerns

Sally Washburn	or	Debra Tetrault
sally@usfirst.org		dmt@usfirst.org

Sponsorship Questions or Concerns:

Susan Howland	or	Nicolle Rizzo
howland@usfirst.org		nicolle@usfirst.org

5.2 FIRST Web Site

FIRST has a site on the World Wide Web. You can visit us at:
<http://www.usfirst.org>.

Although our current network bandwidth does not permit us to make the full text of the rules available via the web site, FIRST will periodically post rules

updates and answers to rules questions in a special limited access area of the site. This area is located at: <http://www.usfirst.org/1997comp/teamonly/>

While this area is not open to the general public, it can be accessed by teams using the account name and password supplied in the Check-out materials at the Kickoff Workshop. The Rules are not for public access, and any team discovered giving out their password will have their access to this site revoked.

The web site also provides links to home pages setup by Teams involved in the FIRST Competition. If you have a school, company, or team-related web page that is not listed, please send email to webmaster@usfirst.org.

5.3 Motorola Midwest Regional

Location

The Motorola Midwest Regional will be held at Harper College. The full address is:

Harper College
Route 62, Algonquin Road
Palatine, IL 60067

Hotels

Below are some suggestions on where to stay if you will need overnight accommodations

Embassy Suites Hotel 1939 North Meacham Road Schaumburg, IL 60173 800-654-8089 \$109 single/double \$119 triple/quad/quintuplet/sextuplet Price includes full breakfast. Cut off 2/14/97	Hampton Inn, Schaumburg 1300 East Higgins Road Schaumburg, IL 60173 847-619-1000 \$69 single/double \$74 triple/quad Price includes continental breakfast. Cut off 2/14/97
Holiday Inn, Schaumburg 1550 North Roselle Road Schaumburg, IL 60195 847-310-0500 \$75 single/double/triple/quad Cut off 2/7/97	Hyatt Regency, Woodfield 1800 East Golf Road Schaumburg, IL 60173 847-605-1234 \$89 single/double/triple/quad Cut off 2/12/97
Wyndham Garden Hotel, Schaumburg 800 National Parkway Schaumburg, IL 60173 847-605-9222 \$77 single/double/triple/quad Cut off 2/5/97	Marriott, Arlington Heights North 3700 North Wilke Arlington Heights, IL 60004 847-394-9999 \$73 single/double/triple/quad Cut off 2/12/97

Radisson Hotel, Schaumburg
 1725 East Algonquin Road
 Schaumburg, IL 60173
 847-397-1500
 \$74 single/double, \$84 triple/quad
 Price includes airport shuttle. Please
 give advance notice.
 Cut off 2/14/97

Please note that all rooms are first come, first served. The rates quoted here can only be guaranteed until the "cut off date" listed for each facility.

5.4 New England Regional

Location

The New England Regional will be held at New Hampshire College. The full address is:

New Hampshire College
 2500 North River Road
 Manchester, NH 03104

Hotels

Below are some suggestions on where to stay if you will need overnight accommodations for the New England Regional.

Center of New Hampshire - Holiday
 Inn
 700 Elm Street
 Manchester, NH 03101
 603-625-1000
 \$72 single/double, \$77 triple/quad
 Cut off 2/20/97

Comfort Inn
 298 Queen City Avenue
 Manchester, NH 03102
 603-668-2600
 \$59 single/double + \$6 per person
 Cut off 2/26/97

Days Hotel
 55 John E. Devine Drive
 Manchester, NH 03103
 603-668-6110
 \$65 single/double + \$6 per person
 Cut off 2/26/97

Highlander Inn
 2 Highlander Way
 Manchester, NH 03101
 603-625-6426
 \$75 single/double + \$10 per person
 Cut off 2/26/97

Susse Chalet
 860 Porter Street
 Manchester, NH 03103
 603-625-2020
 \$49.70 single/double/triple/quad
 Price includes continental breakfast
 Cut off 2/19/97

Wayfarer Inn
 121 South River Road
 Bedford, NH 03110
 603-622-3766
 \$70 single/double, \$80 triple/quad
 Cut off 2/12/97

Please note that all rooms are first come, first served. The rates quoted here can only be guaranteed until the "cut off date" listed for each facility.

5.5 Johnson & Johnson Mid-Atlantic Regional

Location

The Johnson & Johnson Mid-Atlantic Regional will be held at Rutgers University. The full address is:
 Rutgers University
 College Avenue
 New Brunswick, NJ 08903

Hotels

Below are some suggestions on where to stay if you will need overnight accommodations for the Johnson & Johnson Mid-Atlantic Regional.

Clarion Hotel
 2055 Lincoln Highway
 Edison, NJ 08817
 908-287-3500
 \$85 single/double, \$90 triple/quad
 Price includes buffet breakfast.
 Cut off 2/26/97

Comfort Inn
 I-287 & Stelton Road
 South Plainfield, NJ 07080
 908-561-4488
 \$49 single/double + \$5 per person
 Price includes continental breakfast.
 Cut off 3/1/97

Somerset Marriott Hotel
 110 Davidson Avenue
 Somerset, NJ 08873
 908-560-0500
 \$75 single/double/triple/quad
 Cut off 2/27/97

Quality Inn
 1850 Easton Avenue
 Somerset, NJ 08873
 908-469-5050
 \$52 single, \$56 double/triple/quad
 Cut off 2/21/97

Wyndham Hotel
 21 Kingsbridge Road
 Piscataway, NJ 08854
 908-980-0400
 \$74 single/double, \$79 triple/quad
 Cut off 2/26/97

Embassy Suites Hotel
 121 Centennial Avenue
 Piscataway, NJ 08854
 908-980-0500
 \$115 single/double/triple/quad
 Price includes full breakfast.
 Cut off 2/15/97

Please note that all rooms are first come, first served. The rates quoted here can only be guaranteed until the "cut off date" listed for each facility.

5.6 National Championship

The National Championship will be held at Walt Disney World's Epcot. For directions and information about overnight accommodations, please see appendix I.

5.7 Schedule of Events

All Regionals

- | | |
|-------|---|
| Day 1 | • Team arrival, Registration and Practice, Official Weigh-in and Inspection |
| Day 2 | • Seeding Matches
• Celebration Party (following seeding matches) |
| Day 3 | • Double Elimination Tournament & Finals
• Awards Ceremony |

National Championship

- | | |
|-------|---|
| Day 1 | Team arrival, Registration and Practice, Official Weigh-in and Inspection |
| Day 2 | Seeding Matches at Epcot Arena |
| Day 3 | Double Elimination Tournament & Finals
Awards Ceremony at Epcot Arena
Wrap Party at Future World West |

Registration

At each event, teams will need to register in the Pit Area by noon on the first day, or Practice Day, of the event. At this time you will:

- surrender both of your RNETs and two of your batteries

- sign-up for your practice times
- receive an orientation packet to the event site and your pit station
- inform FIRST where the machine will be after The Competition.

See Section # 5, *Administrative Details*, for more information.

Once you have unpacked, a FIRST staff member will be around to photograph your machine. These photographs will be used by the judges, referees and event staff to identify teams and their machines while on-site at the event. Your robot should be clearly identified with your corporate/university/school names.

Practice

In order to make the most of practice time, two fields run at the same time with three teams on a field during an assigned practice slot. It is strongly recommended that each team is respectful of the others sharing the field during this time. Friendly interaction between machines is acceptable if both/all teams are willing. Unsportsmanlike conduct on the part of a team at any time during The Competition could result in penalty or disqualification.

Everyone will receive at least two 15 minute practice slots based on the time you register. The earlier you check-in, the earlier your practice times will be. If additional time is available, an announcement will be made and one additional time slot per team will be assigned on a first-come, first-served basis.

If you need to change a practice slot because of the need for additional prep or repair time, you will be responsible for finding a team with which to switch practice. The staff in the Pit Area will help you locate a team; however, if you cannot arrange the change, that practice slot may be forfeited.

Practices are in the afternoon on the following days:

Motorola Midwest Regional.....	Thursday, March 6, 1997
New England Regional.....	Thursday, March 13, 1997
Johnson & Johnson Mid-Atlantic Regional.....	Thursday, March 20, 1997
National Championship.....	Thursday, April 10, 1997

Official Inspection

Before competing in the Seeding Matches, every machine must pass an inspection for rules compliance. FIRST staff will be on-site all day to inspect your machine.

Seeding Matches

Each team will compete between 4 and 6 times, and will accumulate points towards its seeding rank. Since these matches are pre-set, lists will be distributed to each team during the practice day. From each match, based on the score the winner will receive 3 seeding points, second place will receive 1 seeding point and the third place will receive no points.

After all matches, teams will be ranked by place totals (not points); ties will be determined by total score, last match score, and flip of a coin, in that order. Results of seeding will determine the first round matches of Saturday's competition.

Seeding matches are all day on the following dates:

- Motorola Midwest Regional.....Friday, March 7, 1997
- New England Regional.....Friday, March 14, 1997
- Johnson & Johnson Mid-Atlantic Regional.....Friday, March 21, 1997
- National Championship.....Friday, April 11, 1997

Double Elimination Tournament & Finals

Each team will start off in the double-elimination tree according to their seed. The winning team advances to the next round, and the losing teams move to the losing bracket. Every team will be able to lose at least two matches before being eliminated. Double Elimination concludes when there are only four teams left.

The Finals follow the Double Elimination Tournament. The final four will play 1-on-1, best 2-of-3.

Double Elimination and Final matches are all day on the following dates:

- Motorola Midwest Regional.....Saturday, March 8, 1997
- New England Regional.....Saturday, March 15, 1997
- Johnson & Johnson Mid-Atlantic Regional.....Saturday, March 22, 1997
- National Championship.....Saturday, April 12, 1997

5.8 Shipping & Transportation of Machines

To provide every team, regardless of events in which they participate, approximately the same number of design and build days, the following shipping regulations and dates apply:

Any team competing in the National Championship only

1. Machines **MUST BE OUT OF TEAM HANDS** by 5:00 p.m. on Friday, February 28, 1997. This means you may ship the robot or drive the robot to the drayage/storage facility in Orlando by 5:00 p.m. on February 28.
2. Teams will be asked to provide FIRST with shipping documentation to prove shipment of machines.

All teams competing in a Regional event

1. Machines **MUST BE OUT OF TEAM HANDS** by 5:00 p.m. on Tuesday, February 25, 1997. This means you may ship the robot or drive the robot to the drayage/storage facility of your first event by 5:00 p.m. on February 25.
2. Teams will be asked to provide FIRST with shipping documentation to prove shipment of machines.

Regional Competitors

1. After competing in a Regional, any teams competing in another event will have two days to make repairs and/or changes to their machines, within all rules outlined in this document.
2. Machines **MUST ARRIVE at the next site by the next Tuesday at 5:00 p.m.** The exact dates are listed below.

For teams competing in more than one event...

If you are competing in this Regional...
robot at
5:00 p.m.

then we must receive your
the next site by this date at

Motorola Midwest Regional.....	Tuesday, March 11, 1997
New England Regional.....	Tuesday, March 18, 1997
Johnson & Johnson Mid-Atlantic Regional	Tuesday, March 25, 1997

Shipping & transportation of machines

- ST1. Teams are responsible for the shipment of their machines, including the costs involved in shipping. No COD shipments will be accepted.
- ST2. All machines must be shipped or brought to secured storage sites still to be determined. These addresses can be found in Appendix H. Refer to the deadlines listed above.

- ST3. When shipping, batteries must be unplugged and packaged separately from the rest of the machine. A small box inside of your crate is acceptable. This is a federal law.
- ST4. Cardboard is not acceptable packaging for your robot. Wooden crates must be used to avoid moisture problems. Remember, Florida is a humid state. Robots hand delivered to storage facilities must also be crated.
- ST5. All crates must be clearly marked with the team's complete name, as well as any other information requested by the drayage company for that site. A return address or the name of one team member is not enough information for identification. The team number must be on all shipping containers in a minimum of 6" numbers. The number must appear on all four sides and top of container.
- ST6. The machines may not leave The Competition event site until the conclusion of the that event. If repairs are required, they must be performed on site, unless accompanied by a FIRST staff member to an off-site designated machine shop.

5.9 Submission Deadlines

Team Profiles

FIRST will publish short profiles on each team in the event programs. By **Friday, January 31, 1997** FIRST must receive by mail, email (dmt@usfirst.org) or fax, your typed profile. You may use the following questions as guidelines when you write your description. **Please keep in mind that we are on a deadline and that late submissions run the risk of not being included.**

Important: please spell out the following as you would like them printed:

Company/University:

School(s):

Team and/or vehicle nickname:

You may send us a copy of your team logo (black & white, camera-ready if possible, no larger than 8 1/2 x 11)

- 1) What is unique about your team?
- 2) Briefly tell "your story" - how has your team approached the project?
- 3) What makes your robot "a winner" (any information about your robot will remain confidential until the first day of The Competition).
- 4) How many students and engineers are involved in your effort? How is it organized?

This is your team's chance to tell the world who you are and what makes you great. Team profiles are also sent to judges prior to the events, so they can familiarize themselves with the teams. Profiles should be 200 words or less.

Please review pages 12-27 of the 1996 national event program for a look at team submissions for Hexagon Havoc.

Chairman's Award Materials

Must be received at the FIRST OFFICE NO LATER THAN 5:00 PM ON FRIDAY, FEBRUARY 28, 1997.

Please refer to Section #6 for details on this and other awards. FIRST must receive your number of attendees by mail, email (dmt@usfirst.org) or fax by the following dates:

Event Attendees

Two weeks before each event, we need to get an estimate from you of how many people will be attending from your team. The deadlines are as follows:

Motorola Midwest Regional.....Friday, February 21, 1997
New England Regional.....Friday, February 28, 1997
Johnson & Johnson Mid-Atlantic Regional.....Friday, March 7, 1997
National Championship.....Friday, March 28, 1997

5.10 Before You Come to The Competition

Pit Area

Each team will have a table and power outlet in the pit area. We suggest you bring an extension cord (heavy duty and at least 25') and a power strip to make best use of your power drop. Machines will be delivered to your station.

No personal audio systems will be allowed in the Pit Area. FIRST staff make frequent important announcements which all teams need to hear.

FIRST reserves the right to limit the number of team members in the pit area. If the pit area becomes too crowded for machines and teams to safely and quickly move back and forth to the field, we will request that some team members leave the area. In the event that additional assistance from another team member is necessary, please let FIRST know.

Warm Clothing

If your team attends a Regional, please be sure to bring warm clothing. The weather can be unpredictable in the North and it is often very cold. There may be snow and ice on the ground. It is strongly recommended that you bring warm gloves, boots, hats and jackets.

5.11 Before You Leave The Competition

Return Unused Kit Parts and the Kit Container

Before you leave The Competition for the final time, please return your **unused** kit parts and the kit container to the Pit Registration Area. We must recycle some of these parts and we use the containers from year-to-year. Thanks, in advance, for your help with this.

Take your Machine home

FIRST encourages teams to take their machines back home with them. FIRST robots have appeared in pep rallies, parades, corporate annual meetings and even anti-gang assemblies!

Return the Control System

If you would like to take your machine back for educational, display or recruiting purposes, let us know prior to the last event you will be attending. At that time, you will be asked to provide FIRST with a security deposit of \$1,500 which will cover the lending of a remote control system that can be picked up after The Competition (since RNETs will be confiscated). The control system remains the property of FIRST and the \$1,500 security deposit is to cover possible damage to the control system. Your security deposit will be returned once we receive the control system back. It can be a check or purchase order which will be held until the return of the system. At that time the security deposit will be canceled and returned to you. **The FIRST control system is not for sale.**

6. AWARDS

6.1 Chairman's Award

The Chairman's Award is presented to the team which is judged to have created the best partnership effort between team partners: pre-college school(s), universities and/or businesses. All teams participating in The Competition - 1997 are eligible for this award. The recipient of this award is decided by an independent panel of judges at the National Championship.

While FIRST continues to leave this award without specific criteria, certain themes have developed which seem to best illustrate the partnerships efforts which stand out above others. In 1996, the team efforts continued to progress and develop beyond what we could have predicted so that the judges named finalists. The entries which were among that group consistently showed the impact that this program had on all team members, their families and communities.

Documentation may consist of any combination of the following:

- Video footage in VHS format, 10minute maximum length
- Photos
- Written chronicle
- Electronic document (one file only) on 3.5" disk in one of the following formats:
 - Microsoft Word for Windows 2.0
 - Microsoft Word for Macintosh 5.1
 - ASCII Text with no more than 80 characters per line

The computer used to view the electronic documentation may not have any multimedia capabilities, such as digital audio or motion video, or other applications, such as spreadsheets. Do not embed any sound, video, or links to other applications in the document. Embedded images are acceptable.

This material need not be professionally produced, but should clearly convey the effort made to develop a successful school/university or school/business partnership. The recipient will be announced at the National Championship during the Awards Ceremony on Saturday, April 12, 1997.

ALL DOCUMENTATION MUST BE IN FIRST OFFICES NO LATER THAN 5:00 PM ON FRIDAY, FEBRUARY 28, 1997.

The Chairman's Award will be presented at the Awards Celebration on Saturday evening, April 12, 1997. The team carries home a traveling trophy--a high-tech, custom crafted Dean Kamen Clock, which the *New York Times* called "Art That Ticks." Each finalist carries home one gear from The Clock, symbolizing their team's efforts to build an award winning team.

Chairman's Award Materials: Tips

- Avoid going into great detail on the game itself. Use your valuable video time and written space to tell the judges about your partnership.
- If your team submits a video be sure it is of good visual and audio quality. It does not need to be professional but it is imperative that the judges see and hear your message.

6.2 Founder's Award

Each year FIRST presents this award to honor a company, university or individual that has contributed significantly to the growth of The Competition through year-round efforts. Last year's winner, the City of Manchester, NH, will pass on the trophy clock to the '97 winner at the Awards Celebration in Orlando.

6.3 Judges' Awards

On Saturday evening, April 12, 1997, FIRST will hold an Awards Celebration at the Epcot Arena. At this event, a special judging panel will present the following awards:

- Chairman's Award
- Chairman's Award Finalists (5)
- 1997 National Champion
- Most Creative Design
- Best Offensive Round
- Outstanding Defense
- Best Play of the Day
- Best Team Spirit Display
- Best Sportsmanship
- Lightest Machine in Finals
- Number One Seed
- Most Photogenic
- The Procter & Gamble Creativity Award
- Motorola Quality Award
- Honeywell Leadership in Control Award
- Rookie All-Stars (3)
- Woodie Flowers Award for Teaching Innovation
presented by SMALL PARTS, Inc.

A regional series of judges awards is also planned.

6.4 Autodesk Excellence in Engineering Creativity and Communications Award

This award is determined by a special Autodesk judging panel prior to the event. Information about the Autodesk Animation Competition is located in Appendix E.

6.5 WPI Design Innovation Scholarship

Information about the WPI Design Innovation Scholarship is located in Appendix F.

6.6 Daniel Webster College Scholarship

Details on the Daniel Webster College Scholarship will be forthcoming.

APPENDIX A - COMPLETE LIST OF RULES

- T1. Referees have ultimate authority during The Competition--their rulings are final.
- T2. If a team is disqualified by a referee, their robot is turned off for the remainder of the match, the human player must cease interacting with tubes at the player station, and any points scored during that match will be forfeited.
- T3. If a robot is disabled by a referee, the robot is turned off for the remainder of the match, and any points scored during that match will count. The human player may continue to interact with tubes at the player station.
- T4. A team may not win a match through an advantage gained by breaking a rule, even accidentally. The effect of the infraction on the outcome will be decided by the referees.
- T5. Strategies aimed solely at the destruction, damage, or entanglement of opponents' robots are not in the spirit of The Competition and will not be allowed. Turning over an opponent's robot is not considered damaging and will be allowed, but stabbing, cutting, etc., is illegal. If a breach of this rule occurs the contestant's control system may be disabled by the referees.
- T6. Robot shoving will be allowed and is expected to be quite common; however, if you damage opponents' robots, referees may take action against your team. Possible actions include, but are not limited to: stopping the match to allow the damaged robot to be repaired before resuming play, a complete rematch after repairs have been made, or disqualification of your team and forfeiture of any points scored.
- T7. If a team's robot is damaged to the point that it cannot complete a round on a fair basis, that team may be eligible for a rematch. This decision will be up to the referees.
- T8. If one team intentionally damages another team's robot, it may result in disqualification. However, if the damaged team's robot is considered too flimsy to begin with, the other team may not be disqualified. The ultimate determination will be with the referees.
- T9. Deliberately damaging the playing field, controls, or tubes (using spiked wheels, for example) is strictly illegal and may result in disqualification.
- T10. If a robot damages the playing field, barriers, tubes, or another robot, even inadvertently, and the referees feel that further damage is likely to occur, the referees may decide that corrective measures (such as eliminating a sharp edge) are required to allow the robot to continue competing.
- T11. A robot may not intentionally contaminate the playing field, tubes, goal, or another robot with lubricants.
- T12. After a match, team members are not allowed on the playing field until referees have completed the scoring procedure.

- T13. The barriers in front of the player stations are safety features, not part of the playing field. Robots should not be designed to react against them. Incidental contact with the barriers is acceptable. Pushing a tube against a barrier to allow pickup of the tube is acceptable if the forces applied are not sufficient to damage the barrier or otherwise deform the playing field.
- T14. Robots which become entangled in the barriers or goal will not be freed until after the match has finished, unless the entanglement represents a safety hazard.
- T15. If a robot goes out-of-bounds to the point that it has to apply force to any out-of-bounds surface to rejoin play, its control system will be disabled.
- T16. If one team intentionally moves another robot out-of-bounds, the robot out-of-bounds will be disabled for the remainder of the match.
- T17. Tubes which are knocked out-of-bounds will be placed back into play next to the field border near the exit point without undue delay. Tubes returned to play will not be fed directly to a robot or human player.
- T18. Tubes which are popped will be replaced without undue delay. If a tube pops while being held by a robot, the referees may opt to pause the match and place the replacement tube in the hold of the robot.
- T19. It is not the responsibility of the referees if they damage trapping devices while attempting to retrieve tubes. Please design your robot so that tubes may be retrieved quickly and easily after a match is over.
- T20. No remote communication devices, such as air phones, walkie-talkies, cellular phones, etc., may be used by teams during a match. The wireless communications systems used by FIRST staff have been carefully checked to insure that they do not interfere with the robot control systems.
- T21. During The Competition, teams will be notified of their field positions at least two minutes prior to the start of their match in the staging area. Teams will be allowed a maximum of one minute to set up their robots on the field and a maximum of one minute to remove all robot parts from the playing field following a match. You will have at least 4 minutes before your next scheduled match.
- T22. If a team is not ready to setup their robot on the field, and the two minute notification period is about to expire, and they do not wish to forfeit the match, then they must inform the field coordinator that they are invoking a time-out. Each team may take up to 10 minutes (cumulative) of time-outs during the double-elimination rounds. The duration of a single time-out may not exceed 5 minutes. If a robot is still not ready at the end of the time-out period, the team will forfeit the match.
- T23. During the finals matches (quarter-finals on), each team may take up to 10 minutes (cumulative) of time-outs which can be used to delay the start of a match if their robot is not ready. The duration of a single time-out may

not exceed 5 minutes. Unused time-out time from the double elimination matches is lost.

- T24. **We strongly encourage you to develop and wear team uniforms, including identifying hats and t-shirts that display company and high school team names and/or logos. This will help the audience, announcers, judges and spectators identify you and your robot.**
- P1. Prior to the start of each match, teams will be assigned a color: Red, White, or Blue. This color will be used to determine the placement of the robot, human player, and drivers & coaches around the playing field. Figures 1.1 & 1.2 show the color-based layout of the playing field.
- P2. During setup for each match, robots may be placed in any orientation within the designated starting area, but may not touch the 4x4 boundary.
- P3. During a match, five members per team (two "drivers", two "coaches", and one "player") are allowed in the designated areas next to the field. Operator badges will be supplied by FIRST at each event and must be worn by these team members for field access.
- P4. The two drivers and human player must be students from a pre-college team partner school.
- P5. During a match, the robots may only be operated the drivers and/or by software running in the on-board control system.
- P6. The drivers and coaches must remain at the driver stations during the match, and may not reach over the playing field or player stations.
- P7. Human players must remain at the player stations during a match, and may not reach over the playing field or team operator areas.
- P8. Inside the player station, adjacent to the playing field, is a three foot interaction zone. Although this is part of the player station, players may not apply weight (stand, sit, kneel, etc.) to this portion of the player station during a match. Reaching and/or leaning over the interaction zone, such as to grab or throw tubes, is ok.
- The interaction zone is intended as a safety feature to help prevent potentially dangerous contact between robots and humans. Please exercise caution when reaching into the interaction zone.**
- P9. The player stations are not considered part of the playing field, and are thus off limits to the robots. (*See rule T15.*)
- P10. For safety reasons, no part of a robot may touch the human players. If this occurs due to an intentional act, the team causing the safety hazard will be disqualified. If this occurs by accident, the robot causing the safety hazard will be disabled. The referees will decide whether the violation was intentional or an accident.
- P11. For safety reasons, no robot may launch a projectile of any sort, including tubes, toward the player stations or driver stations, with the one exception

noted below. If this occurs due to an intentional act, the team causing the safety hazard will be disqualified. If this occurs by accident, the robot causing the safety hazard will be disabled. The referees will decide whether the violation was intentional or an accident.

- It is acceptable for a robot to launch tubes, but no other types of projectiles, toward the player station assigned to the same team as the robot.
- P12. During a match, no team member may intentionally touch any robot, except for reasons of personal safety. If this happens, the team will be disqualified.
- P13. During a match, no driver or coach may intentionally touch a tube, except for reasons of personal safety. If this happens, the team will be disqualified.
- P14. A human player may choose not to return tubes to the playing field. However, any tubes which leave the player's station, such as by rolling or being pushed out of the boundaries, will be returned to the playing field near the player's station without undue delay.
- P15. Human players may use only their bodies to interact with the tubes. Special clothing and/or equipment will only be allowed for those who demonstrate a need based on a physical disability.
- P16. Each team will start with 3 tubes in the interaction zone at their player station, and 6 tubes on the playing field. The tubes on the playing field will be arranged in stacks as shown in Figures 1.1 & 1.2.
- P17. Each match will last for two minutes. It will begin when the control system is enabled and end when it is disabled, unless whistled dead by the referees.
- P18. Final scoring will begin when all tubes come to rest or upon a referees' decision. Team members will not be allowed onto the field until all scoring is complete.
- P19. Final Scoring - Phase I
- Each tube on any peg is worth 1 point. A tube will count as "on a peg" if any part of the peg, including the end flange, passes through the hole at the center of the peg. See Figure 1.3 for an example.
 - Each tube on or above the center of the top of the goal is worth 1 point. A tube will be considered "on or above the center of the top of the goal" if the rotational axis of the goal passes through the open middle of the tube, and the tube is above the bottom of the apex bracket.
- P20. Final Scoring - Phase II
- Each tube on or above the center of the top of the goal doubles the score.

- Each vertical row of tubes doubles the score. A "vertical row" occurs when a team has at least one tube on every peg on one corner of the goal. Separate vertical rows may be achieved on separate corners. Alternately, if a team has at least two or three tubes on every peg on one corner of the goal, they will achieve two or three vertical rows, respectively.
- P21. All decisions regarding scoring will be made by the referees.
- P22. The winner of a match is the team with the highest score.
- P23. In the event of a tied score the following tie breaking conditions will be applied in the order below until the tie is won:
- The team with the highest tube in a scoring position wins the tie. To be considered highest, it must be the highest tube on or above the center of the top of the goal. If no tubes are in that position, it is the tube on the highest level of pegs. Subtle variations in height for a given level of pegs will not be considered.
 - The team with the most tubes in scoring position in the highest level of the goal. This starts at the top level of pegs and progresses to the lowest level of pegs until the tie is broken.
 - The team with the most tubes (of any color) in their player station.
 - The team with the highest tube not contacting the floor.
 - The team with the tube closest to the center of the base of the goal.
- P24. Robots may not intentionally move or prevent the free rotation of the goal by placing objects underneath the triangular base of the goal. However, it is acceptable for a robot to move or block the goal via other means.
- F1. All field dimensions listed in Section 2 are ± 1 " non-cumulative.
- F2. Tubes will be inflated to size, not pressure. All tube dimensions listed in Section 2 are ± 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.
- S1. Safety first. Due to the nature of the event in which electrical equipment, springs and tools are used, safety will not be compromised.
- S2. Safety glasses must be worn by all team members in the driver stations and player stations during matches, and in the pit area when working on robots. They are also highly recommended if your neighbor(s) in the pit are working on their robot.
- S3. Any robot which causes a safety hazard during a match will be disabled.

- S4. If at any time the referees determine that a robot is likely to cause safety hazards in future matches, the robot must be modified to the referees' satisfaction or it will not be allowed to compete.
- S5. No energy stored in a rubber band may be used to launch any projectile. This does not apply to the latex tubing provided in the Kit. However, the inner tubes are the only projectiles the latex tubing may be used to launch.
- S6. Projectiles must have a frontal area greater than or equal to 10 square inches and be shaped to avoid eye injury.
- S7. **Do not tamper with the power supply, batteries, chargers, speed controllers, joysticks, or any other control system component except as noted in the control system rules.** Tampering could result in failure or malfunction of the control system, and lead to a safety hazard or damage to the robot.
- S8. Remove batteries from the robot while making adjustments to your robot. Due to the strength of the motors in the Kit, it is important to keep fingers away from the gears while your robot is connected to a power supply.
- S9. The batteries may deliver more than 100 Amperes. Do not let the wires come into contact with any metal surfaces. Route wires carefully to avoid damage and short circuits, which may cause serious burns, fire, and/or permanent destruction of the batteries.
- M1. The energy used by the robots in The Competition must come solely from:
- electrical energy derived from the onboard battery packs
 - storage achieved by deformation of springs or the latex tubing provided in the Kit
 - compressed air (or vacuum) stored in the air accumulator
 - a change in the altitude of the device's center of gravity.
 - storage achieved by deformation of springs purchased from Small Parts, Inc. (SPI) Latex tubing from SPI may not be used as a spring.
- M2. Robots must sit, unconstrained, inside a 36" square footprint and be no more than 48" high at the start of a match. The weight of the robot, including batteries and control system, may not exceed 120.0 pounds.

Size \leq 36" long x 36" wide x 48" high; Weight \leq 120.0 pounds

Keep in mind that these are maximum dimensions. It is recommended that robots be designed for slightly smaller dimensions and weights in order to allow a degree of tolerance for oversized/overweight mechanisms and differences in measurement between the team and the official inspection. Many teams have discovered the hard way that reducing size and weight while preserving functionality is no easy task after the robot has been constructed.

Also, many shippers such as UPS will not ship packages as large as a full robot. Many teams have found it helpful to make ease of disassembly and reassembly one of the design goals.

- M3. All robots will be weighed and measured during the practice day at each Competition event and may be re-inspected anytime during an event. If modifications to your robot are necessary to meet the above requirements, they must be completed before seeding matches begin.
- M4. **Teams are expected to design and build robots to withstand vigorous amounts of interaction with other robots.** (See also rules T6-8.)
- M5. Until the controls are enabled at the beginning of each match, robots and any appendages, extensions or projectiles must remain unconstrained within the 36"x36"x48" starting size. Once a match begins, robots may extend beyond that limit under their own power.
- M6. Robots must be designed to operate by reacting against the surface of the playing field, the innermost face of the 4x4 field border, the goal, the tubes, the other robots, and the air. (See Section 2.2 for Field Diagrams.)
- M7. **Robots must display their team company and school names and/or logos. The judges, referees, and announcers must be able to easily identify them by name. In addition, team numbers must be displayed on at least two opposite sides (180 degrees apart) of the robot. Numbers should be at least 3 inches high and clearly visible from a distance of not less than 50 feet.**
- M8. During a match, robots may be manipulated only by the normal operation of the wireless programmable control system.
- M9. Gaining traction by using adhesives or by damaging the surface of the playing field or the tubes is not allowed. (See also Rules T9-10.)
- M10. During any Competition event, any mechanism which will alter the operation of the robot may not be added or removed after the first match of the seeding rounds unless mandated by the judges for rule compliance reasons. However, mechanisms existing on the robot may be reconfigured between matches. Also, the control system may be reprogrammed as described in the control system rules between matches.
- M11. No substitute robots are permitted; however, functionally identical replacement parts are allowed.
- M12. Only items listed under the PNEUMATICS section of the Kit list may be used to store, generate, or transmit compressed air or vacuum, with the following exceptions:
- Suction cups may be fabricated from legal Kit parts, as defined in rule K1 below.
 - Pneumatic fittings from Small Parts, Inc. may be used.
- Custom-made pneumatic fittings, air cylinders, pumps, air accumulators, and so forth are not allowed, even if they are created from components included in the kits. Also, valves, syringes, tubing, and so forth from SPI or outside sources may not be used for pneumatics.**

- C1. The control system is provided to allow wireless control of the robots. The Transmitter box, Receiver box, servos, speed controllers, RNETs, antennas, batteries, battery chargers, power supply and joysticks may not be tampered with, modified, adjusted or marked in any way, with the following exceptions:
- the dip switches on the Transmitter and Receiver may be set for custom operation.
 - the user programmable code in the Receiver may be customized.
 - the speed controllers may be calibrated as described in the Tekin REBEL Owner's Manual.
 - The connectors on the ends of the 12 AWG wires on the Tekin REBEL Speed Controllers must be removed. Do not remove the connector on the 24 AWG, 3 wire PWM cable.

Tampering includes drilling, cutting, machining, gluing, rewiring, etc. All items listed in Rule C1 must be mounted without alteration. Do not write on or otherwise mark control system components.

- C2. Do not attach tape, stick-on hook & loop fasteners, glue, or other adhesives to control system components. We will re-use many of these components, and these items can be difficult to remove. Instead, use clamps, straps, or existing holes for mounting. The only exceptions to this rule are:
- Tape may be used to secure the position of the trimmers on the Joysticks in order to prevent accidental changes in calibration.
 - Stick-on hook & loop fasteners may be used to attach the speed controllers.

For mounting control system components, use mechanical fasteners, such as cable ties, straps, or brackets. Do not use tape, stick-on hook & loop fasteners, glue, or other adhesives.

- C3. The black/almond project box is intended to serve as a mounting point for the rocker switches and potentiometers and to enclose the associated wiring. You may modify the project box in any manner to accommodate your needs. It may not be used on the vehicle.
- C4. **Only the wire supplied in the Kit may be used to conduct electricity.** Additional wire is not permitted.
- C5. Electrical devices may only be wired as described in Section 4. Some important facts are listed here in Section 3.3.
- C6. The 12 gauge wire must be used for connections from the batteries to the speed controllers, from the speed controllers to any motors, and from the batteries to the Receiver box.
- C7. The 16 gauge jacketed cable must be used for any device connected to a relay output.

- C8. The 22 and 24 gauge wire may only be used for connecting sensors (limit switches, reed switches, rocker switches, air pressure switches, potentiometers) to inputs or for extending the PWM cables.
- C9. **Relay outputs may not power more than one device per output.** (The double-solenoid valve is considered one device, because the diodes may be used to route power to only one solenoid at a time.)
- C10. **Only the Receiver, speed controllers, and muffin fan may be connected directly to the battery outputs.**
- C11. The battery contacts inside the Skil drill shells must be used to draw power from the batteries. If the handle part of a drill shell is cut away from the main body, the wire side of the contacts must be insulated with heat shrink tubing or electrical tape to prevent short circuits.

It is strongly recommended that the contacts be used in conjunction with the handle of the drill shell and the battery clip at the end, as they are designed to hold the battery snugly yet allow for easy changeover of batteries.

- C12. The Skil drill motors may be powered only by the Tekin speed controllers.
Do not connect the drill motors to the relay outputs.
- C13. No more than one motor may be powered by each Tekin speed controller.
- C14. The Delco seat motors and Delphi tape drives may be powered by the Tekin speed controllers or the relay outputs.
- C15. Two 0.1 μ F capacitors, included with each speed controller, must be installed on each motor connected to a speed controller, as described in the Tekin REBEL Owner's Manual.
- C16. One 20A circuit breaker (provided in the Kit) must be installed in series with each drill motor. The circuit breaker must be accessible for inspection at each Competition event.
- C17. One 30A circuit breaker (provided in the Kit) must be installed in series with the positive terminal on each battery contact, such that all battery output flows through this breaker before being distributed to the Receiver, speed controllers, fan, or other battery. The circuit breaker must be accessible for inspection at each Competition event.
- C18. Only the 9 volt power supply included with the Kit should be used to power the Transmitter box. Use of an alternate power supply could damage the Transmitter box or RNet and is therefore prohibited.
- C19. Do not connect 12 volt power or ground wires to the relay outputs. Doing so will cause a short circuit and may damage the Receiver.
- C20. Do not connect power or other outputs to the sensor port on the Receiver. Power for sensors is available from the sensor port.
- C21. Any sensors used on the robot must be connected directly to the sensor port on the Receiver, and may not be wired in series with the motors, pumps, or valves.

- C22. RNETs may not be used in the Pit Area at any Competition event. A tether must be used for bench testing.
- C23. If the control system is damaged due to improper wiring or misuse, FIRST will charge for repair or replacement of the affected items. (*See Section 3.7 for details.*)
- C24. Robots must only be operated with both batteries present and wired in parallel.
- Operating a robot with only one battery can permanently destroy the battery. Don't do it!**
- C25. All wires distributing power with a constant polarity (i.e. not a relay or speed controller output) must be color coded as follows:
- Use Red 12 AWG or White 16 AWG wire for +12Vdc.
 - Use Black 12 or 16 AWG wire for GND.
- C26. **Teams are responsible for any software bugs introduced into the Receiver's control program when using a custom program. If a software bug negatively impacts the performance of a robot during a competition match, it will not be grounds for a rematch or even a pause in the match.**
- K1. Each robot must be constructed exclusively from materials provided in the Kit of Parts ("the Kit") supplied by FIRST, with the following additions and exceptions:
- 2' x 4' x 1" ROHACELL™ P170 structural foam shipped to each team from FIRST.
 - Material available from outside sources, as explained below.
 - Material satisfying the unlimited quantity criteria, as explained below.
 - The Kit container, part packaging, and any documentation in the Kit container may not be used to build the device.
 - Adhesive tape may not be used except as an electrical insulator.
 - Lubricants may not be used except to reduce friction within your own robot.

Outside Sources - Small Parts, Inc. Catalog

Each team receives an account with a \$425 credit balance which will be debited for the actual purchases you make. You may go beyond this dollar limitation for prototyping or to purchase spare parts, but your team is responsible for paying the balance on the account. See Appendix D for more details on accounting and ordering.

Up to \$425 worth of materials purchased from Small Parts, Inc. may appear on your final robot. Items which appear below in the unlimited quantity category do not count against the \$425 limit when used as described.

It has been brought to our attention that the actual prices of components purchased from Small Parts, Inc. may not match the prices printed in the catalog. Please use the catalog prices when calculating the cost of robot components from SPI for compliance with the \$425 limit.

If you use only a portion of what you buy from Small Parts, you may prorate the dollar amount used to the smallest quantity listed for purchase in the catalog. For example, if you buy 5' of rod which could have been purchased by the foot, but end up using only 6", you may calculate the amount used as the purchase price for one foot.

Outside Sources - Additional Hardware List

Materials on the Additional Hardware List may be obtained from any supplier, but in limited quantity. A specific list of materials and maximum quantities/dimensions is provided in Section 3.6. Cost is not considered.

If an item on the Additional Hardware List is available from Small Parts, Inc., then it may be purchased from SPI without being counted against the \$425 limit on materials purchased from SPI. However, any amount of the item purchased from SPI above and beyond the quantity allowed in the Additional Hardware List will count against the \$425 limit. Obviously, any item purchased from SPI will count against your credit limit, regardless of whether or not it is listed in the Additional Hardware List.

Unlimited Quantity Items

The following items may be used in unlimited quantity subject to the following criteria. (*See rule K9*)

- Fasteners, washers and adhesives -- if used for joining and fastening purposes only.
- Fasteners -- if used as pins in a linkage or as hinge pins.
- Crimp-on spade connectors -- if used to conduct electricity, used with the proper gauge wire, crimped properly, and fully insulated, such as the Thomas & Betts units provided in the kits.
- Adhesive tape -- if used as an electrical insulator.
- Lubricants -- if used to reduce friction within your own device.
- Teflon tape -- if used around the threads of pneumatic fittings to prevent leaks.
- Shrink wrap tubing of any diameter -- if used for electrical insulation.
- Pipe fittings (tees, reducers, elbows, and angles) -- if used to join sections of pipe
- Endcaps -- if used to cap pipe.

- K2. Many of the materials in the Kit are raw materials. They are intended to be used for manufacturing structural or mechanical parts for your robot.
- K3. There is no restriction on the total quantity of sprockets/pulleys and chain/belt that can appear on your robot. However, there is a restriction on the amount which can be obtained from outside sources other than SPI. (*See the Additional Hardware List and Rule K4 .*) Any quantity above the amount listed on the Additional Hardware List must therefore be purchased from SPI, or manufactured from raw materials available from either the Kit, the Additional Hardware List, or SPI.
- K4. As denoted in the Additional Hardware List, each team may purchase from an outside source sprockets (not gears) and/or pulleys and additional chain and/or belt, with the following conditions:
- On your final robot, you may use no more than a combined total of 4 sprockets and/or pulleys from outside sources other than SPI.
 - On your final robot, you may use no more than a combined total of 10' of chain and/or belt from outside sources other than SPI. There are no restrictions regarding pitch or width of chain and/or belt. However, you may not purchase a wide belt, slice it lengthwise, and use more than a 10' length in the final robot.
 - These components must be "commercially available," strictly *off-the-shelf* only. No custom or special orders.
 - A double-sprocket or double-pulley assembly counts as two sprockets or pulleys, respectively.
- K5. Gears (not sprockets) must be purchased from SPI, or manufactured from raw materials available from either the Kit, the Additional Hardware List, or SPI.
- K6. The dimensions for sheets and boards listed in the Additional Hardware List represent the maximum length and maximum width which may be purchased, not the total area. The thickness represents a fixed quantity, not a maximum.
- K7. The dimensions for rods and shafts listed in the Additional Hardware List represent the maximum length that may be purchased for a given diameter of rod/shaft.
- K8. You may purchase only one of the three types of 1/2" or thicker wood listed in the Additional Hardware List; Plywood, Chipboard, or Particleboard.
- K9. Items listed as unlimited quantity items, when used without satisfying the criteria for unlimited use, must be purchased from SPI against the \$425 limit or manufactured from raw materials available in the Kit, from the Additional Hardware List, or from SPI.
- K10. Net material is allowed; however, if it is used to entangle opponents' robots, the referees may disallow it.

- K11. For safety reasons, you may not fabricate your own springs. However, it is acceptable to elastically deform and relax materials not designated as springs as long as the rate at which the energy is released does not exceed the rate at which the energy was stored. This is intended to allow reasonable use of the elastic properties of materials without creating unsafe conditions caused by sudden the release of stored energy in materials not designed to act as springs. Materials which are designated as springs include: All items listed in the Springs section of the Kit List, and compression, tension, torsion, constant force, and washer springs available from Small Parts, Inc. Latex tubing from SPI is not considered a spring.
- K12. A limited number of replacement parts will be made available by FIRST upon justified request. Otherwise, lost or damaged Kit materials may be replaced only with identical components of the same material, dimensions and treatment at the team's cost.
- K13. Materials in the Kit may not be changed chemically with the following exceptions:
- rope ends may be singed to prevent loose ends or to bind them together
 - resin and hardener may be mixed to produce epoxy.
 - metal may be heat treated in order to improve surface hardness
 - metal may be anodized to improve appearance
- Completely melting and recasting a material is considered a chemical change. However, merely heating a material, such as a sheet of polycarbonate or ROHACELL™, in order to bend it into a new shape without cracking is not considered a chemical change.
- K14. The mailing tubes provided in the Kit are considered packaging material and may not be used during any Competition event.
- K15. All unused parts and materials must be returned to FIRST for proper recycling.
- K16. The control system is the property of FIRST and certain components must be returned at the conclusion of The Competition. The control system is not for sale. Teams wishing to borrow the control system for a limited amount of time after The Competition may do so by following the procedures outlined in Section 5.5. For teams that wish to operate their robots after this period, FIRST can provide basic instructions on how to refit the robots to use off-the-shelf remote control systems.

APPENDIX C - SUPPLIER CONTACT INFO

<p>Ms. Christine Gondek Air Logic 5102 Douglas Avenue Racine WI 53402-2097 Phone: 800-558-5950 Fax: 414-639-5996</p>	<p>Mr. Jim Aaron Product Manager - Constant Force Springs Associated Spring Raymond P.O. Box 586 1705 Indianwood Circle Maumee OH 43537-0586 Phone: 1-800-458-0867 Fax: 419-891-9879</p>
<p>Ms. Kaki Leyens Autodesk, Inc. Education Department 111 McInnis Parkway San Rafael CA 94903 Phone: 415-507-6418 Fax: 415-507-6113</p>	<p>Mr. Stewart Schuster Brevan Electronics 6 Continental Blvd. Merrimack NH 03054 Phone: 603-429-1900 Fax: 603-429-1001</p>
<p>Ms. Alison Evans Director of Marketing Communications CH Products 970 Park Center Drive Vista CA 92083 Phone: 619-598-2518 Fax: 619-598-2524</p>	<p>Mr. Jim Klemko Delco Electronics Corporation MS 123 700 E. Firmin Street Kokomo IN 46905-9005 Phone: 317-451-3334 Fax: 317-451-3456</p>
<p>Mr. Joseph Johnson Delphi Interior and Lighting Systems 1401 Crooks Road Troy MI 48083-7115 Phone: 810-696-5672 Fax: 810-696-5150</p>	<p>Mr. Richard Wallace Emerson Electric Motor Company 8100 W. Florissant Station 8365/MTC St. Louis, MO 63136 Phone: 314-595-8356 Fax: 314-595-8022</p>
<p>Mr. Mike Mayberry Hitec RCD, Inc. Suite C 10729 Wheatlands Avenue Santee CA 92071 Phone: 800-669-4672 Fax: 619-449-1002</p>	<p>Lowell Medical Instrument Company, Inc. 55 Church Street, Central Plaza Lowell MA 01852 Phone: 508-459-6101 Fax: 508-454-8631</p>

<p>Mr. Dave Gattuso McCord Winn /Subsidiary of Textron, Inc. 645 Harvey Street Manchester NH 03103 Phone: 603-628-3740</p>	<p>Mr. Bruce Crystal Director of Sales McMaster-Carr Supply Co. 473 Ridge Rd., POB 317 Dayton NJ 08810 Phone: 908-329-6666 Fax: 908-329-3772</p>
<p>Mr. Curt Olsen Director of Marketing and Sales Microsemi Corporation - Scottsdale P.O. Box 1390 8700 East Thomas Road Scottsdale AZ 85252 Phone: 602-941-6300</p>	<p>Mr. Mark Madsen Marketing Manager Numatics, Inc. 1450 North Milford Road Highland MI 48357 Phone: 810-887-4111x211 Fax: 810-887-4768</p>
<p>Parallax, Inc. 3805 Atherton Road Suite 102 Rocklin, CA 95677 Phone: 916-624-8333 Fax: 916-624-8003</p>	<p>Mr. Karl Grubb Marketing Communications Planner Potter & Brumfield (A Siemens Company) 200 South Richland Creek Drive Princeton IN 47671-0001 Phone: 812-386-2316 Fax: 812-386-2072</p>
<p>Mr. Jeorg Hübl General Manager Richmond Aircraft Products 13503 Pumice Street Norwalk CA 90650 Phone: 310-404-2440 Fax: 310-404-9011</p>	<p>Serco, Inc. 612 Commercial Ave Covine CA 91723 Phone: 818-331-0517 Fax: 818-331-8584</p>
<p>Mr. Parrey Cremeans Skyway Recreation Products 4451 Caterpillar Road Redding CA 96003 Phone: 800-332-3357 Fax: 916-243-5104</p>	<p>Mr. James Edgar Small Parts, Inc. 13980 NW 58th Court Miami Lakes FL 33014 Phone: 305-820-9371 Fax: 800-423-9009</p>
<p>Mr. Robert Kuczynski Snap-Action, Inc. 1260 Route 22 West Mountainside NJ 07092 Phone: 908-654-4380 Fax: 908-654-7322</p>	<p>Mr. Grant McStay Stanley Hardware Division P.O. Box 1308 [H] New Britain CT 06050 Phone: 203-225-5111x55302 Fax: 203-827-5783</p>

<p>Mr. Kevin Orton President Tekin Electronics, Inc. 940 Calle Negocio San Clemente CA 92673-6201 Phone: 714-498-9518 Fax: 714-498-6339</p>	<p>Mr. Milanne Dielsi Manager of Marketing Communications The Torrington Company 59 Field Street Torrington CT 06790 Phone: 800-626-2936 Fax: 860-496-3625</p>
<p>Mr. David Byers Plant Manager Thomas & Betts 16228 Flight Path Drive Brooksville, FL 34609</p>	<p>Mr. Al Nutter Sales Representative Totalmed 589 Elm Street Manchester, NH 03101 Phone: 603-624-0091 x452 Fax: 603-626-3440</p>
<p>Mr. Moe Cournoyer Customer Service Manager UVEX Safety, Inc. 10 Thurber Blvd Smithfield RI 02917 Phone: 401-232-1200 or 800-343-3411</p>	<p>Value Plastics, Inc. 3350 Eastbrook Drive Fort Collins CO 80525 Phone: 970-223-8306 Fax: 303-223-0953</p>

**APPENDIX D - ORDERING FROM SMALL
PARTS**



SMALL PARTS INC.

e-mail: first@smallparts.com
Web: <http://www.smallparts.com/first>
FAX: 1-800-423-9009
phone: 1-800-220-4242

ORDERING GUIDELINES

FIRST - The Competition 1997

SMALL PARTS INC., an Official Sponsor of The Competition 1997, contributes \$425 of parts from the **SMALL PARTS INC.** catalog to each participating team for use in robot construction. You may purchase additional parts for prototype development, but by the **OFFICIAL RULES** the final machine may not contain more than \$425 of parts. To order parts for your prototypes or for your final machine, please follow these guidelines:

Register *FIRST*

You may register by FAX or e-mail. Once registered, a team may submit orders to **SMALL PARTS INC.** at any time during The Competition.

By FAX: Fill out the Registration Form (next page) and send it to 1-800-423-9009

By e-mail: Go to <http://www.smallparts.com/first> and follow the instructions.

To Place an Order

You must register before ordering. Then you may order by:

FAX: Copy the FAX Order Form (follows the Registration Form), fill it out and FAX to **1-800-423-9009**.

INTERNET: Link to the order form at <http://www.smallparts.com/first>. If your web order requires more than 9 separate line items you will need additional forms. Be sure to indicate in "Notes" that an additional form(s) was used in the order, to facilitate retrieval.

PHONE: Call **1-800-220-4242** or **305-557-8222** and give your order to an order entry agent.

Shipping and Billing Information

Orders must be placed before 12:00 noon in your time zone for same-day shipment.

Orders placed against the \$425 allotment ship **BLUE LABEL - FREE** (2-day delivery).

Orders requiring Overnight or Saturday delivery carry an additional charge.

Orders outside the \$425 allotment are charged the standard shipment fee for Blue Label, \$5.00.

Orders over \$200 ship **BLUE LABEL-FREE**.

Please Note:

If a part is temporarily out-of-stock SMALL PARTS, INC. will advise you immediately by e-mail, fax or phone when it may become available. You may then change the size or part ordered.

Returns must be made within 30 days of receipt and in unopened packages. Please call Mirta Dorta at 305-557-7955 to obtain an RMA number. Be sure to have your packing slip(s) ready when you call, since you must provide the invoice number(s) for the material being returned. Some material may be subject to a 15% restocking fee.



SMALL PARTS INC.

e-mail: first@smallparts.com
Web: <http://www.smallparts.com/first>
FAX: 1-800-423-9009
phone: 1-800-220-4242

REGISTRATION FORM

FIRST - The Competition 1997

Date: _____	Team No.: _____
Team Name: _____	

Contact Person:

Name: _____ Title: _____

Address: _____

City: _____ State: _____ ZIP: _____

Phone: _____ Fax: _____ e-mail: _____

24-hour emergency phone number for problem resolution: _____

Other team members who can order:

Name: _____ Affiliation: _____

For charges beyond the \$425 allotment send invoices to:

Name: _____ Title: _____

Address: _____

City: _____ State: _____ ZIP: _____

Phone: _____ Fax: _____ e-mail: _____

Use Purchase Order No. _____

CREDIT CARD INFORMATION AMEX VISA MASTERCARD Expiration Date: _____

Card No. _____ Cardholder Name: _____

Billing Address: _____

City: _____ State: _____ ZIP: _____

Send packages to:*

Name: _____ Title: _____

Address: _____

City: _____ State: _____ ZIP: _____

Phone: _____ Fax: _____ e-mail: _____

FEDEX Account No. (if applicable) _____

* All packages are shipped to this address unless an alternate is given with the order.

**APPENDIX E - AUTODESK ANIMATION
COMPETITION**



AUTODESK JUDGES AWARD

ENTRY SPECIFICATIONS AND GUIDELINES

For Excellence in Engineering Creativity and Communication

Competition Objective

To clearly and creatively present design solutions for the Competition challenge through computer modeling and animation using industry standard software.

Entry Requirements

The Competition is open to all teams participating in FIRST—THE COMPETITION 1997. The Competition period for this award category is from January 11, 1997 to March 7, 1997 (contact FIRST for other Competition deadlines).

All Entries MUST include not more than 30 seconds (maximum) of animation created using Autodesk® software or Autodesk® Registered Developer products and a hard copy of the storyboard outline for the animation. Limit one (1) submitted Entry per team. Each Entry MUST include a properly completed Competition Entry Form representing each individual contributor (collectively, the “Entrant”). The Entry Form MUST be accompanied by a signed Autodesk® Archive Consent and Release Authorization (AC&R) agreement for the animation entered.

The AC&R form grants to Autodesk, its subsidiaries, associated companies, successor, assigns, agents, and employees the right to use the drawing’s, image’s or animation’s computer code, support files, documents, or other electronic media files (collectively, the “Files”) listed on the AC&R form.

If Entrant’s corporate or college/university sponsor or school has any rights or claims to the images or animation in an Entry, the Entry Form and the AC&R agreement MUST also be signed by an officer of such employer or parent company or school; otherwise, the Entry will be disqualified. Entrant and, where applicable, Entrant’s sponsor and school represent and warrant that the image and animation in each Entry is owned by the Entrant and/or school and/or sponsor free and clear of any liens or claims of any third party; that they have a legal right to grant the permission given in the Entry Form; and that they indemnify and hold harmless Autodesk, its subsidiaries, associated companies, successors, assigns, agents, and employers against liability should any third party claim that the use of the imagery, animation, or sounds by the aforementioned violates any right of such third party.

Entry MUST NOT include any proprietary information, logos, or trademarks.

Responsibility

Autodesk is not responsible for Entries not delivered to Autodesk’s San Rafael, CA, office by the DEADLINE of 5:00 PM on March 7, 1997 (See “Entry Deadline”) nor for any lost, late, misdirected, illegible, incomplete, or damaged Entries.

Prizes and Prize Rules

One (1) FIRST—THE COMPETITION 1997 Judges Award trophy will be presented to the team whose Entry best represents the objectives of this competition category. In addition to the trophy, a limited number of student contributors on the winning team *may* receive a choice of 3D Studio[®] Release 4 or 3D Studio[™] MAX from Kinetix[™], a division of Autodesk, Inc.

Autodesk reserves the right to substitute, at its sole discretion, another prize of equal or greater value for any prize described herein. No part of any prize is transferable. No substitutions of prizes is permitted except as expressly provided above.

The name of the winning team will be announced during the FIRST—THE COMPETITION 1997 National Championship Awards Ceremony being held at Epcot on April 12, 1997. Software awards will be shipped directly to individual student contributors following the Competition.

Judging

Entries will be judged using preset criteria as defined below. Judging will be conducted by employees or consultants of Autodesk, its subsidiaries, or associated companies and organizations. The judges' decisions are final. Judges are not required to award prizes by default.

Entries may incorporate the robot design, the robot's functionality, how the Competition is run, or any other aspect of FIRST—THE COMPETITION. The approach taken will be determined by the Entrant.

Judges will evaluate and score each Entry based on the following:

Creativity/Innovation (50 pts)

An overall measurement of the distinctiveness of the entire piece. The degree to which the use of the technology, storyboard, composition, realism, and aesthetics demonstrate a striving toward a standard of excellence, and the degree to which the final animation is different from other Entries. Quality measured in terms of that "edge" that separates the winning Entry from all others submitted.

Storyboard (15 pts)

A quality measured in terms of effective planning, organization of content, and in terms of what the audience understands from the final animation.

Composition (15 pts)

A quality measured in relation to the storyboard in terms of how well the objectives are implemented and of how the final animation is brought together from storyboard to design, revision through thoughtful editing, and final presentation (see Entry Specifications).

Realism (10 pts)

The degree to which the animation realistically and accurately portrays something about the robot design and functionality, how the Competition is run, or any other aspect of FIRST—The Competition.

Aesthetics (10 pts)

A quality measured in more subjective terms and in relationship to effective use of color, lighting, cameras, motion, sound effects, humor, etc.

Entry Deadline: 5:00 PM, March 7, 1997

All Entries (regardless of preferred shipping method) MUST be received at Autodesk, Inc. not later than 5:00 PM on March 7, 1997. Entries will not be accepted for judging after the deadline.

Ship Entries to Autodesk, Inc., Marketing Support Team—Image Archives, 111 McInnis Parkway, San Rafael, CA 94903, Attn.: Autodesk Judges Award.

Entry Specifications

- MUST submit a hard copy of the storyboard in 8½ -by- 11-inch format and not more than three (3) pictures per page and a total of six (6) pages.
- MUST include not more than 30-seconds (maximum) of animation. Credits are acceptable but will not be included in judging Entries or in the 30-seconds of animation.
- Animation MUST be submitted as videotape in one of the following tape formats: BETACAM SP; ¾ inch; SVHS, Hi-8; or VHS tape in NTSC format.
- Animation MUST NOT include the use of any proprietary information, soundtracks, logos, or trademarks including the official FIRST and/or Autodesk logos.
- Animation MUST be created using Autodesk or Autodesk Registered Developer software products.
- Entry MUST be clearly labeled with the title of the animation submitted, the corporate sponsor, the school, and the name, daytime phone, fax number, and e-mail address of your team's primary contact.
- Entry MUST be accompanied by a completed Competition Entry Form including an appropriately signed Autodesk Archive Consent and Release Authorization (AC&R) Form.**

Note: Entries will remain the property of Autodesk, Inc. No hard copies, digital files, videocassettes, or computer disks will be returned.

Direct all Entries to the following address: Autodesk, Inc.
Marketing Support Team—Image Archives
111 McInnis Parkway
San Rafael, CA 94903
Attn.: FIRST Judges Award

It is *requested*, but not required, that the Entry be accompanied by the source model(s) in DWG, 3DS, and/or PRJ file format, plus ALL texture maps necessary to re-render the model.

If the Entrant decides to accompany the Entry with the source model(s), all copyrighted geometry, textures, and IPAS, POCO or ADS applications that are required to reproduce an image or animation should be omitted from the Entry if Entrant does not have the necessary rights to them or submitting them violates copyright agreements. The Entrant should, however, list all missing elements, describe where they are required in the image or animation and include information about where the elements can be obtained.

If submitted in "compressed" format, the data MUST be retrievable using PKUNZIP®.

If not submitted on standard disk(s), the requested data should be submitted on one of the following preferred media:

- Colorado tape (120 or 250)
- Syquest (44 or 88)
- Bernoulli disk (20 or 90)
- Sun® Unix® TAR tape
- CD ROM

If you have questions regarding these Entry requirements, please contact Kaki Leyens at 415-507-6418 or via e-mail at kaki.leyens@autodesk.com or Laura London at 415-507-6411 or laura.london@autodesk.com.

Autodesk, the Autodesk logo, AutoCAD, and 3D Studio are registered trademarks, and Design Your World and 3D Studio MAX are trademarks, of Autodesk, Inc., in the USA and/or other countries. UNIX is a registered trademark licensed exclusively through X/Open Co. Ltd. All other brand names, product names, or trademarks belong to their respective holders.

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AUTODESK JUDGES AWARD COMPETITION ENTRY FORM

Information provided on this Entry Form will be used in preparation of awards. Please record information as you wish it to appear on all documentation. Please read the Entry Requirements and Specifications carefully before completing this Entry Form.

Entry Deadline: No later than 5:00 PM, March 7, 1997 (regardless of shipping method)

Ship Entries to: Autodesk, Inc.
Marketing Support Team—Image Archives
111 McInnis Parkway
San Rafael, CA 94903
Attn.: Autodesk Judges Award

Entrant information

FIRST Team Number: _____ Entry Title: _____

Team Lead(s): _____

Corporate Sponsor(s): _____

School Name(s): _____

Primary Contact (school): _____

Address: _____

City, State, ZIP Code: _____

Daytime telephone: _____ Fax: _____ E-mail: _____

Individual student contributor(s) awards, if any, should be awarded to the following (limit 5 per team):

Name	Current Address	City, State, ZIP Code	Telephone
1. _____	_____	_____	_____
2. _____	_____	_____	_____
3. _____	_____	_____	_____
4. _____	_____	_____	_____
5. _____	_____	_____	_____

If more than 5 students contributed to this Entry, please have your team select up to 5 potential student contributor award recipients to be listed here. For the purpose of accurately documenting all student contributors, please list additional individual contributors and attach to this Entry Form.

Briefly describe how you used Autodesk and/or other software products in your Competition Entry.

The Autodesk Archive Consent and Release Authorization agreement on the back of this form MUST be completed and included with your Entry.



ARCHIVE CONSENT AND RELEASE AUTHORIZATION

Dear Contributor,

We appreciate your interest in submitting material to Autodesk, Inc. The following allows us to legally use your work.

- By signing and returning this consent form, I and/or if applicable my employer, school, or sponsor... I grant a nonexclusive, irrevocable, perpetual, worldwide license to Autodesk, Inc. to use the images and other material contained in the "Material" in any manner it deems appropriate. Autodesk may change, reproduce, distribute, and sublicense the Material to its subsidiaries, affiliates, customers and to third parties granting them the same rights which Autodesk has received. Autodesk will try to include the credit line shown below when the Material is used and will also try to require others to whom it grants sublicense to do the same.

I represent and warrant that the Material is owned by me free and clear of any liens or claims of any third party; that I have a legal right to grant the permission given in the Entry Form and in this Agreement. I indemnify and hold Autodesk, its subsidiaries, associated companies, successors, assigns, agents, and employees harmless against liability should any third party claim that the use of the Material or any part thereof by Autodesk violates any right of such third party.

I am over 18 years old and own the copyright to the material in these files, or have the right to grant this consent on behalf of the owner, or know that the material in these files is in the public domain. This consent does not conflict with any others I have granted or any other rights to the files.

EMPLOYER, SPONSOR OR SCHOOL (where applicable)

Company Name:
Address:
City, State, ZIP:
Country:
Email:

By: (authorized signatory)
Name:
Title:
Date:
Telephone #: ()
Fax #: ()

Please provide & initial a DOS listing if you have more than 3 files that you are submitting to Autodesk, Inc.

Table with 4 columns: Filename, Description, Software Used, Initial. Example row: CAPECOD.TGA, Cape Code vacation home, AutoCAD, 3D Studio Release 4.

Please list (title) and describe your videotape Entry with as much detail as possible below:

Blank lines for listing videotape entries.

How would you like credits to be given for you, your school, and/or your company? (Please note, however, credits cannot be guaranteed.)

Blank line for providing credit information.

Are you submitting work done by a student(s)? Yes / No (circle one) If yes, please list individual contributors on the reverse side of this form.

The above release shall be void if amended in any manner. Autodesk shall not be responsible for the return of any files submitted.

**APPENDIX F - WPI DESIGN INNOVATION
SCHOLARSHIP**

SPECIAL ANNOUNCEMENT

January 11, 1997

The Competition-1997 WPI Design Innovation Scholarship

FIRST and Worcester Polytechnic Institute (WPI) are proud to once again announce a bold step for the The Competition-1997. This year, WPI and FIRST will award a full four-year undergraduate scholarship to one of the FIRST student participants to attend WPI:

With this WPI Design Innovation Scholarship, FIRST continues on with an academic strategic alliance to provide FIRST participants with not only an introduction to math, science, technology, and engineering, but an opportunity to pursue studies, gain experience, and choose a career in these exciting fields.

One of FIRST's main goals is to show today's kids that it is important to be smart and profitable to use your brain. The addition of this \$75,000 scholarship to WPI is one more way in which WPI and FIRST will show today's students that science and technology can be fun and rewarding.

All teams participating in The Competition-1997 will qualify for the WPI Design Innovation Scholarship. The winning team will be selected through a vote conducted by all of the teams. Each team will receive one ballot containing five criteria with which they must select a first (50 points), second (25 points), and third (10 points) place candidate other than their own team. The criteria includes: (1) the robot with the most innovative design, (2) the team that thrives in a partnership or teamwork atmosphere, (3) the team whose student participants demonstrate enthusiasm for engineering and science, (4) the team displaying the best sportsmanship, and, (5) the best team spirit. All votes must be submitted to FIRST in time for the final awards ceremony to take place at the National Championship at Epcot on April 10-12, 1997. The scholarship award will be presented to the team who receives the most points.

Once the winning team has been selected, the scholarship award will be made to an individual student designated by the corporate member and school of the winning team.

The student selected for the scholarship may be from any grade level and must have demonstrated enthusiasm for engineering and science and possess the ability and innovation necessary to excel as an engineer or scientist. WPI's project-based curriculum is well suited to students with demonstrated ability to take responsibility to thrive in the team environment, to solve problems and to assume leadership; in short, the same characteristics for success in FIRST. The winning student must also meet WPI's admission requirements and must maintain satisfactory academic progress at WPI to maintain the award. Ultimately, the student selected for the WPI Design Innovation Scholarship should exemplify the spirit of the FIRST program.

FIRST would like to congratulate WPI for blazing a trail for other academic institutions to follow. FIRST and WPI remain committed to introducing today's students to the many rewards that science and technology offer. This scholarship will provide a student with the opportunity to obtain an undergraduate degree as a result of their participation and effort in the FIRST program. More importantly, it highlights a key role academic institutions can play in continuing the demand for excellence in science and technology created through the student, teacher, academic institution and corporation partnership.

SAMPLE BALLOT
(To be handed out at The Competitions)
WPI Design Innovation Scholarship Award

Ballot for Team # _____

Criteria for the WPI Design Innovation Scholarship:

1. *Robot with the most innovative design*
2. *Team that thrives in a partnership or teamwork atmosphere*
3. *Team whose student participants demonstrate enthusiasm for engineering and science*
4. *Team displaying the best sportsmanship*
5. *Best team spirit.*

Vote for First Place Team: _____
(50 Points) (TEAM NAME) (ROBOT NAME)

Vote for Second Place Team: _____
(25 Points) (TEAM NAME) (ROBOT NAME)

Vote for Third Place Team: _____
(10 Points) (TEAM NAME) (ROBOT NAME)

Please submit your ballot to FIRST by final awards ceremony on April 10-12, 1997, at Epcot.

(STUDENT OR SCHOOL REPRESENTATIVE)

(PHONE NO.)

(SPONSOR REPRESENTATIVE)

(PHONE NO.)

APPENDIX G - CALENDAR OF EVENTS AND DEADLINES

Hotel Cut Offs:

Motorola Midwest Regional:

Embassy Suites Hotel	2/14/97
Hampton Inn	2/14/97
Holiday Inn	2/7/97
Hyatt Regency	2/12/97
Wyndham Garden	2/5/97
Marriott	2/12/97
Radisson Hotel	2/14/97

New England Regional:

Center of New Hampshire	2/20/97
Comfort Inn	2/26/97
Days Hotel	2/26/97
Highlander Inn	2/26/97
Susse Chalet	2/19/97
Wayfarer Inn	2/12/97

Johnson & Johnson Mid-Atlantic Reg.:

Clarion Hotel	2/26/97
Comfort Inn	3/1/97
Somerset Marriott	2/27/97
Quality Inn	2/21/97
Wyndham Hotel	2/26/97
Embassy Suites	2/15/97

National Championship:

All Star Resort	3/2/97
-----------------	--------

Team logos	5:00 pm, Friday 1/31/97 at FIRST
Team Profiles.....	5:00 pm, Friday 1/31/97 at FIRST
Autodesk Award Submission.....	5:00 pm, Wednesday 3/7/97 at Autodesk
Chairman's Award Submission	5:00 pm, Wednesday 2/28/97 at FIRST

Ship Robots

Teams competing in the National Championship only must ship by 5:00pm, Friday, 2/28/97.

Teams competing in a Regional must ship to the drayage/storage facility of their first competition by 5:00 pm, Tuesday, 2/25/97.

For teams competing in more than one event...

If you are competing in this Regional... then we must receive your
robot at the next site by this date at
5:00 p.m.

- Motorola Midwest Regional, IL.....Tuesday, March 11, 1997
- New England Regional, Manchester, NH.....Tuesday, March 18, 1997
- Johnson & Johnson Mid-Atlantic Regional, NJ Tuesday, March 25, 1997

Complete details on drayage for robots can be found in Appendix H.

Send Team Profiles, Team Logos and Chairman's Award submission to: Send Animation Award Submission to:

FIRST
200 Bedford Street
Manchester, NH 03101

Autodesk, Inc.
Marketing Support Team-Image
Archives
111 McInnis Parkway
San Rafael, CA 94903
Attn: FIRST JUDGES AWARD

Event Attendees

Two weeks before each event, we need to get an estimate from you of how many people will be attending from your team. The deadlines are as follows:

- Motorola Midwest Regional.....Friday, February 21, 1997
- New England Regional.....Friday, February 28, 1997
- Johnson & Johnson Mid-Atlantic Regional.....Friday, March 7, 1997
- National Championship.....Friday, March 28, 1997

APPENDIX H - SHIPPING INFORMATION

FIRST Midwest Competition
March 6-8, 1997
Harper College
Chicago, IL

MIDWEST EXPOSITION SERVICE COMPANY
P.O. Box 297
Bloomington, IL 60108-0297
Phone: 630/351-3976 Fax:630/351-4118

Shipping Information

All shipments made by local teams and/or out of state teams must be shipped to Midwest's warehouse on February 25, 1997. We will provide the following services at the rates shown below:

- A. Complete handling at Midwest's warehouse for unloading your shipments, and hauling to the competition site.
- B. Midwest also agrees to furnish (30) days free storage prior to the opening date of the competition.
- C. Unloading at show site docks and dropping equipment in specific booth.
- D. Storage of empty boxes, crates, or cases once team has set-up pit area.
- E. Return empties once FIRST has authorized Midwest Expo to do so.
- F. Omitted
- G. Omitted
- H. Midwest Exposition shall not be responsible for damage to uncrated materials, materials improperly packed, any concealed damages, loss or theft of materials after same have been picked-up for loading out of competition.
- I. Freight shipments should be made on straight bills of lading and should be carefully prepared to show numbers of pieces, weight, classification, etc. Shipments made on other than straight bills of lading should be accompanied by a delivery ticket showing number of pieces, weight, classification etc. Midwest Exposition will weigh team materials and charge accordingly if accurate weight is not provided.
- J. Omitted
- K. For making arrangements for outbound freight, there will be a handling charge of \$10.00 per box for UPS, FED X or other, regardless of size, if going out other than specified carrier.

FIRST Midwest Competition
March 6-8, 1997
Harper College
Chicago, IL

Shipping Information
Page 2 of 2.

All shipments must be addressed as follows

EXHIBITOR NAME: _____ TEAM # _____

C/O MIDWEST EXPOSITION SERVICE COMPANY
380 MONOCO
ROSELLE, IL 60172

FOR (TEAM NAME) _____ (NAME FOR SHOW) FIRST - THE COMPETITION 1997

SHOW LOCATION: HARPER COLLEGE

For outbound movements, please make arrangements by filling out Bills of Lading, routing, etc. at Midwest's freight desk any time before departing.

L. All shipments must be prepaid. Please send all advanced payments with the name of your company and team number to the attention of:

MIDWEST EXPOSITION SERVICE COMPANY
P.O. BOX 297
BLOOMINGDALE, IL 60108-0297

FIRST New England Regional
March 13-15, 1997
New Hampshire College
Manchester, NH

SPECIAL EVENT RENTALS, INC.
1060 Millbury Street
Worcester, MA 01607
Phone: 508/757-3397 Fax: 508/757-9136

MATERIAL HANDLING INFORMATION

SHIPMENTS TO WAREHOUSE: Special Event Rentals, Inc. will receive crated, boxed or skidded shipments at SER warehouse up to 30 days prior to show move in. Includes delivery to booth, storage of empty packing materials and return.

Label each piece and address all documents as follows:

Competing Team Name
FIRST New England Regional
c/o Special Event Rentals
1060 Millbury Street
Worcester, MA 01607

Shipments must be sent with freight charges prepaid. Collect shipments will not be accepted. All common carriers, Van Line, Air Freight, Fed Ex, etceteras charges are the sole responsibility of the team.

LIABILITIES: The terms and conditions of Special Event Rentals' Liability and Insurance Bulletin apply to all shipments. Shipments made according to the above instructions shall constitute acceptance by the exhibitor of said limits.

Route your shipments through carrier of services that provide bills of lading specifying a piece count.

A copy of the bill of lading indicating the number of pieces, proper description and weights should be forwarded to Special Event Rentals, with the Carriers Pro # and Trailer #.

LIABILITY AND INSURANCE BULLETIN

SPECIAL EVENT RENTALS, INC. shall not be responsible for damage to uncrated materials improperly packed or concealed damage.

SPECIAL EVENT RENTALS, INC. shall not be responsible for loss, theft or disappearance of exhibitors material after same have been delivered to the competition.

SPECIAL EVENT RENTALS, INC. shall not be responsible for loss, theft, or disappearance before they are picked up from team's booth for reloading after the show. Bills of lading covering outgoing shipments which are furnished to SPECIAL EVENT RENTALS' by team will be checked at time of actual pickup from booth and corrections made where discrepancies occur.

FIRST New England Regional
March 13-15, 1997
New Hampshire College
Manchester, NH

SPECIAL EVENT RENTALS, INC. shall not be responsible for loss , damage or delay due to fire, Act of God, strikes, lockouts, or work stoppages of any kind or to any causes beyond its control.

SPECIAL EVENT RENTALS, INC's liability shall be limited to the physical loss or damage to the specific article which is lost or damaged and in any event SPECIAL EVENT RENTALS' maximum liability shall be limited to \$.30 per pound, maximum \$50.00 per claim.

SPECIAL EVENT RENTALS, INC. shall not be liable to any extent whatsoever, for any actual, potential or assumed loss of profits or revenues, or for any collateral costs, which may result from any loss or damage to a team's materials which may make it impossible or impractical to compete.

INSURANCE - It is understood that SPECIAL EVENT RENTALS is not an insurer, that insurance, if any, should be obtained by the team. It is suggested that teams arrange all risk coverage. This can be done by endorsements to existing policies. Team's materials should be insured from the time they leave their firm until they are returned after the close of the show.

The consignment or delivery of a shipment to SPECIAL EVENT RENTALS, INC. by a team, or by any shipper on behalf of the team, shall be construed as an acceptance by such team (and/or other shipper) of the terms and conditions set forth in this Bulletin.

Team requiring additional insurance coverage should arrange to place same through their broker.

All shipments must be prepaid. Collect shipments will not be accepted.

FIRST Mid Atlantic Regional
March 20-22, 1997
Rutgers College
New Brunswick, NJ

SPECIALTY DECORATING & DESIGN
720 MONROE STREET
HOBOKEN, NJ 07030
201/653-1258 Fax: 201/653-1519

Order Form
SHIPPING INSTRUCTIONS

ADVANCE RECEIVING AT OUR WAREHOUSE
DEADLINE DATE:
MARCH 18, 1997

You must ship crated, boxed or skidded materials up to 30 days in advance of the show.
All items **MUST** be labeled as follows:

ORGANIZATION NAME
SHOW DATE
c/o SPECIALTY DECORATING
720 MONROE STREET
HOBOKEN, NEW JERSEY 07030

Shipments must be prepaid. Collect shipments will be refused. If not labeled properly, uncrated or loose shipments can be refused at the warehouse. We will deliver your shipment to the gym and remove the containers with the EMPTY labels on them. We will return the empty containers to you at the end of the competition. No access is possible to empty containers during the competition as they will not be on the premises. Specialty Decorating and Design, Inc. Is not responsible for any contents of a container marked empty. EMPTY labels are available. Each team is responsible to attach the empty label to each container.

INBOUND BILL OF LADING OR DELIVERY RECEIPT

All Shipments must have a bill of lading or delivery receipt showing the number of items, weight and description of merchandise. Trucks arriving without documented weight will be required to go to the nearest weighing station to obtain documentation or a mutual decision will be made as to the weight and will be binding to both parties.

FIRST Mid Atlantic Regional
March 20-22, 1997
Rutgers College
New Brunswick, NJ

SPECIALTY DECORATING & DESIGN
720 MONROE STREET
HOBOKEN, NJ 07030
201/653-1258 Fax: 201/653-1519

Order Form
**MATERIALS SHIPPING
AND HANDLING**

Please return this form to the above address.
FORM DEADLINE DATE: 1 week prior to show date.

Event Name: FIRST Mid Atlantic Regional 1997
Company: _____ Team # _____
Address: _____
Ordered by: _____ Title: _____
Phone: _____ Fax: _____
Signature: _____

SHIPMENTS TO WAREHOUSE:

Shipper: _____ From City/State _____

How Shipped: Common Carrier _____ Company Truck _____ Airfreight _____

Shipping Date: _____ No. pieces _____ Weight _____

Carrier _____ Pro.No. _____

Comments or Special Handling Requirements

Attach copies of this form for multiple shipments

FIRST Mid Atlantic Regional
March 20-22, 1997
Rutgers College
New Brunswick, NJ

SPECIALTY DECORATING & DESIGN
720 MONROE STREET
HOBOKEN, NJ 07030
201/653-1258 Fax: 201/653-1519

LIMITS OF LIABILITY OF SPECIALTY DECORATING & DESIGN, INC.

1. We are not responsible for damages to uncrated materials, materials improperly packed or concealed damages.
2. We are not responsible for loss, theft, or disappearance of any materials improperly packed or concealed damages.
3. We are not responsible for loss, theft, or disappearance of any materials before they are picked up from the pit area for reloading after the show. Bills of lading covering outgoing shipments will be checked at the time of actual pickup from the pit table and discrepancies will be corrected.
4. We are not responsible for any loss, damage or delay due to fire, Acts of God, strikes, lockout, or work stoppages of any kind or to causes beyond our control.
5. Our liability shall be limited to the specific loss or damage to the specific article which is lost or damaged. In any event our maximum liability shall be limited to \$.25 per is lost or damaged. In any event our maximum liability shall be limited to \$.25 per pound per article with a maximum liability of \$50.00 per item or \$1,000.00 per shipment which ever is less. Claims must be filed by the Team before the close of the show.
6. We are not liable to any extent whatsoever for any actual, potential or assumed loss of profits or revenues or for collateral costs, which may result from any loss or damage to a team's materials which may make it impossible or impractical to compete.
7. The consignment or delivery of a shipment to Specialty Decorating by a team (and/or other shipper) on behalf of the team shall be construed as acceptance by the team of the conditions set forth.

FIRST Final Competition
April 10-12 1997
Epcot
Orlando, FL

FREEMAN DECORATING COMPANY
2300 Principal Row
Orlando, Florida 32837
Phone:407/857-1500 Fax: 407/850-9328

SHIPPING TO THE WAREHOUSE

Freeman Decorating Company, as the exclusive drayage contractor, will receive crated, boxed or skidded materials at the warehouse. Shipments must be sent with freight charges PREPAID. COLLECT SHIPMENTS CANNOT BE ACCEPTED.

Label each piece and address all shipping documents/bills of lading as follows for shipments to the warehouse:

NAME OF TEAM & TEAM NO. _____

HOLD FOR:

c/o Freeman Decorating Company
2300 Principal Row
Orlando, Florida 32837

(To check on the arrival of warehouse
freight, please call 407/857-1500 x.152)

The warehouse will receive shipments Monday through Friday during the hours of 8:00 a.m. - 4:30 p.

All shipments must have a bill of lading or delivery slip showing the number of pieces, type of merchandise and weight. Shipments received without freight bills, or specified unit counts on receipts, will be delivered to team tables without guarantee of piece count or condition.

CERTIFIED WEIGHT RECEIPTS

Driver will be required to submit certified weight receipts when receiving shipments for unloading. Freeman Decorating reserves the right of refusal to unload such shipments until a CERTIFIED WEIGHT RECEIPT is presented. In the event no weight is indicated on delivery documents presented, Freeman Decorating Company shall estimate the weight. If actual scale weight figures are not submitted prior to the move out period, the estimated weight will be final and binding. All shipments received at the warehouse and show site are subject to reweigh.

OUTBOUND SHIPPING AND HANDLING

Outbound materials will be moved from pit area to dock and reloaded on designated vehicles. To assist you with arrangements for outbound shipments, Freeman Decorating Company will have a Service desk where labels, bills of lading and shipping information will be available.

**APPENDIX I - NATIONAL CHAMPIONSHIP
ACCOMMODATIONS**

Welcome Back to
Walt Disney World,
Florida!



1997 FIRST
National Championship

Walt Disney World,
Florida

Epcot

FIRST National Championship Team Representative

- ♥ Please choose one contact person who will handle the reservations for your team and be responsible for collecting and disseminating all pertinent information regarding your team's reservations.
- ♥ Coordinate all communications to Disney Special Events.
- ♥ Sign and return Reservation/Planning Agreement.
 - Send a complete rooming list with names, addresses, ages, arrivals and departures times.
- ♥ Collect and send one (1) deposit no later than March 2, 1997. Because WDW is in the midst of its 25th Anniversary Celebration, all unreserved rooms will be released after 8:00 am on March 3, 1997.



FIRST National Championship Accommodations: Disney's All-Star Resort

Group Hospitality

- ♥ FIRST exclusive
- ♥ Registration and Event Information
- ♥ Event Orientations in hospitality location on April 9th and 10th
- ♥ Daily breakfast location
- ♥ Hospitality location open daily



FIRST National Championship Package Offering

Dates: April 9-14, 1997

Four (4) Night Packages

- ♥ Four (4) nights' accommodations at Disney's All-Star Resort.
- ♥ Five (5) days' Park Hopper Pass that allows unlimited admission to the Magic Kingdom, Epcot, and the Disney-MGM Studios.
- ♥ Four (4) breakfast coupons for use at Disney's All-Star Resorts Food Court location.
- ♥ Four (4) Theme Park counter service lunch coupons.
- ♥ Unlimited use of our existing Transportation Systems.
- ♥ One (1) commemorative T-Shirt per person.

<u>SINGLE</u>	<u>DOUBLE</u>	<u>TRIPLE</u>	<u>QUAD</u>
\$568.00	\$381.00	\$331.00	\$306.00

FIRST National Championship Package Offering Continued

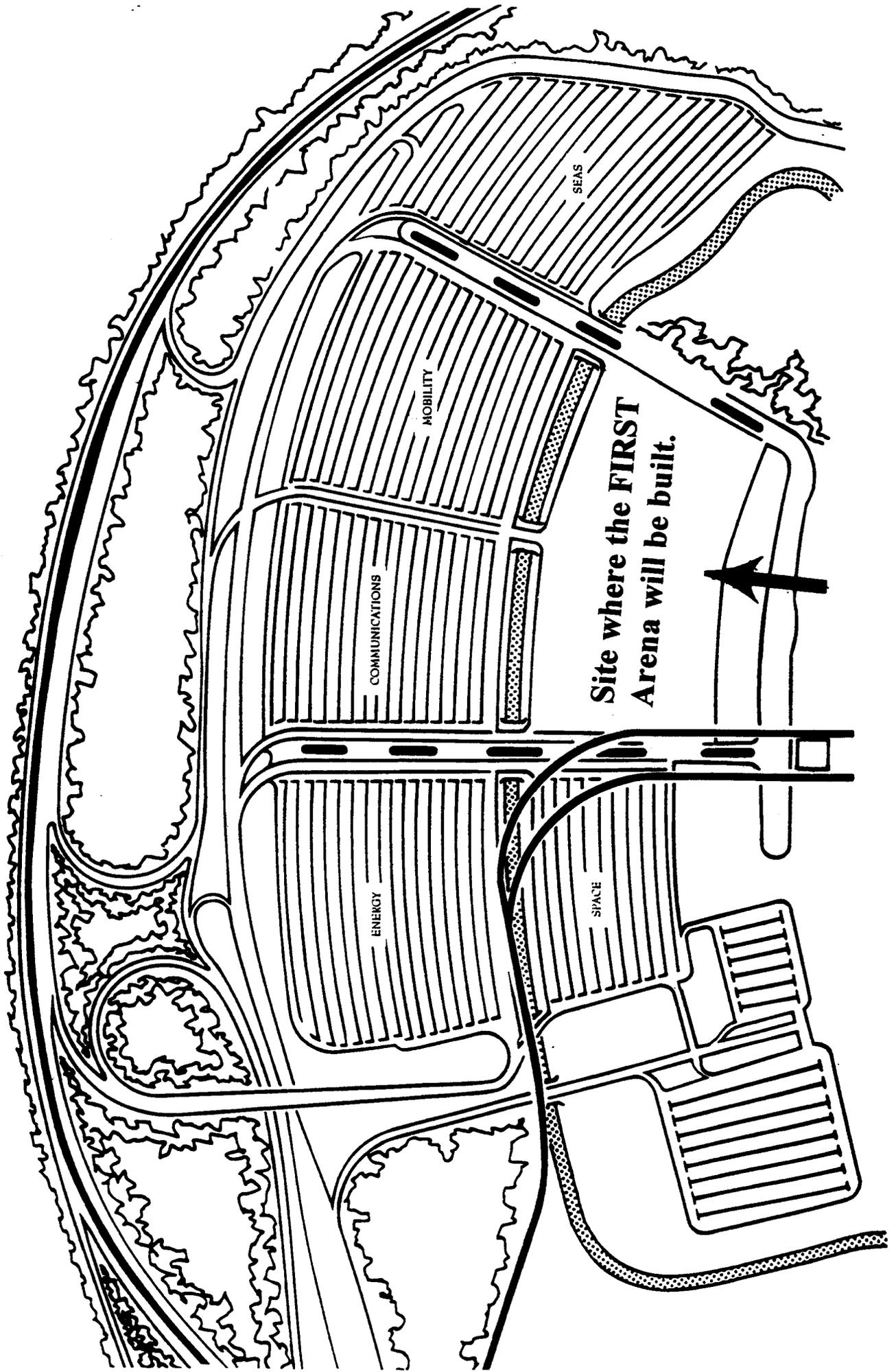
Three (3) Night Packages

- ♥ Three (3) nights' accommodations at Disney's All-Star Resort.
- ♥ Four (4) day Park Hopper that allows unlimited admission to the Magic Kingdom, Epcot, and Disney-MGM Studios.
- ♥ Three (3) breakfast coupons for use at Disney's All-Star Resorts Food Court location.
- ♥ Three (3) Theme Park counter service lunch coupons.
- ♥ Unlimited use of our existing Transportation Systems.
- ♥ One (1) commemorative T-Shirt per person.

<u>SINGLE</u>	<u>DOUBLE</u>	<u>TRIPLE</u>	<u>QUAD</u>
\$435.00	\$295.00	\$257.00	\$239.00

Epcot Arena

Located at the Epcot Main Entrance



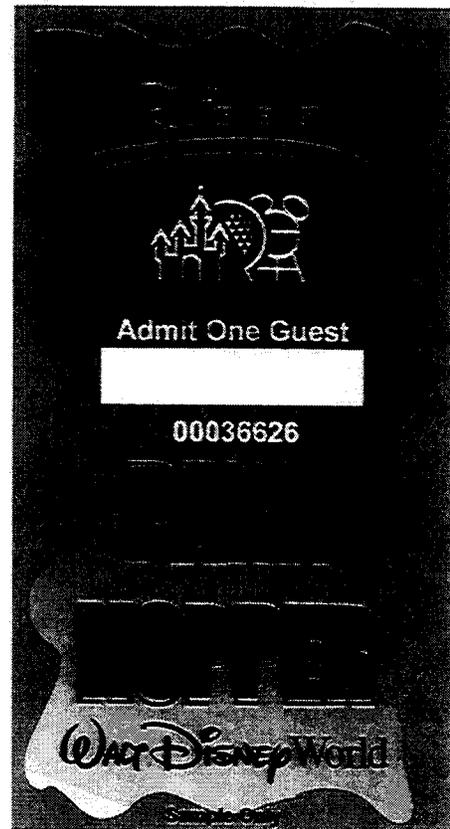
FIRST National Championship Access Credentials

Competition Access

- ♥ Must show Competition ID Badge to access pit. This badge will be distributed upon your arrival.

Park Access

- ♥ Must show your Park Admission Ticket daily.



FIRST National Championship Event Itinerary

🏆 Thursday, April 10

- ▣ Practice Rounds

🏆 Friday, April 11

- ▣ Opening Ceremonies
- ▣ Seeding Matches

🏆 Saturday, April 12

- ▣ Double Elimination
- ▣ Finals
- ▣ Closing Ceremony
- ▣ Wrap Party

FIRST National Championship Key WDW Telephone Numbers

Event Reservations and Information

- Phone Number: 1-407-827-7600
- Fax Number: 1-407-828-5479
 - Resort Reservation
 - Itinerary Information
 - Check-in Locations
 - Shipping
 - Tickets/Credentials
 - Orientations Times and Locations
 - Transportation



FIRST National Championship WDW Event Reservations

Event Reservations may begin as early as Monday, January 13, 1997.

- Telephone calls welcomed
- Faxed information preferred



Please call or fax Monday through Friday, 8:30 AM to 5:00 PM EST.

We are looking forward to hosting one of the most dynamic and inspirational events ever..... see you at Epcot!

APPENDIX J - DEFAULT RECEIVER PROGRAM

```

'
' PROGRAM: RXSLAVE.BS2
' Program run by User Programmable CPU in '97 FIRST Receiver Board
' Written by: Eric Rasmussen
' Date: 12/12/96
'
' Declare variables
'
x1      VAR byte
y1      VAR byte
x2      VAR byte
y2      VAR byte
aux1    VAR byte
wheel1  VAR byte
aux2    VAR byte
wheel2  VAR byte
tx_sw   VAR word
rx_sw   VAR word
sensor1 VAR byte
sensor2 VAR byte
relays  VAR word
'
' Define Aliases (variables which are sub-divisions of those defined above)
'           (aliases don't require any additional RAM)
'
sw1_fwd VAR tx_sw.bit0 ' Aliases for each TX switch input
sw1_rev VAR tx_sw.bit1
sw2_fwd VAR tx_sw.bit2
sw2_rev VAR tx_sw.bit3
sw3_fwd VAR tx_sw.bit4
sw3_rev VAR tx_sw.bit5
sw4_fwd VAR tx_sw.bit6
sw4_rev VAR tx_sw.bit7
sw5_fwd VAR tx_sw.bit8
sw5_rev VAR tx_sw.bit9
sw6_fwd VAR tx_sw.bit10
sw6_rev VAR tx_sw.bit11
sw7_fwd VAR tx_sw.bit12
sw7_rev VAR tx_sw.bit13
sw8_fwd VAR tx_sw.bit14
sw8_rev VAR tx_sw.bit15
rx_sw1  VAR rx_sw.bit0 ' Aliases for each RX switch input
rx_sw2  VAR rx_sw.bit1
rx_sw3  VAR rx_sw.bit2
rx_sw4  VAR rx_sw.bit3
rx_sw5  VAR rx_sw.bit4
rx_sw6  VAR rx_sw.bit5
rx_sw7  VAR rx_sw.bit6
rx_sw8  VAR rx_sw.bit7
rx_sw9  VAR rx_sw.bit8
rx_sw10 VAR rx_sw.bit9
rx_sw11 VAR rx_sw.bit10
rx_sw12 VAR rx_sw.bit11
rx_sw13 VAR rx_sw.bit12
rx_sw14 VAR rx_sw.bit13

```

```

rx_sw15    VAR rx_sw.bit14
rx_sw16    VAR rx_sw.bit15
rly1_fwd   VAR relays.bit0      ' Aliases for each relay output
rly1_rev   VAR relays.bit1
rly2_fwd   VAR relays.bit2
rly2_rev   VAR relays.bit3
rly3_fwd   VAR relays.bit4
rly3_rev   VAR relays.bit5
rly4_fwd   VAR relays.bit6
rly4_rev   VAR relays.bit7
rly5_fwd   VAR relays.bit8
rly5_rev   VAR relays.bit9
rly6_fwd   VAR relays.bit10
rly6_rev   VAR relays.bit11
rly7_fwd   VAR relays.bit12
rly7_rev   VAR relays.bit13
rly8_fwd   VAR relays.bit14
rly8_rev   VAR relays.bit15
'
' Define Constants
'
MASTERCPU CON 0      ' Pin used to communicate with Master CPU
FPIN       CON 1      ' Pin used to for flow control with Master CPU
RLYDATA    CON 5      ' Shift Register Data Pin for Relay Outputs
RLYCLOCK   CON 6      ' Shift Register Clock Pin for Relay Outputs
RLYLATCH   CON 7      ' Shift Register Latch Pin for Relay Outputs
SWDATA     CON 8      ' Shift Register Data Pin for Switch Inputs
SWCLOCK    CON 9      ' Shift Register Clock Pin for Switch Inputs
SWLATCH    CON 10     ' Shift Register Latch Pin for Switch Inputs
SSC        CON 11     ' Pin used to communicate with Serial Servo Controller
ADCDATA    CON 12     ' Analog to Digital Converter Data Pin
ADCCLOCK   CON 13     ' Analog to Digital Converter Clock Pin (for data)
ADC1SEL    CON 14     ' Pin to select ADC #1 (selected = low)
ADC2SEL    CON 15     ' Pin to select ADC #2 (selected = low)
GOODLED    CON 3      ' Pin used to turn status LED green
ERRLED     CON 4      ' Pin used to turn status LED red
SSCBAUD    CON $0020  ' Baud rate for communications with SSC
BS2BAUD    CON $4020  ' Baud rate for communications with BS2 (Master CPU)
PWM1       CON 8      ' Define SSC addresses for PWM outputs
PWM2       CON 9
PWM3       CON 10
PWM4       CON 11
PWM5       CON 12
PWM6       CON 13
PWM7       CON 14
PWM8       CON 15
SSC_CMD    CON 255    ' Command Prefix for SSC
'
' Initialize Hardware and Variables on Power Up or Reset
'
' All pins default to low (ground) & input (floating) on powerup or reset.
'
Output SSC      ' Prevent floating before data is sent (low)
Output FPIN
Output RLYDATA
Output RLYCLOCK
Output RLYLATCH
Output SWDATA
Output SWCLOCK
Output SWLATCH

```

```

Output GOODLED
Output ERRLED
High SWLATCH      ' These should be normally high
High ADC1SEL
High ADC2SEL
' Set Relay Outputs all off (in case shift register contains junk)
Shiftout RLYDATA, RLYCLOCK, LSBFIRST, [0\16]
Pulsout RLYLATCH, 1
'
' Main Program
'
Loop:
  ' Get data from Master CPU
  Serin MASTERCPU\FPIN, BS2BAUD, [Wait(255,255), x1, y1, x2, y2,
tx_sw.lowbyte, aux1, wheel1, tx_sw.highbyte, aux2, wheel2]

  High GOODLED ' Turn LED Green to show loop is running
  Serout SSC, SSCBAUD, [SSC_CMD, PWM1, x1] ' Update PWM outputs
  Serout SSC, SSCBAUD, [SSC_CMD, PWM2, y1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM3, x2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM4, y2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM5, aux1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM6, wheel1]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM7, aux2]
  Serout SSC, SSCBAUD, [SSC_CMD, PWM8, wheel2]
  Low GOODLED ' Turn LED off

  ' Read Switch Inputs into rx_sw
  Gosub ReadSwitches

  ' Read Analog Sensor Inputs into sensor1 & sensor2
  Gosub ReadSensors

  ' Set relays to match TX switches
  relays = tx_sw

  ' Use 1st 8 RX switches (rx_sw1-8) as STOP switches for Relays 1-4
  relays.lowbyte = relays.lowbyte &~ rx_sw.lowbyte

  ' Use 2nd 8 RX switches (rx_sw9-16) as GO switches for Relays 5-8
  relays.highbyte = relays.highbyte | rx_sw.highbyte

  ' Set Relay Outputs
  Shiftout RLYDATA, RLYCLOCK, LSBFIRST, [relays\16]
  Pulsout RLYLATCH, 1

Goto Loop: ' Start over at Loop:
End ' It should actually never get here!
'
' Subroutines
'
ReadSwitches: ' Reads receiver switch inputs into variable rx_sw
  Pulsout SWLATCH, 1
  Low SWLATCH
  Pulsout SWCLOCK, 1
  High SWLATCH
  Shiftin SWDATA, SWCLOCK, LSBPRE, [rx_sw\16] ' Read in the data
  rx_sw = rx_sw ^ 65535 ' Invert bits so that a closed switch is true (1)
Return

```

```
ReadSensors: ' Read receiver sensor inputs into variables sensor1 & sensor2
  Low ADC1SEL           ' Select the 1st Analog to Digital Converter
  Pulsout ADCCLOCK, 1
  Shiftin ADCDATA, ADCCLOCK, msbpost, [sensor1] ' Read in the data
  High ADC1SEL          ' Deselect ADC1
  Low ADC2SEL           ' Select the 2nd Analog to Digital Converter
  Pulsout ADCCLOCK, 1
  Shiftin ADCDATA, ADCCLOCK, msbpost, [sensor2] ' Read in the data
  High ADC2SEL          ' Deselect ADC2
Return
```

**APPENDIX K - MANUFACTURERS'
SPECIFICATIONS**

The following pages are manufacturers' specifications for parts provided in the Official Kit of Parts.

Additional booklets are in the Kit.

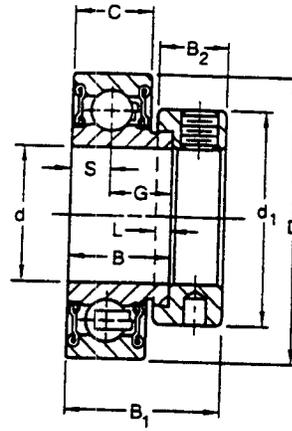
Be sure to read these spec sheets in order to properly allocate and use components.

RA-RR, RA-RRB Series Non-Relubricatable Types

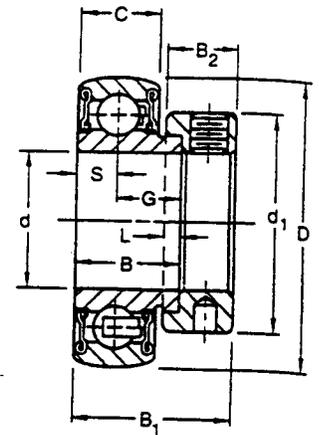
The RA-RR Series bearings are extended inner ring type with self-locking collar. A positive contact, land riding R-seal provides improved protection against harmful contaminants and effectively retains the lubricant under severe operating conditions. A 6/6 molded nylon retainer has proven extremely effective under conditions of misalignment. RA-RR Series bearings are factory prelubricated.

The RA-RR Series has cylindrical outside diameters.

The RA-RRB Series has spherical outside diameters for use in housings with corresponding spherical inside surfaces to provide unrestricted initial self-alignment.



RA-RR Two Seals
Cylindrical O.D.



RA-RRB Two Seals
Spherical O.D.

Recommended shaft tolerances: $\frac{1}{4}$ "-1 $\frac{1}{4}$ " \pm , nominal to $-.0005$ ", $-.013$ mm;
2"-2 $\frac{3}{4}$ " \pm , nominal to $-.0010$ ", $-.025$ mm.

TO ORDER, SPECIFY BEARING NUMBER FOLLOWED BY "AND COLLAR". EXAMPLE: RA100RRB AND COLLAR.

Bearing Number	Collar Number	Basic Outer Size	Bore ⁽¹⁾		O.D.		Ring Widths		S	G	L	d ₁	B ₂	B ₁	Brg. & Collar Wt.		Static Load C ₀	Extended Dynamic Rating C _E
			in.	mm	in.	mm	in.	mm							in.	mm		
RA08RR RA09RR RA10RR RAE17RR	RA08RRB RA09RRB RA10RRB RAE17RRB	S1008K S1009K S1010K SE17K	203	$\frac{1}{2}$ $\frac{3}{4}$ $\frac{1}{2}$	17	1.5748 40	0.750 0.512 ⁽²⁾ 19.05 13	0.256 6.5	0.494 12.55	$\frac{1}{2}$ -4.0	1 $\frac{1}{4}$ 28.6	$\frac{1}{2}$ 13.5	1 $\frac{1}{4}$ 28.6	0.34 0.28	0.154 0.127	1000 4400	2360 10600	
RA012RR RAE20RR	RA012RRB RAE20RRB	S1012K SE20K	204	$\frac{3}{4}$	20	1.8504 47	0.844 0.591 ⁽³⁾ 21.44 15	0.295 7.49	0.548 13.92	$\frac{1}{2}$ 4.0	1 $\frac{1}{8}$ 33.3	$\frac{1}{2}$ 13.5	1 $\frac{1}{2}$ 31	0.29 0.29	0.132 0.132	1400 6200	3200 14300	
RA013RR RA014RR RA015RR RA100RR RAE25RR	RA013RRB RA014RRB RA015RRB RA100RRB RAE25RRB	S1013K S1014K S1015K S1100K SE25K	205	$\frac{1}{8}$ $\frac{1}{4}$ $\frac{3}{8}$ 1	25	2.0472 52	0.844 0.591 21.44 15	0.295 7.49	0.548 13.92	$\frac{1}{2}$ 4.0	1 $\frac{1}{2}$ 38.1	$\frac{1}{2}$ 13.5	1 $\frac{1}{2}$ 31	0.51 0.47 0.44 0.41 0.41	0.231 0.213 0.2 0.186 0.186	1560 5950	3450 15600	
RA101RR RA102RR RA103RR RA103RR2 RAE30RR	RA101RRB RA102RRB RA103RRB RA103RRB2 RAE30RRB	S1101K S1102K S1103K S1103K3 SE30K	206	$1\frac{1}{8}$ $1\frac{1}{4}$ $1\frac{3}{8}$ $1\frac{1}{2}$	30	2.4409 62	0.938 0.709 23.82 18	0.354 8.99	0.583 14.81	$\frac{1}{2}$ 4.0	1 $\frac{1}{4}$ 44.1	$\frac{5}{8}$ 15.9	1 $\frac{1}{2}$ 35.7	0.77 0.72 0.7 0.65 0.7	0.349 0.327 0.318 0.295 0.318	2280 10000	4800 21600	
RA104RR RA105RR RA106RR RA107RR RAE35RR	RA104RRB RA105RRB RA106RRB RA107RRB RAE35RRB	S1104K S1105K S1106K S1107K SE35K	207	$1\frac{1}{4}$ $1\frac{3}{8}$ $1\frac{1}{2}$ $1\frac{3}{4}$	35	2.8346 72	1.000 0.748 25.4 19	0.374 9.5	0.626 15.9	$\frac{1}{2}$ 4.0	2 $\frac{1}{4}$ 54.40	$\frac{3}{4}$ 17.1	1 $\frac{1}{2}$ 38.9	1.24 1.19 1.13 1.05 1.13	0.562 0.54 0.513 0.476 0.513	3050 13700	6400 28500	
RA108RR RA109RR RAE40RR	RA108RRB RA109RRB RAE40RRB	S1108KT S1109KT SE40K	208	$1\frac{1}{2}$ $1\frac{3}{4}$	40	3.1496 80	1.188 0.866 ⁽⁴⁾ 30.18 22	0.433 11	0.755 19.18	$\frac{3}{8}$ 4.8	2 $\frac{1}{2}$ 60.3	$\frac{3}{4}$ 18.3	1 $\frac{3}{4}$ 43.7	1.53 1.43 1.43	0.694 0.649 0.649	4000 17600	8150 36000	
RA110RR RA111RR RA112RR RAE45RR	RA110RRB RA111RRB RA112RRB RAE45RRB	S1110K S1111K S1112K SE45K	209	$1\frac{3}{4}$ $1\frac{7}{8}$ $1\frac{1}{2}$	45	3.3465 85	1.188 0.866 30.18 22	0.433 11	0.755 19.18	$\frac{3}{8}$ -8	2 $\frac{1}{2}$ 63.5	$\frac{3}{4}$ 18.3	1 $\frac{3}{4}$ 43.7	1.72 1.62 1.5 1.5	0.78 0.735 0.68 0.68	4000 17600	8150 36000	
RA113RR RA114RR RA115RR RA115RR2 RAE50RR	RA113RRB RA114RRB RA115RRB RA115RRB2 RAE50RRB	S1113K S1114K S1115K S1115K2 SE50K	210	$1\frac{7}{8}$ $1\frac{1}{2}$ $1\frac{3}{4}$ 2	50	3.5433 90	1.188 0.866 30.18 22	0.433 11	0.755 19.18	$\frac{3}{8}$ 4.8	2 $\frac{1}{2}$ 69.9	$\frac{3}{4}$ 18.3	1 $\frac{3}{4}$ 43.7	1.94 1.83 1.70 1.58 1.79	0.88 0.83 0.771 0.717 0.771	4500 19600	8800 3900	
RA200RR RA201RR RA202RR RA203RR RAE55RR	RA200RRB RA201RRB RA202RRB RA203RRB RAE55RRB	S1200K S1201K S1202K S1203K SE55K	211	2 2 $\frac{1}{4}$ 2 $\frac{1}{2}$ 2 $\frac{3}{4}$	55	3.9370 100	1.281 0.945 32.54 24	0.472 11.99	0.809 20.55	$\frac{1}{4}$ 4.8	3 76.2	$\frac{1}{4}$ 20.6	1 $\frac{3}{4}$ 48.4	2.12 1.98 1.89 1.78 1.78	0.962 0.898 0.857 0.807 0.807	5630 25000	10800 48000	

⁽¹⁾ Bore tolerance is nominal to $+.0005$ ", $.013$ mm

⁽²⁾ Spherical O.D. outer ring width is $.472$ ", 12 mm

⁽³⁾ Spherical O.D. outer ring width is $.551$ ", 14 mm

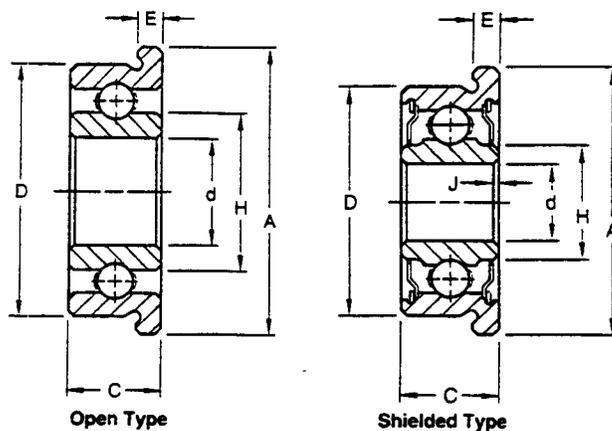
⁽⁴⁾ Spherical O.D. outer ring width is $.827$ ", 21 mm

Flanged Series

CYLINDRICAL O.D.

Four sizes in the cylindrical O.D. series are offered in a flanged construction. Flanged bearings have integral shoulders for mounting in through-bored housings. These flanged bearings have straight outside diameters and are interchangeable with the corresponding unflanged sizes. The flanged group is available with double shields.

These bearings are electric motor quality for applications where extra quietness is a requirement.



DIMENSIONS - TOLERANCES

Bearing Number	Bore d		chamfer J x 45°		Outside Diameter D		Width C		Inner Ring Shoulder		Flange				Shielded Type Overall Width				Wt		Static Load Rating C ₀		Extended Dynamic Load Rating C _E		
	open	shielded*	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	lbs.	kg.	lbs.	N	lbs.
F33K3	F33KDD3	0.1250	3.175	0.012	0.30	0.3750	9.525	0.156	3.96	0.202	5.13	0.440	11.18	0.030	0.76	0.156	3.96	0.183	4.65	0.01	0.005	48	212	160	710
F33K5	F33KDD5	0.1875	4.762	0.012	0.30	0.5000	12.700	0.156	3.96	0.270	6.86	0.565	14.35	0.042	1.07	0.196	4.98	0.248	6.30	0.01	0.005	110	490	325	1430
FS1K7	FS1KDD7 ⁽¹⁾	0.2500	6.350	0.012	0.30	0.6250	15.875	0.196	4.98	0.349	8.86	0.690	17.53	0.042	1.07	0.196	4.98	0.332	8.43	0.01	0.005	125	560	365	1630
FS3K	FS3KDD ⁽¹⁾	0.3750	9.525	0.016	0.41	0.8750	22.225	0.219	5.56	0.517	13.13	0.969	24.61	0.062	1.57	0.281	7.14	0.475	12.06	0.02	0.009	310	1400	830	3650

⁽¹⁾ Also available in stainless steel. To specify, add prefix "A" before bearing number.

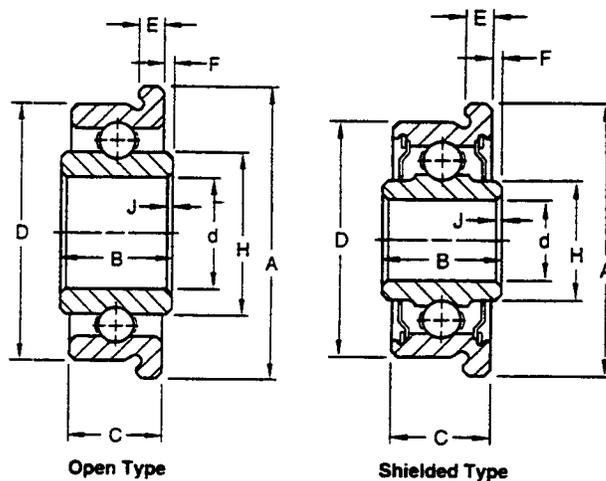
* Also available with two contact seals. To specify, replace "KDD" in part number with "PP".

TAPERED O.D.

The F Flanged Series has shoulders integral with the bearings for mounting in through-bored housings. They are used where compactness is essential or where it is not desirable to machine housing shoulders. All sizes in this series have tapered outside diameters, and all are available with double shields.

These bearings are particularly suitable for such applications as precision instruments, packaging machinery, motion picture projectors and the like. Several sizes in this series are manufactured in both standard bearing quality, chromium-alloy, high carbon steel and stainless steel, as indicated in the tables. To specify stainless steel, use the prefix A before the basic bearing number. Example: AF4.

These bearings are electric motor quality for applications where extra quietness is a requirement.



DIMENSIONS - TOLERANCES

Bearing Number	Bore d		chamfer J x 45°		Outside Diameter D		Ring Widths				Flange				Wt		Static Load Rating C ₀		Extended Dynamic Load Rating C _E								
	open	shielded	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	lbs.	kg.	lbs.	N	lbs.	N	
F2 ⁽¹⁾	—	0.1875	4.762	0.010	0.25	0.4382	11.130	0.189	4.80	0.016	0.41	0.273	6.93	0.163	4.14	0.080	2.03	0.500	12.70	0.042	1.07	0.01	0.005	106	465	260	1160
—	F2DD-2	0.1250	3.175	0.010	0.25	0.3757	9.534	0.188	4.77	0.015	0.38	0.181	4.60	0.163	4.14	0.075	1.90	0.438	11.13	0.037	0.94	0.01	0.005	48	212	160	710
F3	—	0.1675	4.762	0.010	0.25	0.5632	14.305	0.218	5.54	0.015	0.38	0.273	6.93	0.195	4.95	0.080	2.03	0.625	15.88	0.042	1.07	0.01	0.005	110	490	325	1430
—	F3DD	0.1875	4.762	0.010	0.25	0.5632	14.305	0.250	6.35	0.015	0.38	0.245	6.22	0.226	5.74	0.068	1.73	0.625	15.88	0.042	1.07	0.01	0.005	110	490	325	1430
F4	F4DD	0.2500	6.350	0.010	0.25	0.6257	15.893	0.250	6.35	0.015	0.38	0.331	8.41	0.226	5.74	0.068	1.73	0.687	17.45	0.042	1.07	0.01	0.005	125	560	365	1630
F5	FSDD	0.3125	7.938	0.010	0.25	0.6882	17.480	0.250	6.35	0.015	0.38	0.410 ⁽²⁾	10.41	0.226	5.74	0.068	1.73	0.750	19.05	0.042	1.07	0.01	0.005	196	865	540	2400

⁽¹⁾ Full type, no retainer. Not recommended for speeds over 500 RPM.

⁽²⁾ H dimension is .381" (9.68 mm) for FSDD.

⁽³⁾ Land dimension of the inner ring.

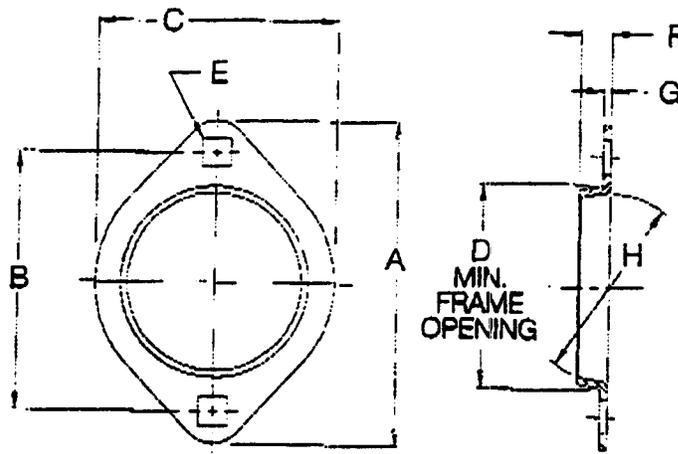
General Flangette Information

LUTCO is the largest manufacturer of precision flangettes in North America. With an extensive tooling inventory, we are able to offer a wide variety of standard and custom units.

Fit and surface contact between the flangettes and the bearing contribute to the life of the assembly. By allowing the bearing to misalign in the housing under a predetermined torque, premature failure can be eliminated. Sophisticated measuring and torque rating equipment are employed to provide statistical process control, through charting and minimum 1.0 CPK values.

For more specific information on the processes utilized, please contact the factory.

2 Bolt Self-Aligning Flangettes



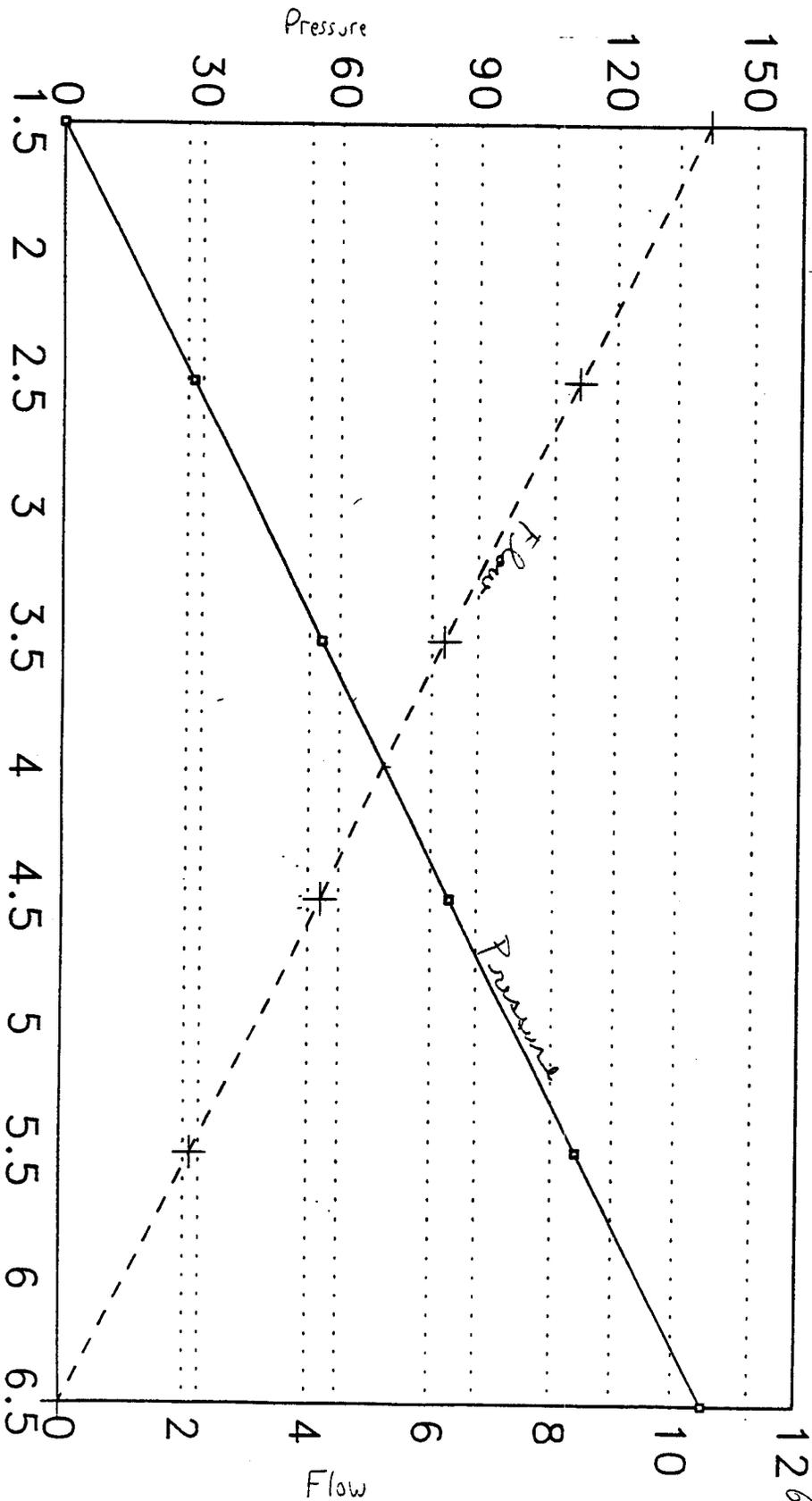
PART NUMBER	A	B	C	D	E	F	G	H	RADIAL LOAD LBS. N	UNIT WT. LBS.
	in. mm	in. mm	in. mm	in. mm	in. mm	in. mm	in. mm	nom. mm		
2 BOLT										
35MST	2 ⁷ / ₁₆ 73.0	2 ¹ / ₂ 63.50	2 ⁵ / ₁₆ 58.74	1 ⁵ / ₈ 41.28	9 ³ / ₃₂ 7.14	7 ¹ / ₃₂ 5.54	0.054 1.37	35	350 1556	0.06
40MST	3 ³ / ₁₆ 80.96	2 ¹ / ₂ 63.50	2 ⁵ / ₁₆ 58.74	1 ⁷ / ₈ 47.63	9 ³ / ₃₂ 7.14	9 ³ / ₃₂ 7.14	0.075 1.905	40	750 3100	0.08
47MST	3 ⁵ / ₁₆ 90.49	2 ¹³ / ₁₆ 71.44	2 ⁵ / ₈ 66.68	2 ³ / ₁₆ 55.56	1 ¹ / ₃₂ 8.73	5 ¹ / ₁₆ 7.94	0.083 2.11	47	900 3900	0.10
52MST	3 ³ / ₄ 95.25	3 76.20	2 ⁵ / ₁₆ 71.04	2 ³ / ₈ 60.33	1 ¹ / ₃₂ 8.73	1 ¹ / ₃₂ 8.73	0.083 2.11	52	1000 4450	0.11
62MST	4 ⁷ / ₁₆ 112.71	3 ³ / ₁₆ 90.49	3 ⁵ / ₁₆ 84.14	2 ¹³ / ₁₆ 71.44	1 ³ / ₃₂ 10.31	3 ³ / ₈ 9.53	0.104 2.64	62	1400 6200	0.33
72MST	4 ⁵ / ₁₆ 125.41	3 ¹⁵ / ₁₆ 100.01	3 ¹¹ / ₁₆ 93.66	3 ³ / ₁₆ 80.96	1 ³ / ₃₂ 10.31	1 ³ / ₃₂ 10.31	0.104 2.64	72	1750 7500	0.40

For Torque rated flangettes, add the prefix "T".
Add, "ZP" for standard zinc plate and "YZP" for yellow chromate finishes.
Special designs available upon request.

McCord Winn TEXTRON High Output Air Pump 12 Vdc Performance

$$\frac{N}{m^2} \times 10^3 \quad \frac{N}{m^2} \times \frac{m^3}{s} = \frac{N \cdot m}{s} = P \times F = P_{\text{aver}} \times F_{\text{aver}} = \text{Watts}$$

Pressure (kPa) Flow (L/MIN)

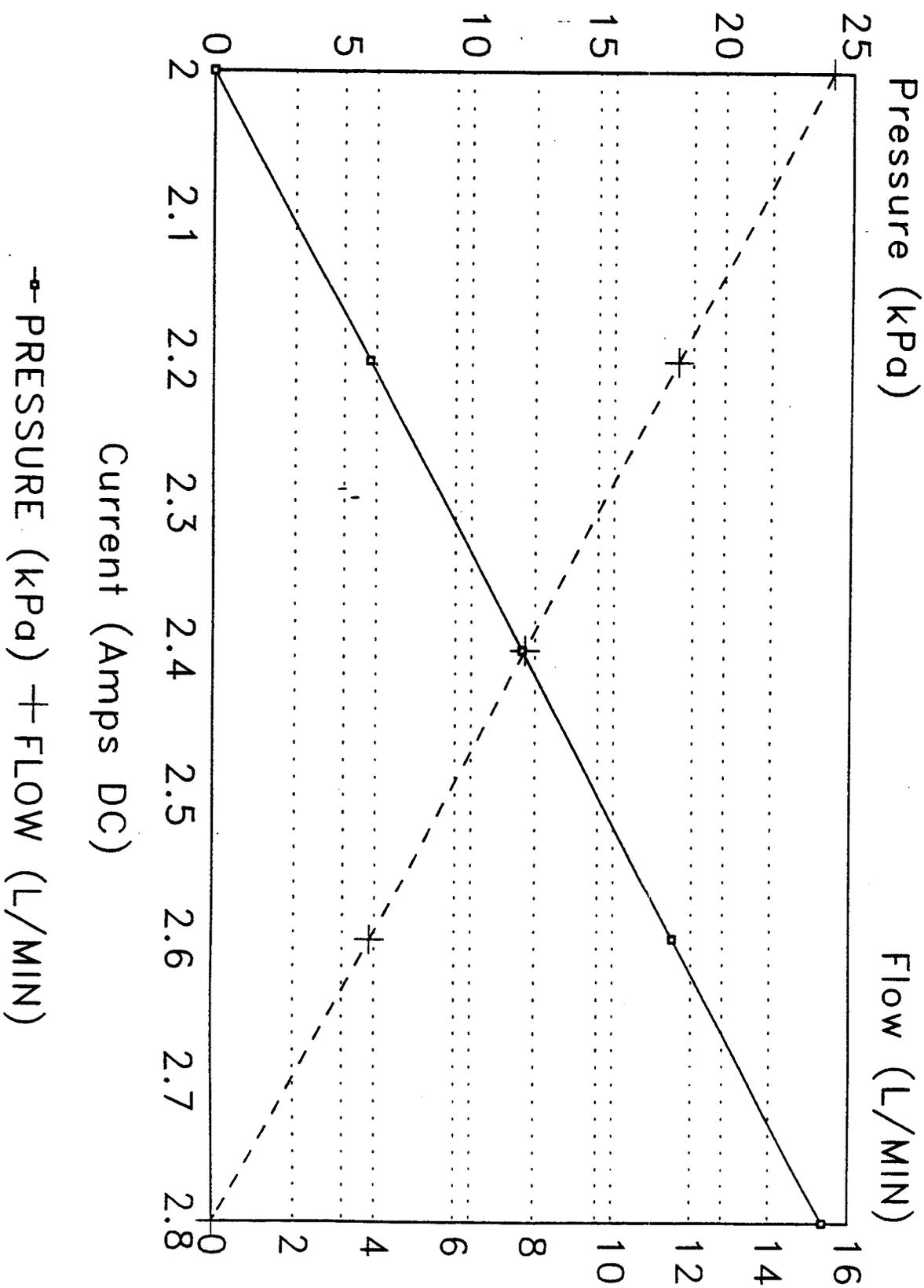


$$= \left(\frac{m^3}{min} \right) 10^{-4} = \frac{m^3}{min} \times \frac{1}{1000} = \frac{m^3}{min} \times \frac{1}{60 \times 1000} = \frac{m^3}{min} \times \frac{1}{600000}$$

Current (Amps DC)

→ PRESSURE (kPa) + FLOW (L/MIN)

McCord Winn TEXTRON
Low Pressure Pump
12.6 Vdc Performance



- Magnetic piston optional on all double acting 1 1/16" bore cylinders (except in combination with viton option).

1-1/16" BORE CYLINDER

1062D04-00A

Double Acting
Double Nose or Rear Pivot Mount

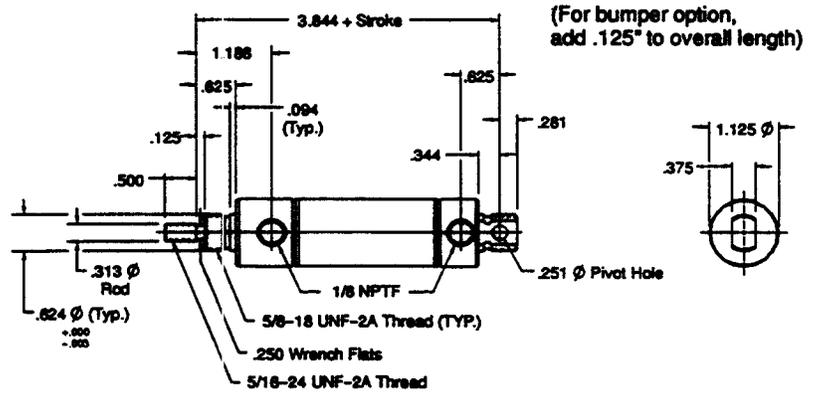
Available Stroke Lengths:

1/2", 1", 1-1/2", 2", 2-1/2", and
1" increments from 3" to 12"

Maximum Stroke: 32"

* Optional Accessories:

M117005 Mounting Bracket
M129003 Pivot Bracket
M127004 Rod Clevis



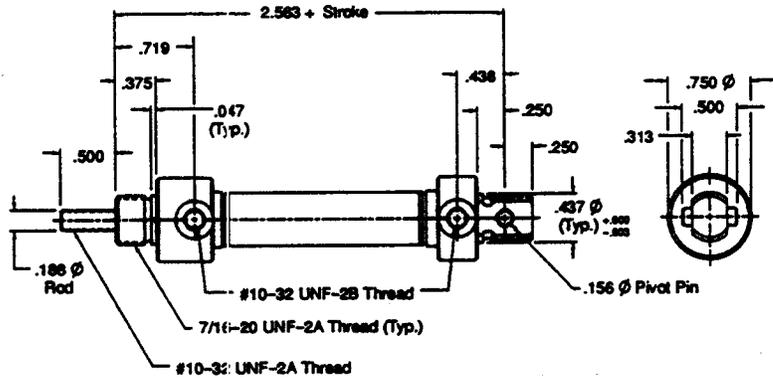
7/16" BORE CYLINDER

0438D02-00A Double Acting Rear Pivot Mount

Available Stroke Lengths:
1/2", 1", 1-1/2", 2", 2-1/2", 3", 4"

Maximum Stroke: 12"

- Optional Accessories:
M029002 Pivot Bracket
M127002 Rod Clevis

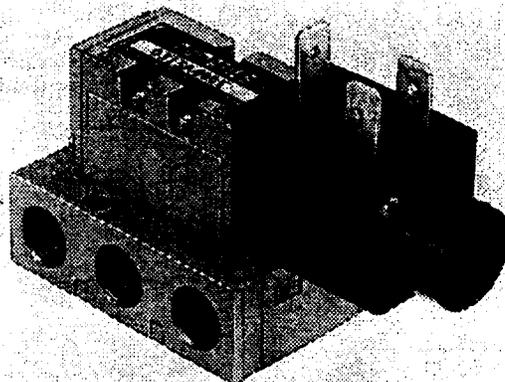




1450 North Milford Rd., Highland, Mi 48357, Phone: (810) 887-4111, Fax: (810) 887-9190

MARK 3 Series

030SA4414 and 030SS4414 Direct Acting Solenoid Valves

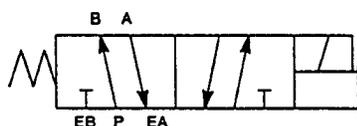


DESCRIPTION

MARK 3 miniature power valves have all of the quality features of larger Numatics valves. They contain a multi-purpose floating spool and sleeve with no dynamic rubber seals to wear out. All valves are 5-ported, 4-way, 2-position valves that may be used as 2-way, 3-way, 4-way, selector or diverter valves. They are fully balanced and pressures through the valve do not affect the solenoid force required to shift the spool.

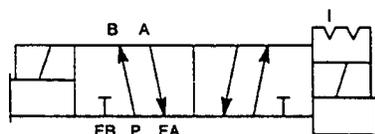
Direct solenoid actuated valves are available in two configuration:

Single solenoid, spring return valves are actuated by a "maintained" electrical signal. The spring returns the spool to the original position when the electrical signal is released.



2-Position
Single Solenoid
Spring Return

Double solenoid, detented valves are actuated by either a "momentary" or "maintained" electrical signal alternately on each solenoid. The detent holds the spool in position after electrical power is removed and prevents inadvertent spool shift due to vibration or shock.



2-Position
Double Solenoid
Detented

OPERATING DATA

TEMPERATURE RANGE:

Solenoid Valves: -10° F to +115° F ambient

PRESSURE RANGE:

Main Valve: 28" Hg. vacuum to 150 PSIG.

Pilot Pressures:

Spring Return: 15-100 PSIG

Detented: 10-100 PSIG

FLOW CAPACITY:

10-32 Ports with .109 I.D. Fitting Installed: Cv = .18

SERVICE:

Valves can be used on the following properly filtered media:

Lubricated air, dry (oil-free) air, vacuum, and noncorrosive, nontoxic, nonflammable dry gases.

ELECTRICAL:

Solenoids are continuous duty rated.

Voltage: 12 VDC

Wattage: 6.0

Time to energize:

030SA4414 .012

030SS4414 .012

Time to de-energize:

030SA4414 .006

Maximum Cycle Rate (continuous):

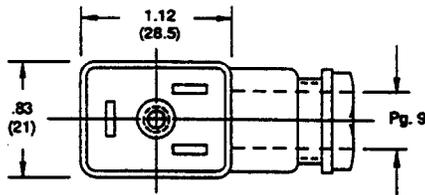
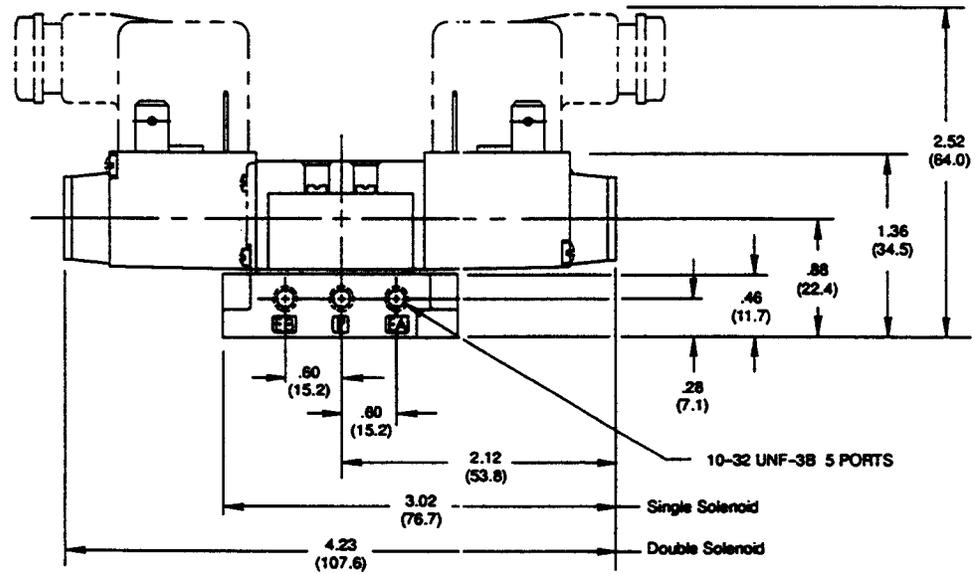
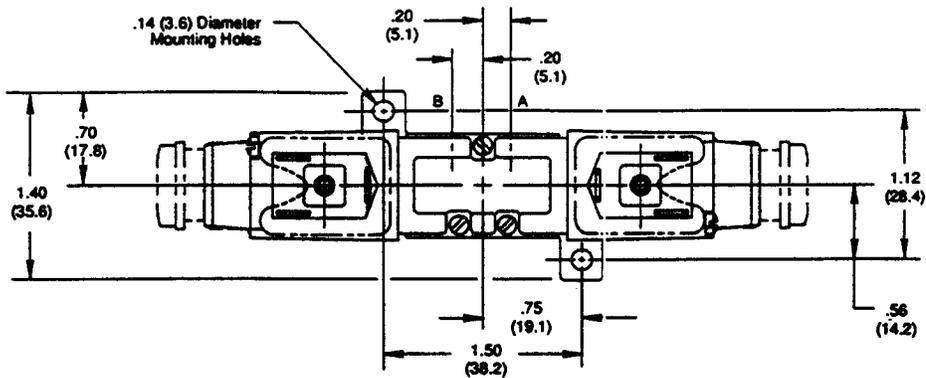
030SA4414 500 cpm

030SS4414 500 cpm

NUMATICS MARK 3 Series

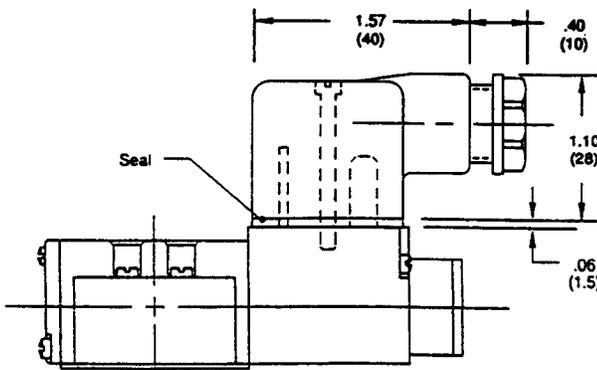
10-32 UNF-3B Side Ported Base

Top Dimension = Inches
Bottom Dimension (in parenthesis) = Millimeters



PLUG ASSEMBLIES ACCEPTS CABLE DIA. .240 TO .310

The electrical plug assembly provides a strain relief gland nut size Pg.9. This accepts cables with a diameter of .240 to .310 inches. All plugs provide a degree of protection that complies with DIN 40050. They also comply with IP65 for dust tightness and water resistance. Plugs are available either black, grey, or translucent with a built-in indicator light.



Plug assemblies are supplied, as shown, with the cord hub exiting away from the valve. The plug insert is reversible. This allows the assembly to be reversed 180°, if desired.

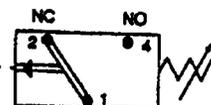
PRESSURE SWITCHES

► APPLICATION

Numatics PS180 is a new line of pressure switches designed for accurate indication that proper system pressure is being achieved. Available in 1/8 or 1/4 threads, it is easily incorporated into an air system using a Flexiblok® diverter plate or other manifold.

With its rugged housing made from zinc coated steel, the PS180 is designed for industrial multi-million cycle life applications. The four pin connector plug is included and contains a key way preventing accidental misconnection. Pressure adjustment is tamper resistant hindering unauthorized changes. It can be wired in either normally open or normally closed configurations and includes a case ground pin.

normally open or normally closed



ANSI SYMBOL

► SPECIFICATIONS

- Contact Rating: 4 A @ 250 VAC
- Protection: IP 65, terminals IP00
- Maximum Operation: 200/min.
- Temperature Range: 0°F to 190°F / -15°C to 85°C
- Maximum Pressure: 300 PSI / 20 BAR
- Maximum Voltage: 250 VAC / 200 DC
- Hysteresis Adjustment: 15%
- Connector Material: Polyamid
- Diaphragm Material: Buna N
- Housing Material: Zinc Plated Steel



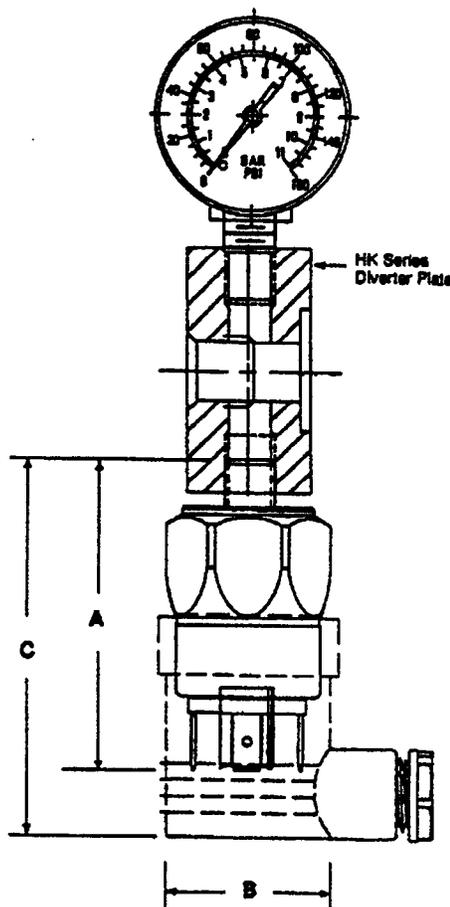
► MODEL SELECTION

Part number includes connector cap.

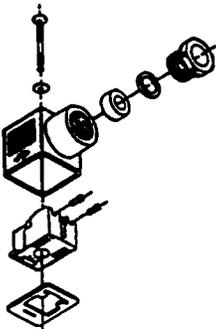
thread	model no.	PSIG	dimensions		
			A	B	C
NPT	PS180				
* 1/8	PS180BAN01	4-20 (0.3-1.5 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/8	PS180CAN01	14-150 (1-10 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/4	PS180BAN02	4-20 (0.3-1.5 bar)	2.5 (64)	1.0 (27)	3.1 (79)
1/4	PS180CAN02	14-150 (1-10 bar)	2.5 (64)	1.0 (27)	3.1 (79)
thread	model	PSIG	dimensions		
G	PS180CAG		A	B	C
1/4	PS180BAG02	4-20 (0.3-1.5 bar)	2.3 (58)	1.0 (27)	2.9 (74)
1/4	PS180CAG02	14-150 (1-10 bar)	2.3 (58)	1.0 (27)	2.9 (74)

Replacement Connector Cap: Model No. PSC180

dimension = inches; (in parentheses) = millimeters



SOLENOID CONNECTOR



STRAIN RELIEF



CONDUIT

WIRING

NO. 1 TERMINAL POWER (+)
NO. 2 TERMINAL NEUTRAL (-)
THIRD TERMINAL IS FOR GROUND \perp

F-2804 Series Check Valves



The F-2804 Series Check Valves permit flow in one direction only. The operation of the check valve is based on the movement of a small disc. The disc shifts within the housing as the pressure differential changes from forward to reverse. A flat surface on one side of the disc seals off flow, while the other side allows flow to pass.

Two models are available from the Standard Units, F-2804-401, 402 & 403 to the High Flow Unit, F-2804-404.

The advantages of the check valve design is the low "cracking pressure", minimum differential required for forward flow, which is less than 0.005 PSI differential in the Standard Units. Secondly, there is no residual pressure difference across the check valve once flow has ceased. Flow in the forward direction is relatively unrestricted, approximately equivalent to the restriction of a 0.040 inch orifice in the Standard Units. The amount of flow permitted in the reverse direction, which is the sealing side, and the forward direction, which is full flow, is shown in the graphs below.

ORDERING INFORMATION (Order by model number and specify accessory letters required.)

F-2804 - 404 - B85

Model	Color	Accessories
F-2804-401	Orange	B80—Barbs for 1/16" I.D. tubing B85—Barbs for 1/8" I.D. tubing No accessory numbers required for straight ports
F-2804-402	Green	
F-2804-403	Blue	
F-2804-404	Black	B80—Barbs for 1/16" I.D. tubing B85—Barbs for 1/8" I.D. tubing 10-32 threads. No accessory numbers required.

FEATURES

- Minimum Cracking Pressure
- Miniature Size
- Low Cost

SPECIFICATIONS

- Maximum Supply: F-2804-401 • 10 PSI
 F-2804-402 • 10 PSI
 F-2804-403 • 10 PSI
 F-2804-404 • 75 PSI
- Operating Temperature: 40° to 120°F. (5° to 48°C.)
 Recommended Filtration: 5 micron
- Cracking Pressure: F-2804-401 • Less than .8" H₂O
 F-2804-402 • Less than .8" H₂O
 F-2804-403 • Less than .8" H₂O
 F-2804-404 • Less than 10" H₂O

MATERIALS

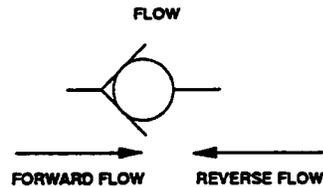
- Housing: Polysulfone
- Disc: F-2804-401 • Calcon Disc
 F-2804-402 • Calcon Disc
 F-2804-403 • Silicone
 F-2804-404 • Silicone

MOUNTING

Inline

PORT CONNECTIONS

Straight ports for 1/16" I.D. flexible tubing
 Barbs for 1/16" or 1/8" I.D. flexible tubing
 The F-2804-404 has 10-32 Threads

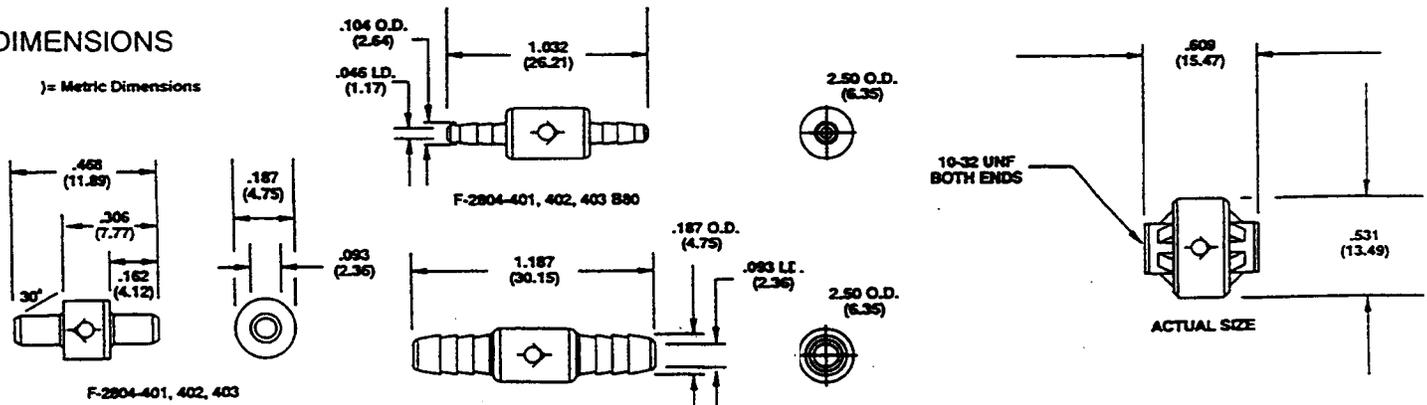


TYPICAL FLOW CHARACTERISTICS

Model	Cracking Pressure (PSI)	Flow (SCFM) at 1 PSI Supply
F-2804-401	Less than 2.96	0.12 SCFM 1 PSI Supply
F-2804-402	Less than 1.00	
F-2804-403	Less than 0.20	
F-2804-404	Less than 0.06	2.0 SCFM 75 PSI Supply

DIMENSIONS

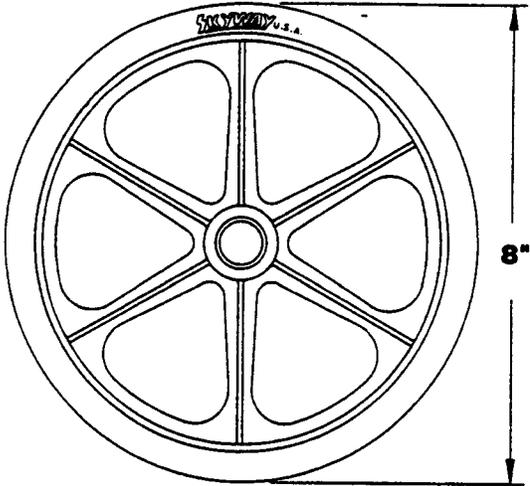
() = Metric Dimensions



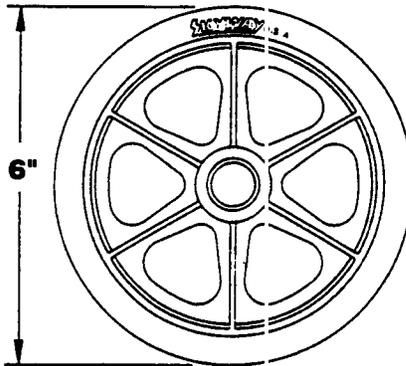


4451 Caterpillar Rd., Redding, CA 96003
916/243-5151 (FAX 916/243-5104)

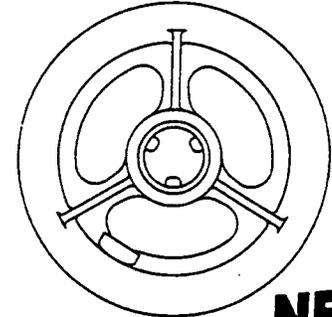
STANDARD UTILITY WHEELS
WHEELCHAIR WHEEL ACCESSORIES
WHEELCHAIR WHEELS
CASTER WHEELS



**8" CASTER
NON-PNEUMATIC**



**6" CASTER
NON-PNEUMATIC**



NEW

**5" CASTER
PNEUMATIC OR
NON-PNEUMATIC**

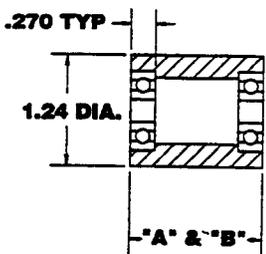
SKYWAY 6" and 8" Non-Pneumatic caster wheels feature a molded DuPont ZYTEL® nylon wheel with a coinjected Monsanto Santoprene® thermoplastic rubber molded-in tire.

Accepts 6" x 1-1/4" Pneumatic Tires. Also Accepts Various 5" & 6" Non-Pneumatic Snap-On Tires. Available Only In Hub #1. 1" Precision Bearing.

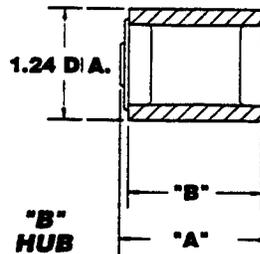
CASTER HUB SPECIFICATIONS

Hub configurations shown are SKYWAY standards, however, if you require a custom design, we stand ready to work with you to create a special hub to suit your needs.

5" Caster Only Available with Standard Hub #1, 1" Overall Width.



HUB #1
Precision Bearing Hub
7/8" O.D. Maximum x 5/16" and 3/8" I.D.'s



HUB #2
Unground, Flanged Bearing Hub
.906 O.D. Maximum x 1/4", 5/16", 3/8" and 7/16" I.D.'s

	BASIC OVERALL	"A" ACROSS BEARING REFERENCE	"B" HUB WIDTH
PRECISION BEARING			
HUB #1 For 5", 6" & 8" casters only	1"	.99	.98
HUB #1 For 6" & 8" casters only	1-1/2"	1.50	1.48
HUB #1 For 6" & 8" casters only	2-3/16"	2.18	2.17
UNGROUND, FLANGED BEARING			
HUB #2 For 6" & 8" casters only	1"	1.23	.98
HUB #2 For 6" & 8" casters only	2-3/16"	2.43	2.17
HUB #2 For 6" & 8" casters only	1-1/2"	1.73	1.48

While we recommend uses for our products based on tests done in laboratories we in no way guarantee particular methods of use or applications or performance when installed or made to operate under special conditions. Skyway has a policy of continuous improvement of products and reserves the right to make improvements or changes on products without notice.

NATWELD

CARBON & LOW ALLOY BARE STEEL WELDING WIRE

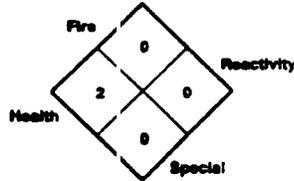
NO: 119

Material Safety Data Sheet

IN COMPLIANCE WITH OSHA'S HAZARD COMMUNICATION STANDARD 29CFR 1910.1200

Manufacturers Name:
National Welding Alloys, Inc.
1600 South Canal Street
Pittsburgh, PA 15215

HAZARD RATING
4 = EXTREME
3 = HIGH
2 = MODERATE
1 = SLIGHT
0 = INSIGNIFICANT



Date issued: 8/1/90
Date Revised:
Emergency Phone Numbers:
Natweld: (412) 781-4255
Chemtec: 800-424-9300

This Material Safety Data Sheet (MSDS) provides information on a specific group of manufactured metal products.
The following alloys can be found on this MSDS: See Section II and Section VI for important health hazard data.

SECTION I — MATERIAL IDENTIFICATION

TRADE NAME	APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)									
	Al	C	Cu	Fe	Mn	P	Si	S	Ti	Zr
Bare Wire RG 45	0.02	0.08	0.30	Balance	0.50	.035	0.10	0.04	---	---
Bare Wire RG 60	0.02	---	0.30	Balance	0.90-1.40	.035	0.10-0.35	.035	---	---
Bare Wire RG 65	0.02	---	---	Balance	---	.035	---	.035	---	---
Bare Wire ER70S-2	0.05-0.15	0.07	0.50	Balance	0.90-1.40	.025	0.40-0.70	.035	0.05-0.15	0.02-0.12
Bare Wire ER70S-3	---	0.06-0.15	0.50	Balance	0.90-1.40	.025	0.45-0.70	.035	---	---
Bare Wire ER70S-6	---	0.07-0.15	0.50	Balance	1.40-1.85	.025	0.80-1.15	.035	---	---

TRADE NAME	APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)									
	C	Cr	Fe	Mn	Mo	Ni	P	Si	S	V
Bare Wire 4130	0.31	0.93	Balance	0.52	0.20	---	.012	0.28	.023	---
Bare Wire 4140	0.40	1.03	Balance	0.87	0.20	0.09	.007	0.26	---	---
Bare Wire 8620	0.20	0.51	Balance	0.81	0.22	0.52	.015	0.25	.023	---

TRADE NAME	APPROXIMATE CHEMICAL COMPOSITION - % (Single figures are maximum)									
	C	Cr	Cu	Fe	Mn	Mo	Ni	P	Si	S
Bare Wire ER80S-B2	0.07-0.12	1.20-1.50	0.35	Balance	0.40-0.70	(0.40-0.65	0.20	.025	0.40-0.70	.025
Bare Wire ER80S-B2L	0.05	1.20-1.50	0.35	Balance	0.40-0.70	(0.40-0.65	0.20	.025	0.40-0.70	.025
Bare Wire ER90S-B3	0.07-0.12	2.30-2.70	0.35	Balance	0.40-0.70	(0.90-1.20	0.20	.025	0.40-0.70	.025
Bare Wire ER90S-B3L	0.05	2.30-2.70	0.35	Balance	0.40-0.70	(0.90-1.20	0.20	.025	0.40-0.70	.025
Bare Wire ER80S-D2	0.07-0.12	---	0.50	Balance	1.60-2.10	(0.40-0.60	0.15	.025	0.50-0.80	.025
Bare Wire ER100S-1	0.08	0.30	0.25	Balance	1.25-1.80	(0.25-0.55	1.40-2.10	0.01	0.20-0.50	0.01
Bare Wire ER110S-1	0.09	0.50	0.25	Balance	1.40-1.80	(0.25-0.55	1.95-2.60	0.01	0.20-0.55	0.01
Bare Wire ER120S-1	0.10	0.60	0.25	Balance	1.40-1.80	(0.30-0.65	2.00-2.80	0.01	0.25-0.60	0.01

SECTION II — HAZARDOUS CONSTITUENTS

IMPORTANT — Welding electrodes are a non-hazardous solid at ambient temperatures. This section covers the materials from which these products are manufactured. The fumes and gases produced while welding during normal use of these products are covered in Sections V and VI.

BARE WIRE

HAZARDOUS COMPONENTS	CAS NO.	OSHA PEL mg/m ³	ACGIH TLV mg/m ³	STEL mg/m ³
*Chromium (VI)	7440-47-3	1.0C	0.50	---
*Nickel	7440-02-0	1.0C	1.00	---
Aluminum	7429-80-5	15.C	10.0	---
Carbon	1333-86-4	3.5C	3.50	---
Manganese	7439-96-5	5.00 (ceiling)	5.00 (ceiling)	---
Molybdenum (soluble)	7439-98-7	5.0C	5.00	---
Iron (oxide fume)	1309-37-1	10.C	5.00	---
Phosphorus	7723-14-0	0.1C	0.10	---
Zirconium	7440-67-7	5.0C	5.00	10.0
Silicon	7440-21-3	15.C	10.0	---
Sulfur	7446-09-05	13.C	5.00	13.0
Copper (fume)	7440-50-8	1.0C	1.00	---
Thallium	7440-28-0	0.1C	0.10	---
Vanadium	1314-62-1	0.50 (ceiling)	0.05	---

SUBSTANCES OF VARIABLE COMPOSITION

HAZARDOUS COMPONENTS	CAS NO.	OSHA PEL mg/m ³	ACGIH TLV mg/m ³	STEL mg/m ³
Welding Fume	NOC	---	5.00	---

* SUBSTANCE IDENTIFIED BY OTHER SOURCES AS A SUSPECTED OR CONFIRMED HUMAN CARCINOGEN

SECTION III — PHYSICAL DATA

Solid wire or rod, grey to copper in color.

SECTION IV — FIRE AND EXPLOSION DATA

FLASH POINT (WITH TEST METHOD): None **FLAMMABLE (EXPLOSIVE) LIMITS V/V%** **LEL:** None **UEL:** None

EXTINGUISHING MEDIA: This alloy is noncombustible. Use extinguishing media appropriate to the surrounding fire.

SPECIAL FIRE FIGHTING PROCEDURES: If this material is reduced to powder form, caution must be used to prevent fire or explosion. To extinguish a metal powder fire use dry sand, dry graphite or other class "D" fire extinguishing powder.

UNUSUAL FIRE AND EXPLOSION HAZARD: No unusual fire or explosion hazards are associated with this material.

INCOMPATIBILITY (MATERIALS TO AVOID): Avoid contact with mineral acids and oxidizing agents which may generate hydrogen gas; the evolution of hydrogen may be an explosion hazard.

HAZARDOUS DECOMPOSITION PRODUCTS: Various elemental metals and metal oxides may be generated from melting or gross handling operations. Refer to Section II for permissible exposure limits.

SECTION V — HEALTH HAZARD DATA — CARBON & LOW ALLOY BARE STEEL WELDING WIRE

Welding generates fumes, gases and electromagnetic radiation with known adverse health effects. The composition of welding emissions varies substantially with the welding process.

Exposure: Section I lists normal composition of aluminum welding wire. Section II lists exposure limits for hazardous decomposition products which might be present in fume generated during welding or brazing. Actual exposure should be determined by monitoring fume in the operator's breathing zone.

Possible Effects of Exposure: Short term exposure to welding fume may result in discomfort, dizziness, nausea and dryness or irritation of the throat. Long term exposure to welding fume, gases or dust may contribute to pulmonary irritation or pneumoconiosis. Long term exposure to iron fume may produce siderosis, which is generally regarded as benign. Nickel and chromium should be considered a possible carcinogen per OSHA, 29CFR 1910.1200. Certain nickel compounds have been implicated based on experience in some nickel refining operations. The specific compounds, however, have not been determined and a direct association between nickel in welding fume and cancer has not been demonstrated. Some compounds of hexavalent chromium have been reported to be carcinogenic. No clear association, however, has been established between chromium in welding fume and the development of cancer. Exposure limits should be maintained below the levels listed in Section II.

Routes of Entry: (1) Inhalation of Fume (2) Burns from Electromagnetic Radiation

Pre-existing Medical Condition: Individuals with impaired pulmonary function or illness may have symptoms exacerbated by irritants contained in welding fumes.

SECTION VI — REACTIVITY DATA

Hazardous Decomposition Products

Exposure Limits: Welding fumes and gases cannot be classified simply. The composition and quantity of both are dependent upon the metal being welded, the process, procedure and electrodes used. Other conditions which also influence the composition and quantity of the fumes and gases to which workers may be exposed include: coatings on the metal being welded (such as paint, plating or galvanizing), the number of welders and the volume of work area, the quality and amount of ventilation, the position of the welder's head with respect to the fume plume, as well as the presence of contaminants in the atmosphere (such as chlorinated hydrocarbon vapors from cleaning and degreasing activities).

When the electrode is consumed, the fume and gas decomposition products generated are different in percent and form from the ingredients listed in Section II. Fume and gas decomposition products, and not the ingredients in the electrode, are important. The concentration of a given fume or gas component may decrease or increase by many times the original concentration in the electrode. Also, new compounds not in the electrodes may form. Decomposition products of normal operation include those originating from the volatilization, reaction or oxidation of the materials shown in Section II, plus those from the base metal and coating, etc., as noted above.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5mg/m³. That which does, should be controlled.

SECTION VII — SPILL OR LEAK PROCEDURES

NOT APPLICABLE

SECTION VIII — SPECIAL PROTECTION INFORMATION

Ventilation: Use enough ventilation, local exhaust at the arc (or flame), or both, to keep the fumes and gases below PEL's, TLV's or STEL's in the worker's breathing zone and the general area. Train the employee to keep his head out of the fumes. See ANSI/ASC Z49.1 Section 5.

Respiratory Protection: Use respirable fume respirator or air supplied respirator when welding, brazing or soldering in confined space or where local exhaust or ventilation does not keep exposure below PEL, TLV or STEL.

Eye Protection: Wear helmet or use face shield with filter lens of appropriate shade number (see ANSI/ASC Z49.1 Section 4.2). Provide protective screens and flash goggles, if necessary, to shield others.

Protective Clothing: Wear head and body protection which help to prevent injury from radiation, sparks, flame and electrical shock. See ANSI Z49.1. At a minimum this includes welder's gloves and a protective face shield, and may include arm protectors, aprons, hats, shoulder protection, as well as dark substantial clothing. Train the employee not to touch live electrical parts and to insulate himself from work and ground. Welders should not wear short sleeve shirts, short pants or cutoffs.

Waste Disposal Method: Prevent waste from contaminating surrounding environment. Discard any product, residue, disposable container or liner in an environmentally acceptable manner, in full compliance with federal, state and local regulations.

Emergency First Aid: Remove from dust or fume exposure. If breathing has stopped perform artificial respiration. Summon medical aid immediately.

Read and understand the manufacturer's instructions and the precautionary label on the product. See American National Standard Z49.1, *Safety in Welding and Cutting* published by the American Welding Society, P.O. Box 351040, Miami, FL 33135 and OSHA publication 2206 (29CFR 1910), U.S. Government Printing Office, Washington D.C. 20402 for more detailed information.

SECTION IX — SPECIAL PRECAUTIONS

Other Precautions: Use exhaust system to clear welding fumes. Make sure that inhaled air does not contain fume constituents above permissible levels.

NOTE: For other precautions or additional safety information on welding and cutting, see American Standard Z49.1-1980, *Safety In Welding and Cutting*, and the *Welding Handbook*, Volume 1, Chapter 9, *Safe Practices In Welding and Cutting*, both available from the American Welding Society, Inc. 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135, Telephone number (305) 443-9353.

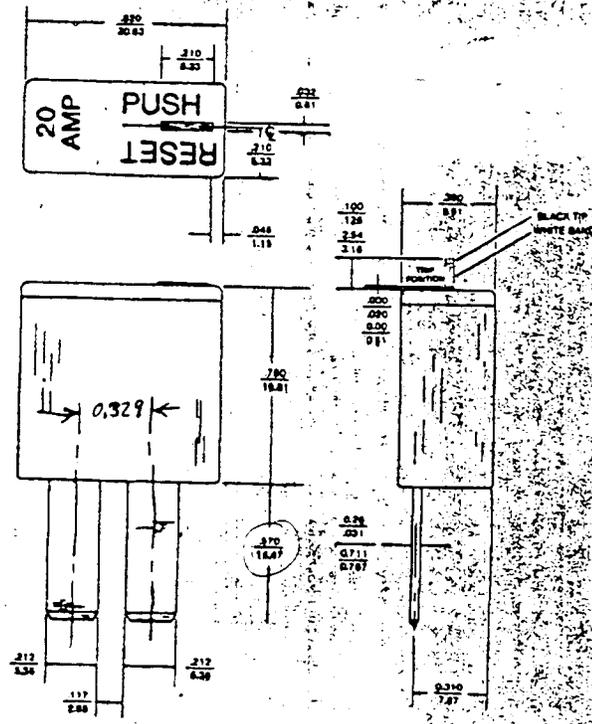
TOMORROWS STANDARD - AVAILABLE TODAY

QUALITY:

- Snap Action sensor provides increasing contact pressure to effect trip, and promotes wiping action of contacts.
- Trip time of 2.6 to 6.5 seconds with 200% overload for all ratings.
- Precise correlation of trip time to rating in any unit.
- Must hold 100% — must trip 135%
- Withstands normal start-up and short duration surges without nuisance tripping.
- Fast response time.
- Unusual tolerance to vibration and shock environment.
- 100% final inspection test before the name goes on.

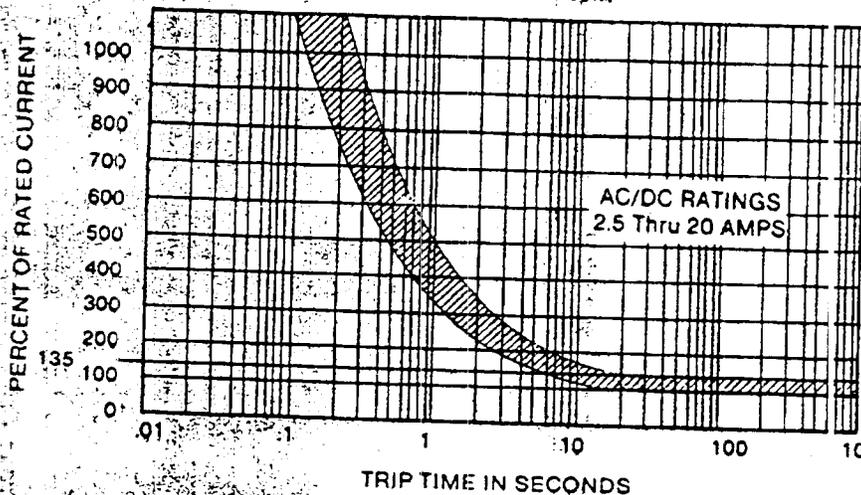
FEATURES:

- Housed in engineering plastic (non-corrosive - U.L. rated 94VO).
- Visual trip indicator is push to rest (Model VB3-M).
- SAE Type (self-resetting) has well defined open/close cycle on over-load. (Model VB3-A)
- Cannot be held manually closed (trip free).
- Ambient compensated (to 40°C).
- Introduces new convenience and quality to circuit protection.



400

Time vs. Current



SPECIFICATIONS

- MODELS:** VB3-A Cycling (SAE Type I), VB3-M Manual, reset non-cycling new concept (SAE Type II)
- VOLTAGE:** Up to 50 V.D.C.
- RATINGS:** 3 thru 20 AMPS
- TEMPERATURE COMPENSATION:** To 40°C
- CALIBRATION:** Must carry rated current at 25°C & 40°C. Must trip 135% of rating within ten minutes.
- RESET TIME:** Less than 15 seconds.

25 & 30 AMPS. NOW AVAILABLE

ORDERING INFORMATION

EXAMPLE: VB3- M20 -F57

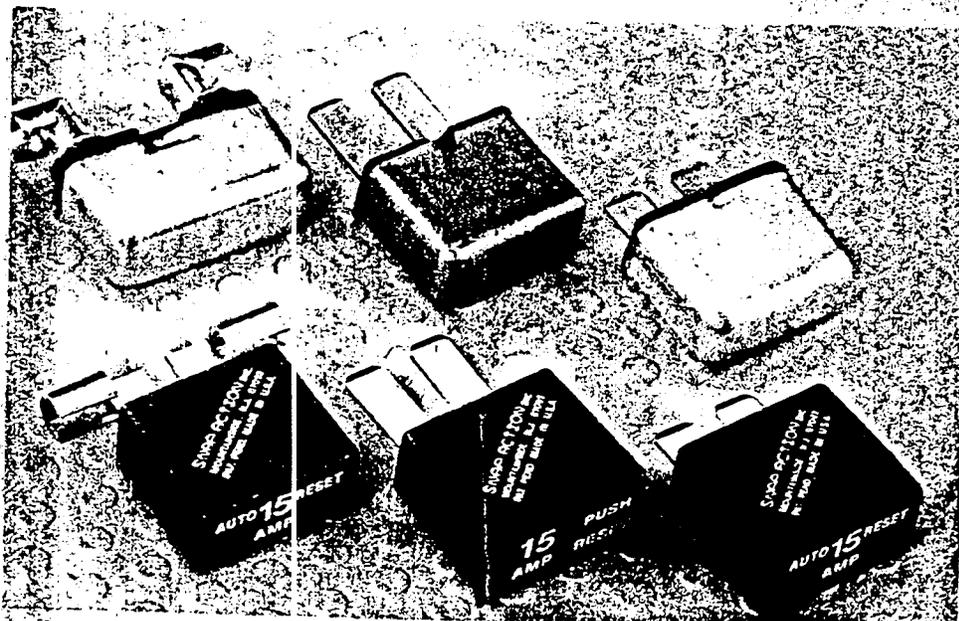
SERIES NUMBER: _____

TYPE RESET: A (automatic),
M (manual)

AMP RATING: 3 thru 20 _____

TERMINAL CONFIGURATION: F57
standard (flat .570x.110x.032). Consult factory for other terminal designs and modifications.

AUTO - TRUCK - RV's
AVIATION - MARINE
GENERATORS - BATTERY CHARGES
AND MANY OTHER
AC OR DC APPLICATIONS



MODEL VB3 REPLACES SENSORS WHICH LOSE CONTACT PRESSURE

SECTION X — DISCLAIMER OF LIABILITY

As the conditions or methods of use are beyond our control, we do not assume any responsibility and expressly disclaim any liability for any use of this material. Information contained herein is believed to be true and accurate but all statements or suggestions are made without any warranty, expressed or implied, regarding accuracy of the information, the hazards connected with the use of the material or the results to be obtained from use thereof.

References:

Air Contaminants — Permissible Exposure Limits
Title 29 Code of Federal Regulations Part 1910.1000

Threshold Limit Values and Biological Exposure Indices for 1989-1990 Second Printing
American Conference of Governmental Industrial Hygienists

Code of Federal Regulation
Parts 1900 to 1910 Revised July 1, 1988

Operator's Manual for Oxyfuel Gas Cutting
ANSI/AWS C4.2-90 An American National Standard

Effects of Welding on Health — VI
Prepared for: Safety and Health Committee of the American Welding Society

OSHA: Employee Workplace Rights
U.S. Dept. of Labor, OSHA 3071 Revised

Respiratory Protection
U.S. Dept. of Labor, OSHA 3079 Revised 1988

Modern Welding
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National Welding Alloys, Inc. A Division of National Torch Tip Co., Inc.

Reed Switch Specification



SERIES FR2

Clare

Over the past three decades, billions of reed switches have been used in hundreds of applications. Operating in microseconds, they are quiet in operation and need little or no energy for actuation. When driven with an electromagnetic coil, reed switches can accumulate millions of fault-free operations at speeds up to 500 Hz continuously. Reed switches actuated by permanent magnets may lay poised for years, even in hostile environments, and operate perfectly when called upon.

Enhancements made by Clare to reed switch design and manufacturing processes have opened exciting new application possibilities. With more than 30 years experience in reed switch manufacturing, Clare is the world leader in glass-sealed contact technology. Clare DYAD reed switches deliver immediate improvements in end user yields and productivity.

The CLARE FR2 series reed switch is trademarked the DYAD. Unique features of the DYAD include:

- Patented glass to metal seal provides a stronger hermetic seal. Glass breakage is virtually eliminated.
- Sputtered ruthenium contacts provide stable contact resistance throughout life.
- Bifurcated contacts reduce bounce on closure offering faster momentary action and longer life.
- Flat glass dampens the kinetic energy of the blades on opening, virtually eliminating reclosure.
- Flat leads offer more reliable solder, weld, or crimp joints.
- Flat glass and flat leads also lend themselves to surface mount processing capability.

Specifications

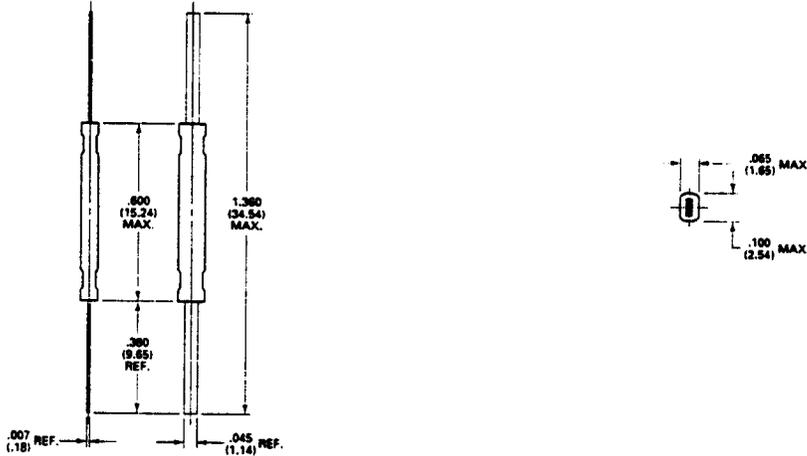
Clare

PHYSICAL AND MECHANICAL REQUIREMENTS	
■ Contact Form	SPST, Form A (center gap)
■ Contact Material	Ruthenium
■ Standard Overall Length	1.360 inches (34.54mm)
■ Maximum Glass Length	0.600 inches (15.24mm)
■ Terminals*	Nickel iron alloy 52
■ Test Coil	NARM I test coil: See page 3 for details
CONTACT RATING	
■ Maximum Switching Power	10 VA
■ Maximum Switching Voltage	200 VDC, VAC
■ Maximum Switching Current	0.50 A
■ Maximum Continuous Carry Current	1.50 A
ELECTRICAL RATING	
■ Operate Sensitivity Available in Minimum 5 NI Ranges	5-45 NI
■ Maximum Initial Contact Resistance	150 milliohms
■ Minimum Dielectric Voltage	250 VDC
■ Maximum Capacitance	1.0 pF
■ Minimum Insulation Resistance	10 ¹¹ Ohms
OPERATING CHARACTERISTICS	
■ Maximum Operate Time, Including Bounce	0.50 ms
■ Maximum Release Time	0.20 ms
■ Maximum Operating Frequency	500 Hz
■ Operating Temperature Range	-40°C to +125°C
■ Shock	100g, 11 ms, 1/2 sinewave
■ Vibration	20g, or .125" D.A., 10 - 5000 Hz
■ Solderability	As defined by MIL-STD-202 F, Method 208D
■ Resistance to Solvents	The reed switch operating characteristics shall not be affected by water wash, rinse procedures, the use of mild to semi-active fluxes or conformal coating processes.

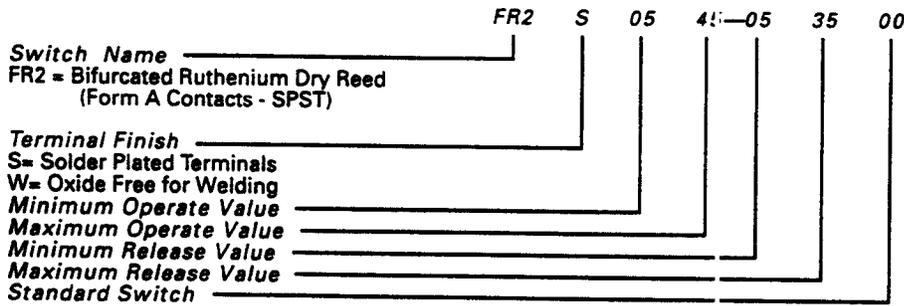
* If the switch is to be soldered in place, a solder plated terminal finish should be specified.

Ordering Information

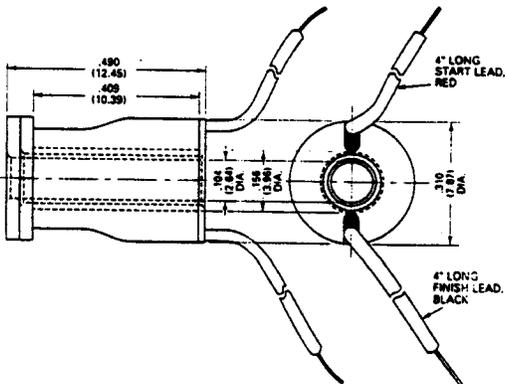
Dimensions



How to Order Clare Reed Switches



Standard Test Coil



Introduction

The magnetic force (expressed in NI, AT, or Ampere Turns) required to cause the reed switch contacts to close is called the pull-in or operate value.

■ Coil Definition	EIA/NARM I Standard
■ Wire size	AWG 46
■ Number of turns	5000 ± 5 turns
■ Coil resistance	1200 Ohms ± 10%
■ Recommended Mounting Conditions	Vertical, with the coil magnetic field opposing the local earth's magnetic field.

The reed switch shall be placed in the test coil with the gap centered in the core of the coil winding.

Test leads and their clips must be non-magnetic.

The longitudinal axis of the test coil and test switch shall be vertical.

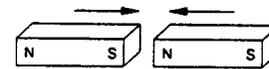
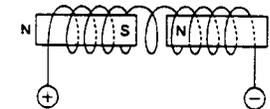
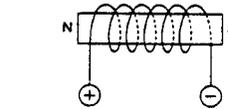
Switch Actuation

Clare

Operation of a Reed Switch Permanent Magnet and Electromagnetic Coil Actuation

The reed switch depends upon an induced magnetic field for its operation. Reed switches are activated by the presence of a magnetic field with sufficient flux to pull the reed blades together.

This can be accomplished by either using a permanent magnet—bringing the magnet close to the switch to turn it on—or by energizing an electromagnetic coil that is mounted around or near the switch. The balance of this page will review the actuating characteristics of a reed switch via these two methods.



Coil Actuation

The operation of a reed switch via an electromagnetic coil provides the designer with a method of actuation from a remote source. This is a very simple method of actuation.

When the reed switch is placed inside or close to a coil of wire and a current is passed through the coil, each lead of the reed switch becomes strongly magnetized. One end of the reed switch will become a north pole and the other a south pole. Because the reed blades overlap in the center of the glass housing, with a few thousandths of an inch separating the overlapping ends, each lead will have a north and south pole. The overlapping reed blades come together (close) when the

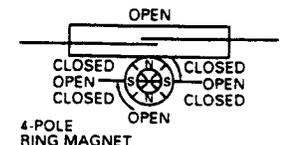
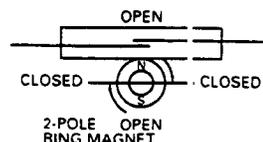
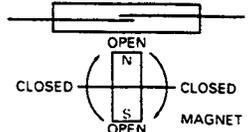
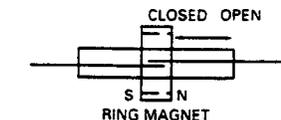
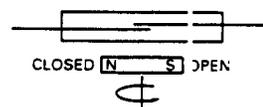
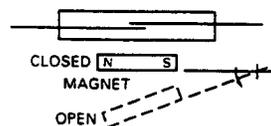
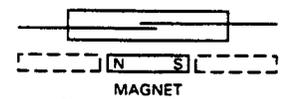
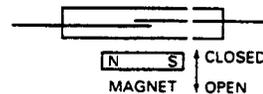
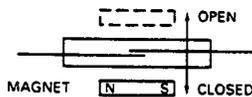
electrical current generates sufficient magnetic flux in the coil. When the current to the coil is turned off, the reed blades return to their open condition.

The efficiency of the reed switch actuation is largely dependent upon the coil. The size, shape, wire type, and the number of turns of wire on the coil determines its efficiency. In addition, the proximity of the switch to the coil determines the efficiency of the coil (ie, if the switch is placed inside or very close to the coil, the coil requires little current to actuate the switch. The farther the switch is from the coil, the more magnetic flux the coil must generate to cause switch closure). Two or more switches can be actuated by a single coil.

Permanent Magnet Actuation

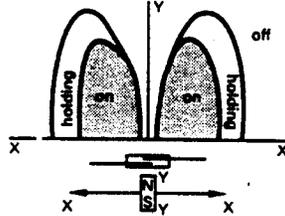
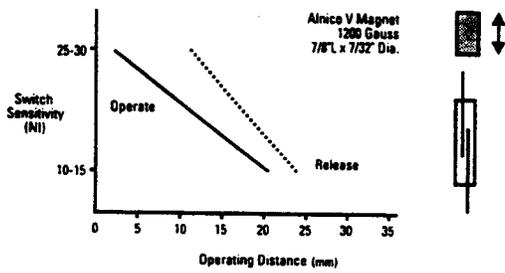
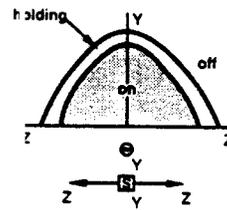
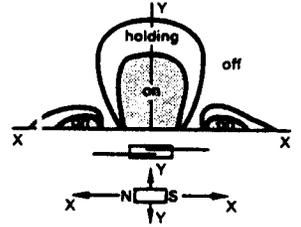
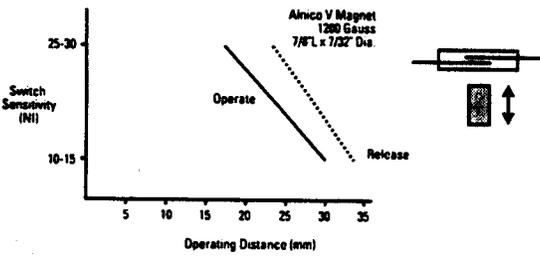
A permanent magnet is the most common means of operating the reed switch. As with a coil, to actuate the reed switch, a magnet and switch must be positioned within a specific proximity of each other. This distance is related to the sensitivity of the switch and the strength of the magnet. For the normally open reed

switch, when the magnetic field is close enough the contacts will close and when the magnetic field is taken away, the contacts will open. There are many ways to use a permanent magnet to actuate the reed switch. Below we have addressed the most popular techniques.



Switch Actuation

Permanent Magnet Actuation Distance (N. O. Contacts)



Form B Reed Switch Actuation

Bias Actuation

Form B, N. C. contact actuation is achieved by Clare through the use of the standard Form A dry reed switch that is biased closed by mounting a permanent magnet to the switch housing. This magnet is located such that it keeps the switch in the on (or closed) condition.

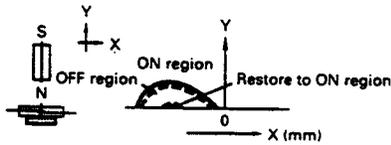
The switch is turned off (or opened) by bringing another magnet in the proximity of the switch/magnet assembly.

Note in the actuation charts shown below, that an on-off-on condition may occur if the proximity of the

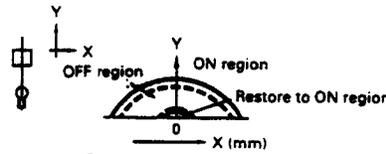
actuating magnet is brought very close to the switch/magnet assembly. This condition is, of course, dependent upon the size and strength of the actuating magnet.

Magnets

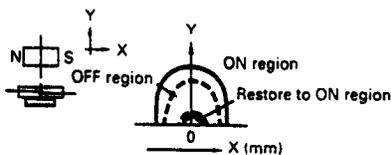
ALNICO V, ALNICO VIII, Ceramic and Barium ferrite are the most popular magnet materials used. The magnet type is usually chosen based on size, coercivity, cost, and temperature characteristics as defined by the application.



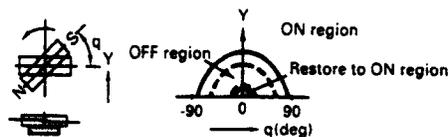
1. Perpendicular



3. Transverse



2. Horizontal

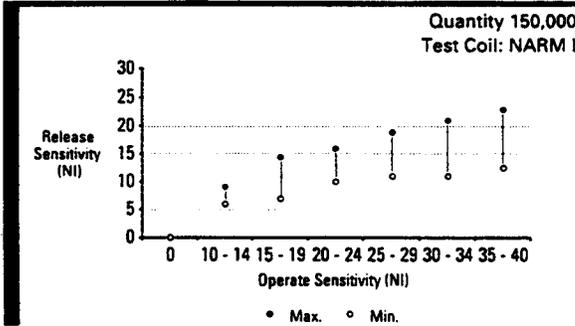


4. Rotational

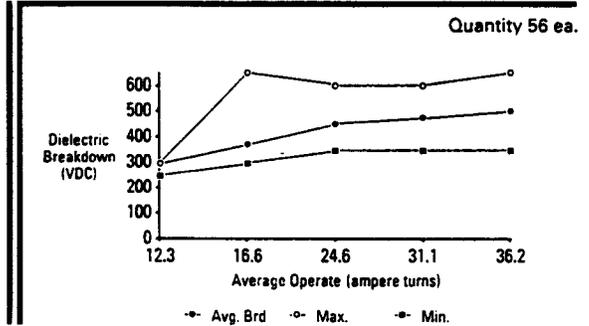
Performance Data

Clare

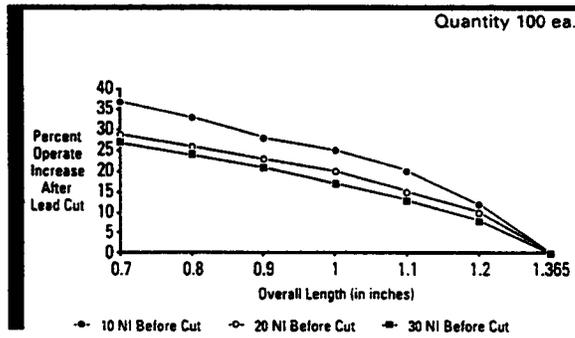
Operate NI vs. Release NI



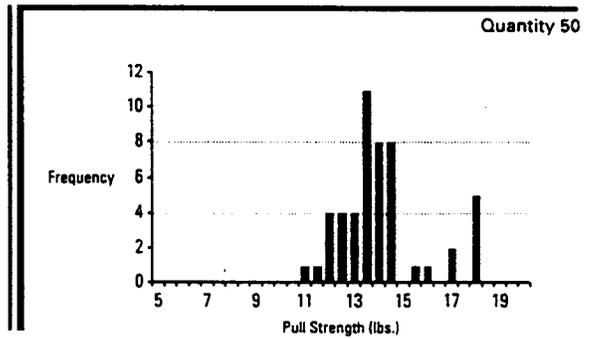
Dielectric Breakdown vs. Operate Sensitivity



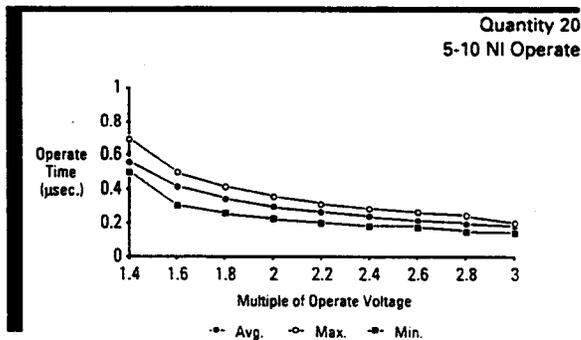
Operate Shift After Lead Trimming



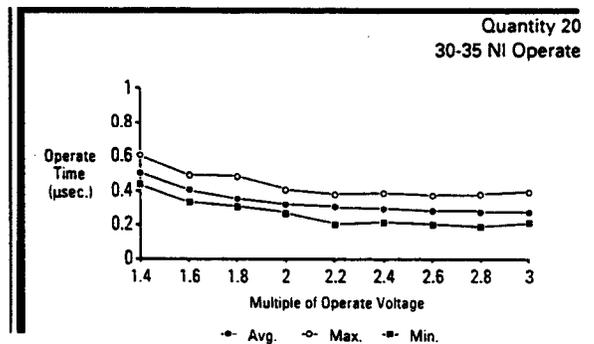
Pull To Fracture Test Distribution



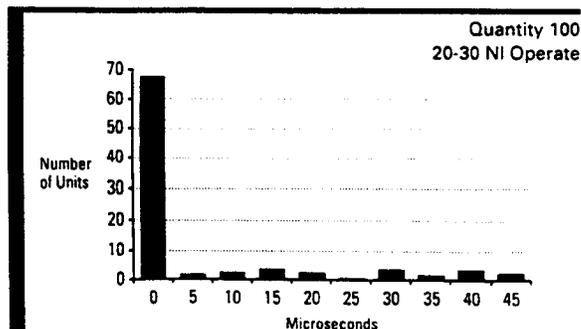
Operate Time vs. Coil Drive



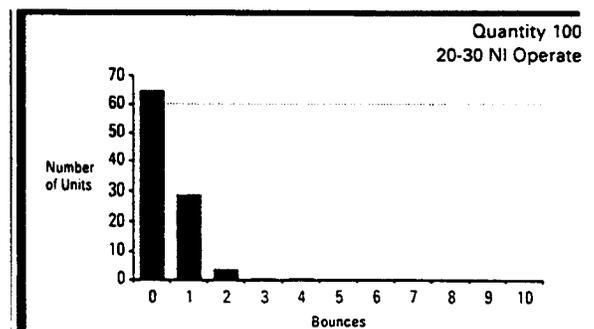
Operate Time vs. Coil Drive



Bounce Time

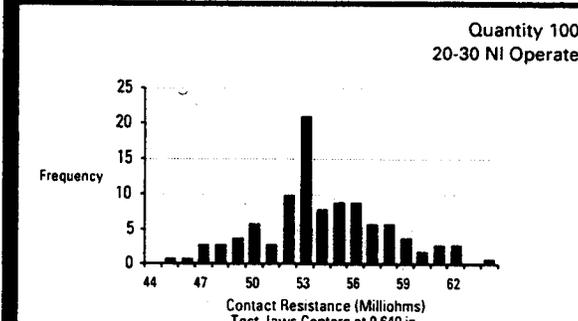


Number of Bounces

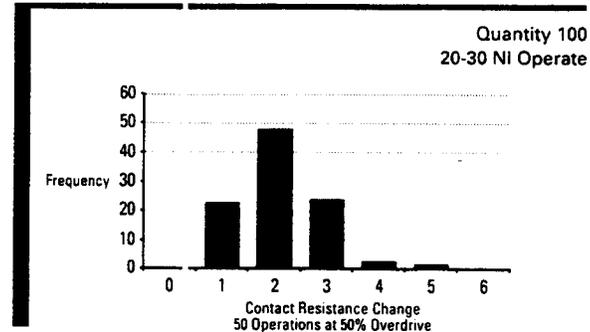


Performance Data

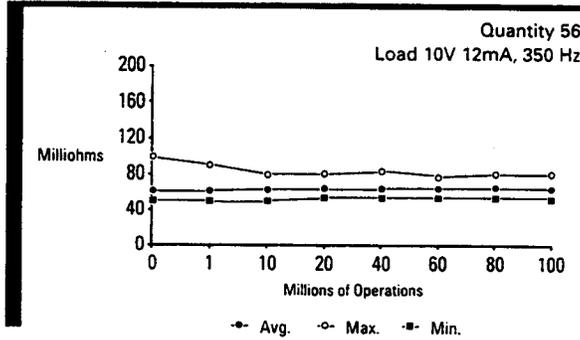
Contact Resistance



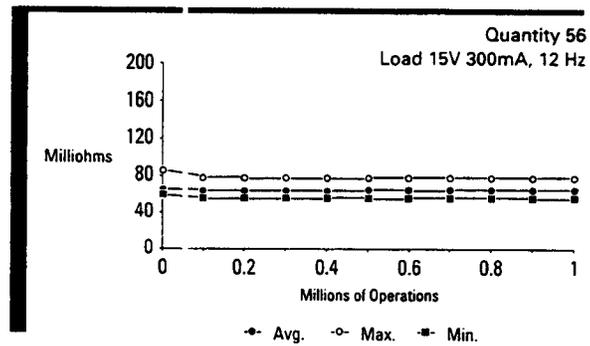
Contact Resistance Stability



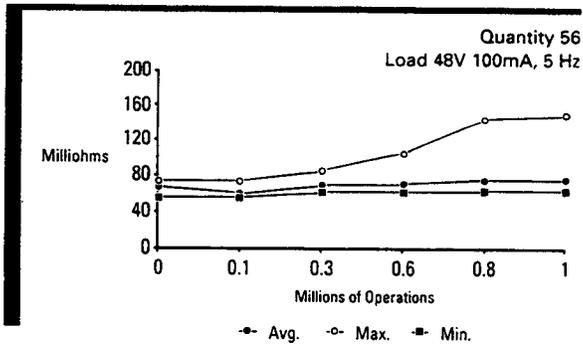
Contact Resistance vs. No. of Operations



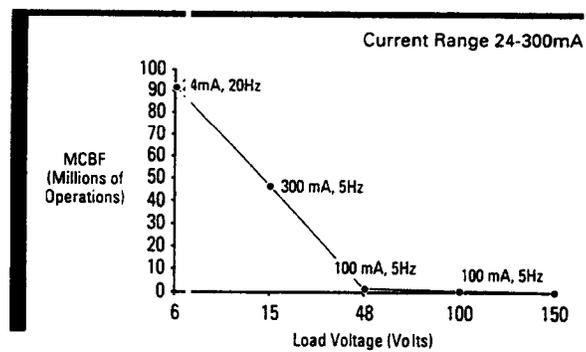
Contact Resistance vs. No. of Operations



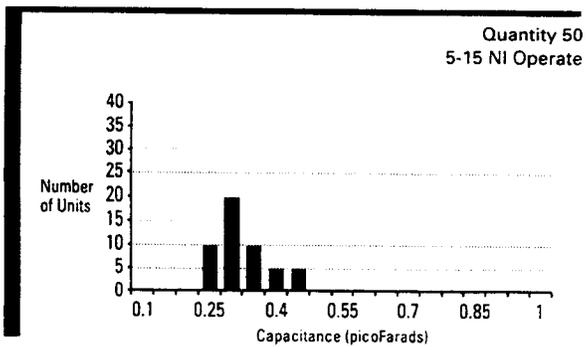
Contact Resistance vs. No. of Operations



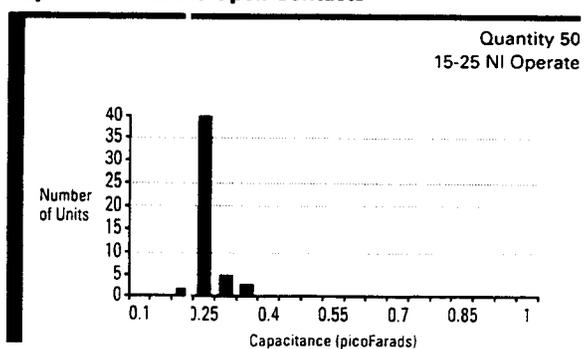
Load Life



Capacitance Across Open Contacts



Capacitance Across Open Contacts



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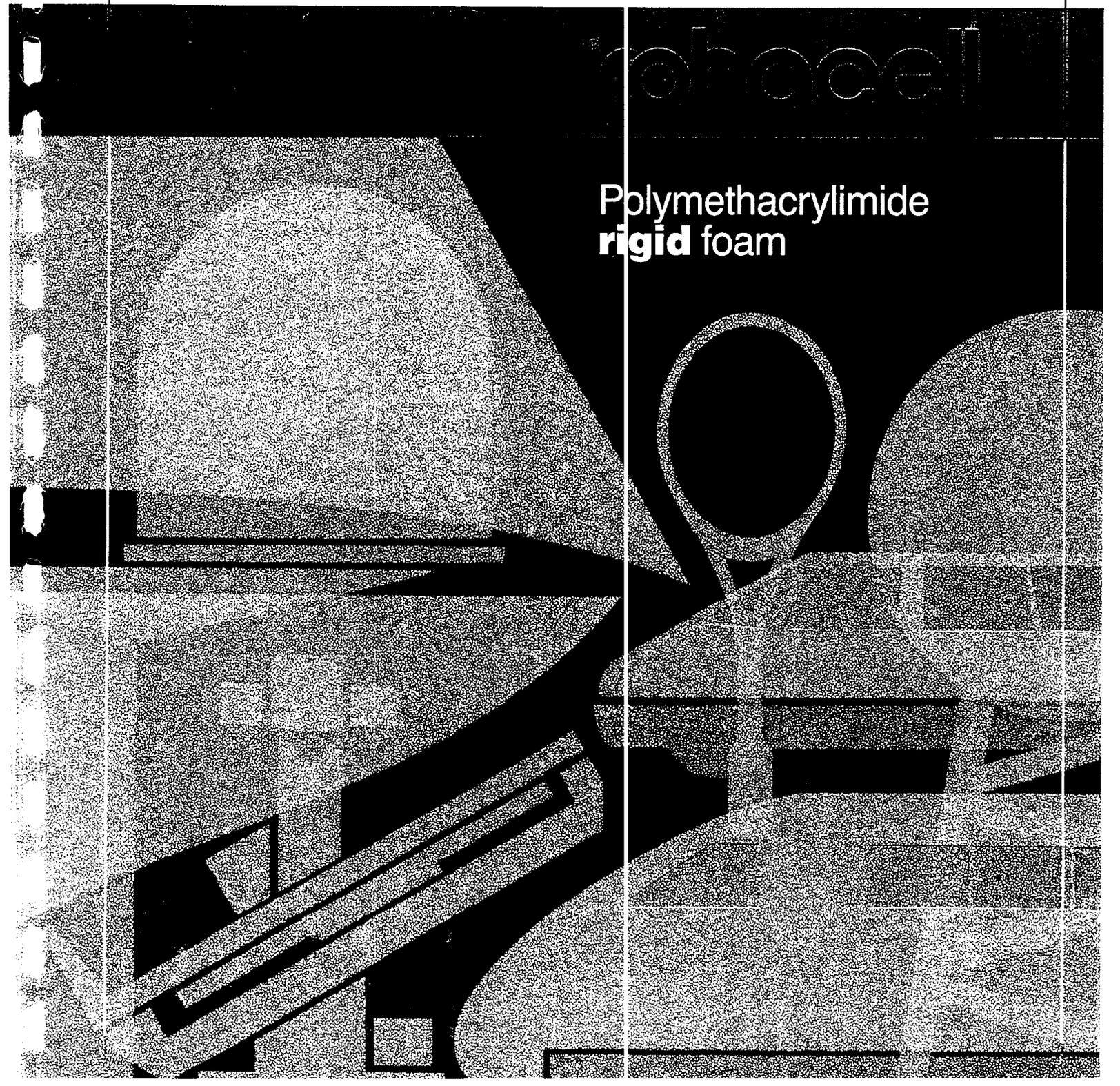
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TECHNICAL PRODUCTS

Polymethacrylimide
rigid foam



® rohacell

Technical Information

Contents

Page

The product profile of ROHACELL	3
What is ROHACELL?	3
The manufacture of ROHACELL	3
ROHACELL supply	4
The properties of ROHACELL	5
Mechanical properties	5
Thermal properties	6
Material behavior at elevated temperatures	7
Material behavior at low temperatures	8
Water vapor diffusion	8
Water absorption	9
Material behavior upon simultaneous exposure to moisture and heat	10
Electrical properties	10
X-ray transmission	11
Chemical resistance	11
Fire behavior	12
Comparison with other foam plastics	12
Test methods for ROHACELL	14
Fabricating ROHACELL	15
Cutting and stamping	15
Machining	15
Compressing	17
Forming	18
Bonding	20
Application of laminates	21
Painting	21
Manufacture of prepreg moldings (SMC) with ROHACELL 71	21
Practical examples of ROHACELL	22

The product profile of ROHACELL

What is ROHACELL?

ROHACELL is a closed-cell rigid expanded plastic material or, more accurately, polymethacrylimide rigid foam (PMI) for lightweight sandwich construction. The natural color of ROHACELL is white.

ROHACELL has excellent mechanical properties, high dimensional stability under heat, solvent resistance and, particularly at low temperatures, a low coefficient of heat conductivity. The strength values and the moduli of elasticity and shear are presently not exceeded by any other foamed plastic having the same density.

ROHACELL is manufactured by hot foaming of methacrylic acid/methacrylonitrile copolymer sheets. During foaming this copolymer is converted to polymethacrylimide.

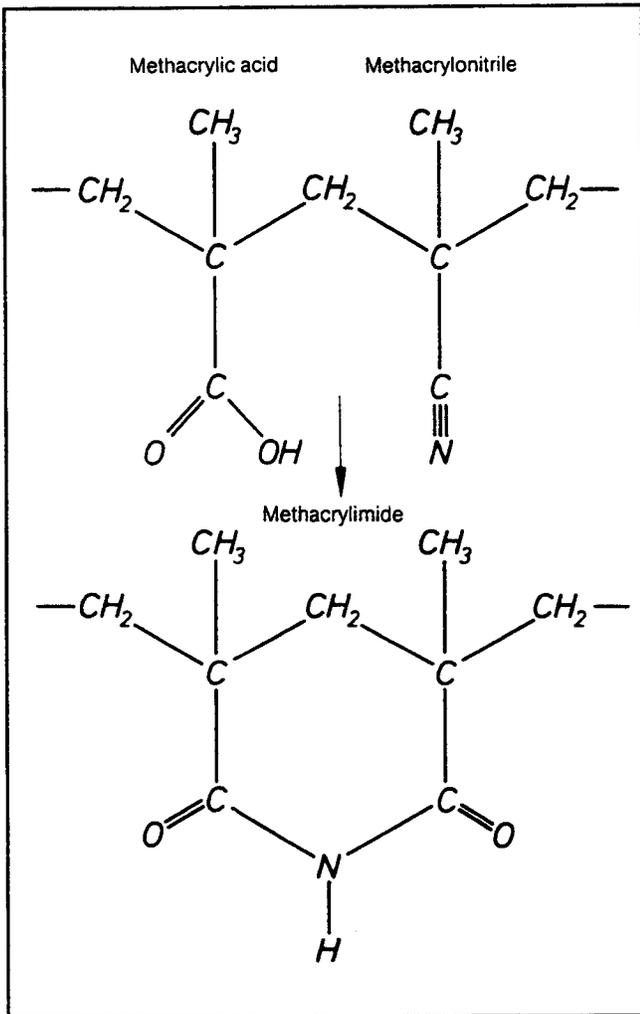


Fig. 1: Formation of polymethacrylimide (PMI)

The manufacture of ROHACELL

The foaming temperature is above 338 °F (170 °C), depending on the density and grade. After foaming, the block is cooled to room temperature. Due to the low heat conductivity of the foamed plastic, a temperature gradient develops which results in internal stresses. Therefore, when the block is cut into sheets some bowing may occur. However, the stresses are so slight that even thin sandwich skins yield flat sandwich panels.

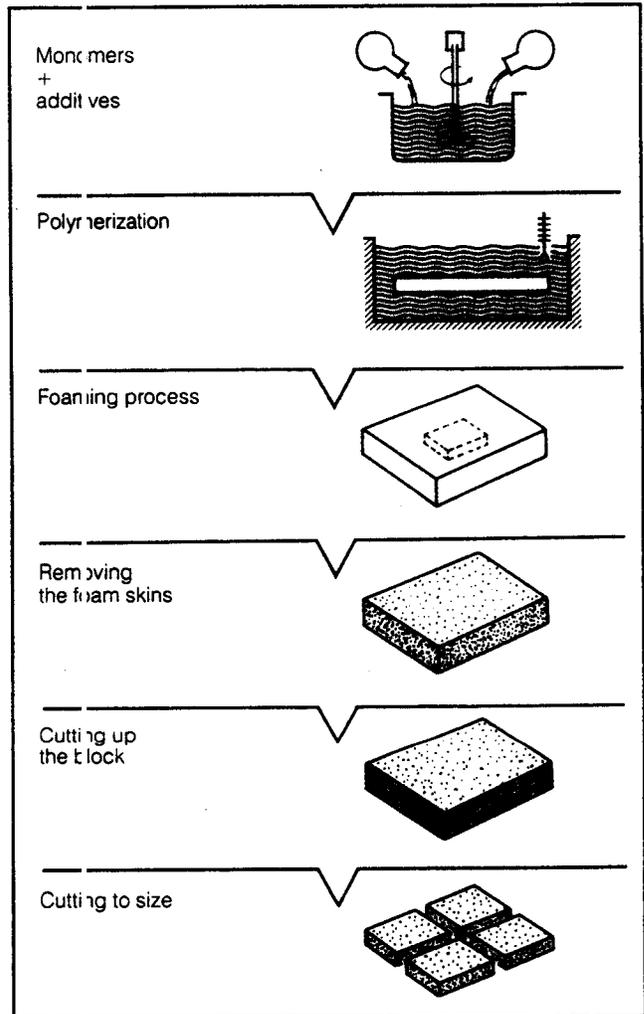


Fig. 2: Production scheme of ROHACELL

ROHACELL supply

Grades that can be supplied

ROHACELL is supplied in different densities

Grade	Density lbs/ft ³ /kg/m ³	Description
ROHACELL 31	2.0 32	Grades which, for foam plastics, have the best ratio between specific gravity and strength and therefore a very wide useful technical range.
ROHACELL 51	3.2 52	
ROHACELL 71	4.7 75	
ROHACELL 110	6.9 110	Special grade which closes the property gap between lower-density ROHACELL and the compacted, higher-density grades.
ROHACELL P 170	10.6 170	Compacted grades with oriented cell structure which have the highest strength and rigidity in the plane of the sheet
ROHACELL P 190	11.9 190	

Availability

ROHACELL is only supplied in the form of sheets.

ROHACELL 31, 51, 71

Thicknesses and sizes according to the standard sales range; other thicknesses than those quoted in the sales range can be produced on request.

ROHACELL 110

Thickness and size in accordance with the standard sales range.

ROHACELL P 170, P 190

Thickness and size in accordance with the standard sales range.

Sales range

Sheet thickness inch mm	.25	.5	.75	1	1.5	2	2.559
	6.35	12.7	19.5	25.4	38.1	50.8	65
ROHACELL 31	+	+	+	+	+	+	+
ROHACELL 51	+	+	+	+	+	+	
ROHACELL 71	+	+	+	+	+	+	

Size: + = 98.4 x 49.2 inch 2500 x 1250 mm

Custom type sheet thicknesses are available

Sheet thickness inch	1.9
mm	48

ROHACELL 110 +

Size: 85 x 21.6 inch 2160 x 550 mm

Sheet thickness inch	.9	1.1
mm	23	28

ROHACELL P 170 +

ROHACELL P 190 +

Size: 98.4 x 23.6 inch 2500 x 600 mm

The properties of ROHACELL

The mechanical properties

Mechanical properties of ROHACELL 31, 51, 71, 110, P 170, P 190

Properties ¹⁾	Units	31	51	71	110	P 170	P 190	Standard
Density	lbs/ft ³ (kg/m ³)	2.0 (32)	3.2 (52)	4.7 (75)	6.9 (110)	10.6 (170)	11.9 (190)	ASTM D 1622-63
Tensile strength	psi (N/mm ²)	142 (1.0)	270 (1.9)	398 (2.8)	491 (3.5)	1070 (7.5)	1210 (8.5)	ASTM D 638-68
Compressive strength	psi (N/mm ²)	57 (0.4)	128 (0.9)	213 (1.5)	427 (3.0)	924 (398)²⁾ (6.5) (2.8) ²⁾	1110 (455)²⁾ (7.8) (3.2) ²⁾	ASTM D 1621-64
Flexural strength	psi (N/mm ²)	114 (0.8)	228 (1.6)	356 (2.5)	641 (4.5)	1490 (1420)²⁾ (10.5) (10.0) ²⁾	1780 (1710)²⁾ (12.5) (12.0) ²⁾	ASTM D 790-66
Shear strength	psi (N/mm ²)	57 (0.4)	114 (0.8)	185 (1.3)	347 (2.4)	640 (427)²⁾ (4.5) (3.0) ²⁾	782 (427)²⁾ (5.5) (3.0) ²⁾	ASTM C 273-61
Modulus of elasticity	psi (N/mm ²)	5120 (36)	9950 (70)	13100 (92)	22700 (163)	45500 (320)	54000 (380)	ASTM D 638-68
Shear modulus	psi (N/mm ²)	1990 (14)	2990 (21)	4270 (30)	8210 (58)	17000 (120)	26300 (185)	ASTM D 2236-69
Shear modulus	psi (N/mm ²)	1850 (13)	2700 (19)	4120 (29)	7100 (50)	12500 (88)	14200 (100)	ASTM C 273-61
Elongation at break	%	3.5	4	4.5	4.5	5	6	ASTM D 638-68
Dimensional stability under heat	°F °C	356 (180)	356 (180)	356 (180)	356 (180)	266³⁾ (130) ³⁾	266³⁾ (130) ³⁾	DIN 53424

¹⁾ Test conditions 73.4 °F (23 °C) and 50% relative humidity

²⁾ Measured at right angles to the plane of the sheet

³⁾ Beyond this temperature the oriented cell structure starts to decrease

ROHACELL P 170 and P 190 have very high specific strengths. The cell structure has been oriented by a special method which produces a difference in strength between the plane of the sheet and at right angles to it. In this way, and depending on the situation in which the ROHACELL sheets are installed, excellent sandwich constructions can be obtained. For a number of uses in sandwich construction it is therefore reasonable to allow the direction of the principal stress to coincide with the direction of the highest material strength, i.e. to use the core with an upright cell structure.

Here is an example of this technique (Fig. 3):

The compacted ROHACELL rigid foams are supplied as sheets. Normally they are bonded with adhesives to a height corresponding to the width of the required sandwich core. Out of the resultant block the cores are sawn at right angles to the joints so that their cell structure is vertical when the core is in a horizontal position.

It is not necessary for this technique to be used in every case. If the strength values measured in the molding direction satisfy a given purpose, the ROHACELL sheets may be used flat.

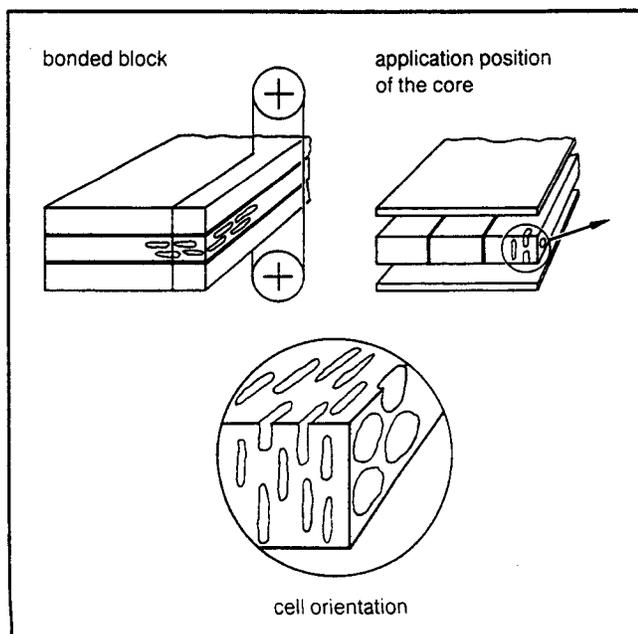


Fig. 3

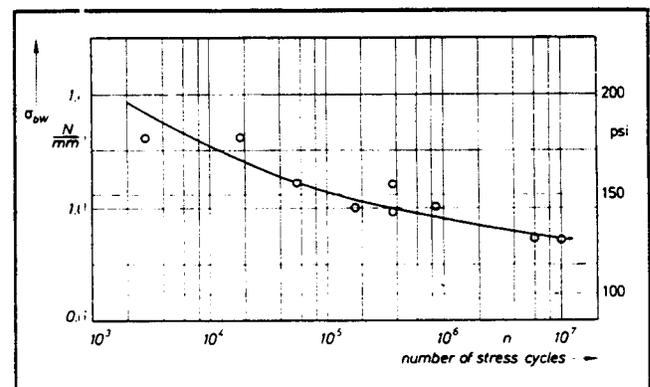


Fig. 4: Fatigue strength in alternating bending test of ROHACELL 51 at a stress frequency of 10 Hz.

The long-term behavior of ROHACELL under dynamic stress is excellent. There was no measurable, time-dependent decrease in the stress up to an exposure time of 10⁷ load cycles.

The thermal properties

Thermal properties of ROHACELL 31, 51, 71

Properties	Units	ROHACELL			Standard
		31	51	71	
Dimensional stability under heat	°F	356	356	356	DIN 53424
	°C	(180)	(180)	(180)	
Coefficient of linear thermal expansion ¹⁾	K ⁻¹	3.7	3.3	3.5	ASTM D 696-70
		$\times 10^{-5}$	$\times 10^{-5}$	$\times 10^{-5}$	
	in./in./°F	2.3	2.1	2.2	
Thermal conductivity ¹⁾	BTU in./ft ² h °F	0.215	0.201	0.208	ASTM C 177-63
	(W/mK) ²⁾	(0.031)	(0.029)	(0.030)	

¹⁾ Tested at 68 °F (20 °C)

²⁾ 1 W/mK = 0.86 kcal/m h deg.

Dimensional stability under heat

Normally the 'dimensional stability under heat' of a product is adequately described by the practical requirements made on its strength, weight stability and dimensional stability.

The following tables therefore show the changes in weight, volume and linear dimensions of ROHACELL specimens kept in air at different temperatures for 30 days. The measurements were taken immediately after the specimens had cooled down from the air temperature at which they had been kept.

Changes in weight and dimensions of ROHACELL 31, 51 and 71 after being kept at different temperatures for 30 days.

ROHACELL		31			51			71		
Storage temp.	°F	212	248	320	212	248	320	212	248	320
	(°C)	(100)	(120)	(160)	(100)	(120)	(160)	(100)	(120)	(160)
Change in weight	%	-3.3	-4.4	-5.2	-4.0	-5.1	-6.1	-3.7	-4.2	-6.0
Change in length	%	-0.8	-1.0	-1.6	-1.0	-1.4	-1.8	-0.8	-1.0	-1.9
Change in volume	%	-1.7	-3.2	-4.2	-2.3	-3.9	-4.8	-2.3	-3.0	-3.3

Changes in weight and dimensions of ROHACELL 31, 51, 71 after storage as above, followed by keeping under standard conditions (73.4 °F, 23 °C, 50% r.h.) until the weight was approximately constant.

ROHACELL		31			51			71		
Storage temp.	°F	212	248	320	212	248	320	212	248	320
	(°C)	(100)	(120)	(160)	(100)	(120)	(160)	(100)	(120)	(160)
Change in weight	%	0	-0.2	-1.6	-0.2	-0.6	-2.5	-0.3	-0.9	-2.9
Change in length	%	0	-0.2	-1.2	0	-0.4	-1.3	-0.2	-0.4	-1.5
Change in volume	%	-0.1	-0.2	-2.7	-0.1	-1.1	-3.7	-0.5	-1.3	-2.0

Linear thermal expansion

The linear thermal expansion of ROHACELL is unusually low for a plastic material.

Coefficient of linear thermal expansion of ROHACELL 31, 51, 71 at various temperatures:

Temperature	ROHACELL 31	ROHACELL 51	ROHACELL 71
°F	in./in. °F	in./in. °F	in./in. °F
(°C)	(K ⁻¹ · 10 ⁻⁵)	(K ⁻¹ · 10 ⁻⁵)	(K ⁻¹ · 10 ⁻⁵)
-238	1.38	1.33	1.66
(-150)	(2.5)	(2.4)	(3.0)
-148	1.38	1.33	1.66
(-100)	(2.5)	(2.4)	(3.0)
-58	1.55	1.49	1.66
(-50)	(2.8)	(2.7)	(3.0)
+32	1.66	1.66	1.77
(0)	(3.0)	(3.0)	(3.2)
+68	2.05	1.83	1.94
(+20)	(3.7)	(3.3)	(3.5)

The expansion coefficients are distinctly lower than those of other rigid foams, and the values at very low temperatures in particular are similar to those of metals and fibre-reinforced laminates, thus making the stress-deformation behavior of sandwich systems very useful.

Thermal conductivity

The thermal conductivity values of ROHACELL grades differ only slightly; they are within the ranges given in the table below for different temperatures. These values were determined for aged specimens whose cells contained essentially only air rather than propellant gas. They are therefore stable, ultimate values which no longer rise under normal conditions.

Thermal conductivity of ROHACELL 31, 51, 71 at different temperatures

Temperature	ROHACELL 31, 51, 71	
°F	BTU in./ft ² h °F	(W/mK*)
(°C)		
-256	0.104 - 0.132	(0.015 - 0.019)
(-160)		
-148	0.132 - 0.146	(0.019 - 0.021)
(-100)		
-40	0.159 - 0.194	(0.023 - 0.028)
(-40)		
+68	0.194 - 0.234	(0.028 - 0.034)
(+20)		
+176	0.243 - 0.284	(0.035 - 0.041)
(+80)		
+284	0.291 - 0.333	(0.042 - 0.048)
(+140)		

*) 1 W/mK \cong 0.86 kcal/m h deg.

Material behavior at elevated temperatures

The illustrations show the tensile, compressive and flexural strengths, the moduli of elasticity and shear of ROHACELL as functions of temperature as well as the creep behavior as a function of the compressive stress at 266 °F (130 °C).

For special techniques, like the manufacture of sandwich panels in the autoclave, the creep behavior of ROHACELL may not be adequate. In this case we recommend the use of ROHACELL WF.

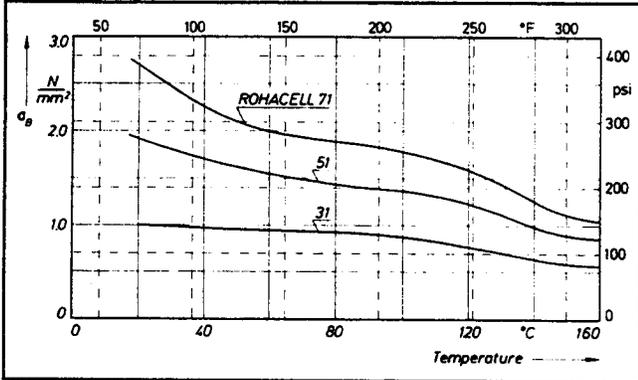


Fig. 5: Tensile strength (ASTM D 638-68) as a function of temperature

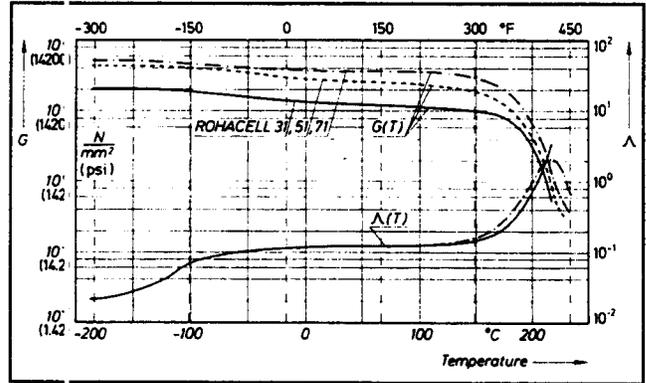


Fig. 8: Shear modulus G and mechanical damping Δ (ASTM D 2236-69) as a function of temperature

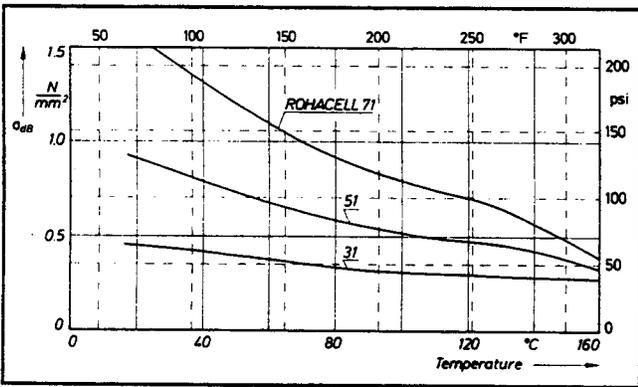


Fig. 6: Compressive strength (ASTM D 1621-64) as a function of temperature

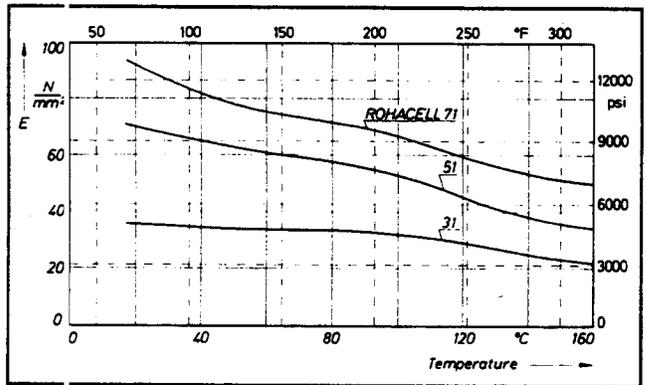


Fig. 9: Modulus of elasticity (ASTM D 638-68) as a function of temperature

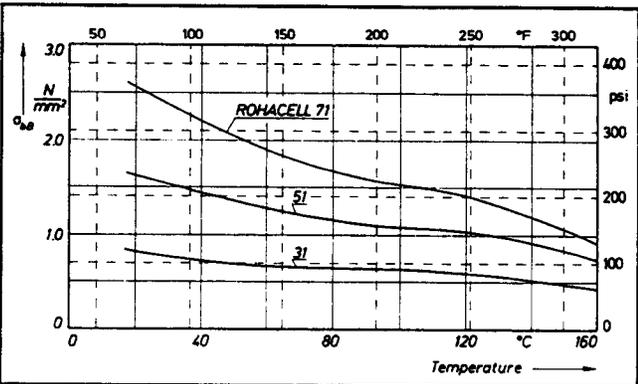


Fig. 7: Flexural strength (ASTM D 790-66) as a function of temperature

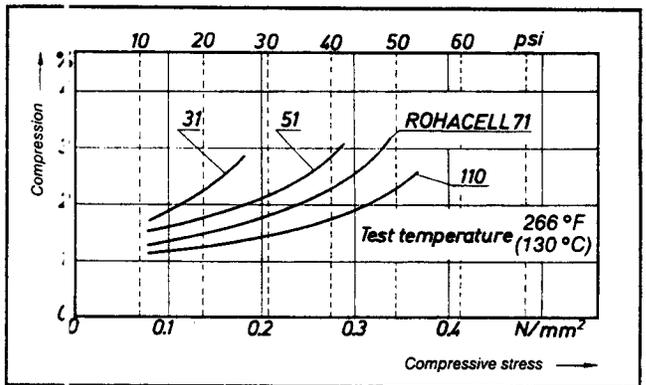


Fig. 10: Creep behavior of ROHACELL; test period 2 hrs., specimen inserted cold, initial compression c. 0.6 mm

The properties of ROHACELL

Material behavior at low temperatures

The following table presents a few properties of ROHACELL 31, 51 and 71 which permit an assessment of these materials for use at low temperatures. It is of particular interest that the elongation at break at -320.0°F (-196°C) is still above 1%. For further data look under "The thermal properties" (page 6). The moderate heat expansion and cold contraction of ROHACELL is emphasized by the following example: for a temperature change between room temperature of $+73.4^{\circ}\text{F}$ ($+23^{\circ}\text{C}$) and -320.8°F (-196°C) the expansion or contraction is only .005 in./in. to .006 in./in. (5 to 6 mm/m). These low values are normally only reached by fiber-reinforced materials and metals. As a result, sandwich systems with a ROHACELL core show a very favorable stress-deformation behavior.

Tensile strength, compressive strength and elongation at break of ROHACELL 31, 51, 71 at low temperatures

Properties	Units	Test temperatures	ROHACELL			Standard
			31	51	71	
Tensile strength	psi N/mm ²	73.4 °F	142	270	398	ASTM D 638-68
		(23 °C)	(1.0)	(1.9)	(2.8)	
		- 94 °F	156	284	427	
		(-70 °C)	(1.1)	(2.0)	(3.0)	
Compressive strength	psi N/mm ²	-320.8 °F	156	313	455	ASTM D 1621-64
		(-196 °C)	(1.1)	(2.2)	(3.2)	
		73.4 °F	56.9	128	213	
		(23 °C)	(0.40)	(0.9)	(1.5)	
Elongation at break	%	- 94 °F	3.5	4.0	4.5	ASTM D 638-68
		(-70 °C)	2.5	2.7	3.0	
		-320.8 °F	1.4	1.4	1.5	
		(-196 °C)	1.4	1.4	1.5	

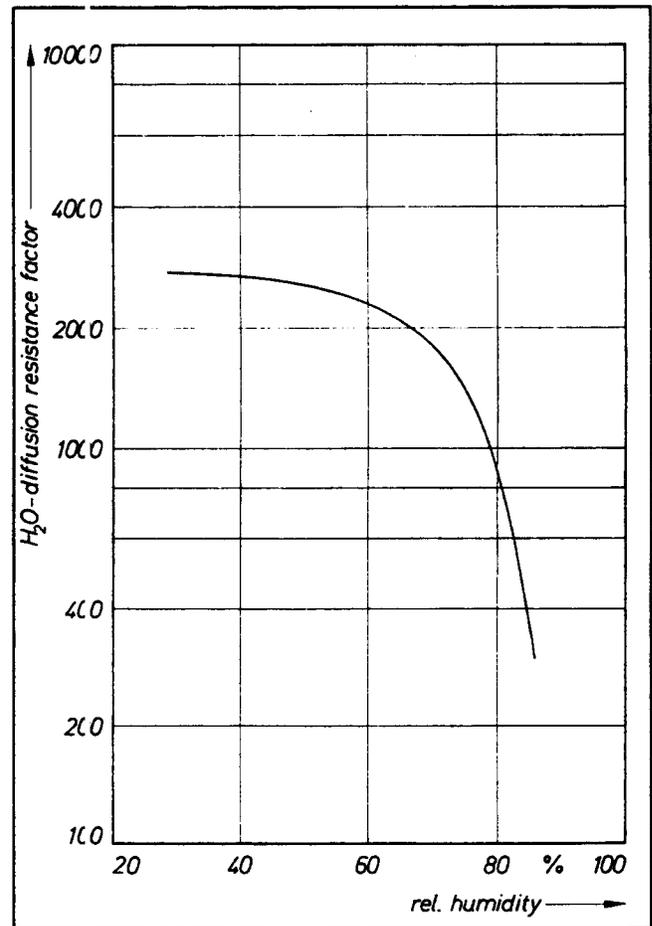
Water vapor diffusion

Water vapor diffusion resistance factor of ROHACELL 31, 51, 71

Property ¹⁾	Unit	ROHACELL			Standard
		31	51	71	
H ₂ O diffusion resistance factor	1	400	650	900	ASTM E 96

¹⁾ Test conditions 68 °F (20 °C) and 85 % relative humidity.

The values given in the table are surprisingly high. Measurements have shown that the water vapor diffusion of ROHACELL above 65% relative humidity increases with the humidity reading.



Water absorption

Polymethacrylimide (PMI) absorbs water in a manner similar to polyamide. The following table shows the sorption equilibria (equilibrium water content with respect to dried samples) of ROHACELL in damp air. Size of samples $2 \times 2 \times 0.08$ inches ($50 \times 50 \times 20$ mm).

Atm. humidity % r.h.	ROHACELL 31		ROHACELL 51		ROHACELL 71	
	vol. %	weight %	vol. %	weight %	vol. %	weight %
15	0.05	1.5	0.07	1.3	0.08	1.2
30	0.09	2.9	0.13	2.6	0.17	2.4
50	0.14	4.7	0.21	4.2	0.25	3.6
65	0.18	6.0	0.25	5.0	0.30	4.3
98	0.59	19.5	0.88	17.4	1.1	15.5

The following table illustrates the water absorption and change in volume of test specimens after 50 days of total immersion in water. These values show that despite the relatively high water absorption, the dimensional stability is satisfactory. Shrinkage of the samples is only observed after prolonged immersion at water temperatures above 122°F (50°C).

Property	Unit	ROHACELL		
		31	51	71
H ₂ O absorption at				
68 °F (20 °C)	vol. %	13	15	16
122 °F (50 °C)	vol. %	18	23	26
Vol. increase on water immersion				
68 °F (20 °C)	vol. %	<1	<2	<3
122 °F (50 °C)	vol. %	<2	<2	<3

The diagram below shows that, irrespective of the period of water immersion, the compressive strength of ROHACELL settles at a constant value.

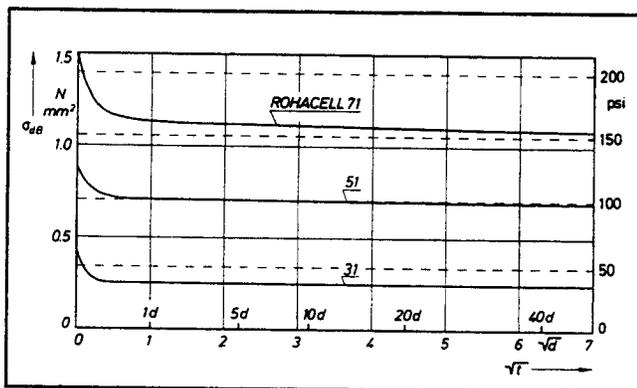


Fig. 12: Compressive strength (ASTM D 1621-64) of ROHACELL immersed in water as a function of time

40-month water permeation tests with ROHACELL P 170 in a sandwich structure

For boat building and similar uses, the water penetration into FRP structural sandwich parts with damaged skins is of particular interest. Corresponding tests were conducted. ROHACELL P 170 with the dimensions $15.7 \times 15.7 \times 1.1$ in. ($400 \times 400 \times 28$ mm) was laminated on all sides with glass-reinforced polyester resin. The skins consisted of: mat (.09

lbs/ft² 450 g/m²), roving (.1 lbs/ft²/500 g/m²), mat (.09 lbs/ft² 450 g/m²), roving (.1 lbs/ft²/500 g/m²) and mat (.09 lbs/ft² 450 g/m²). The laminating resin was a polyester (PALATAL F' 51). The skins were applied manually and cold-cured with a thickness of about .2 in. (5 mm).

In the middle of one of the surfaces a part of the skin with a diameter of 2.8 in. (70 mm) was removed. A tube was placed into this opening and sealed with silicone against the remaining skin. The tube was then filled with water to a height of 11.8 in. (300 mm). Since ROHACELL is a foam with closed cells, the penetration of water is purely due to diffusion, a fact which was confirmed by preliminary tests.

After 40 months, the skins were removed and the ROHACELL core examined for water absorption. The places from which the samples were taken are shown in the illustration. The specimens were dried in a vacuum cabinet at 158°F (70°C) and the water content thus determined in per cent by weight. The size of each sample was $2 \times 2 \times 1.1$ in. ($50 \times 50 \times 28$ mm). The water content reduces very quickly from the center outwards, i.e. even after being in water for 40 months the specimen was not soaked. At a distance of about 5.9 in. (150 mm) from the water tube the material was practically dry.

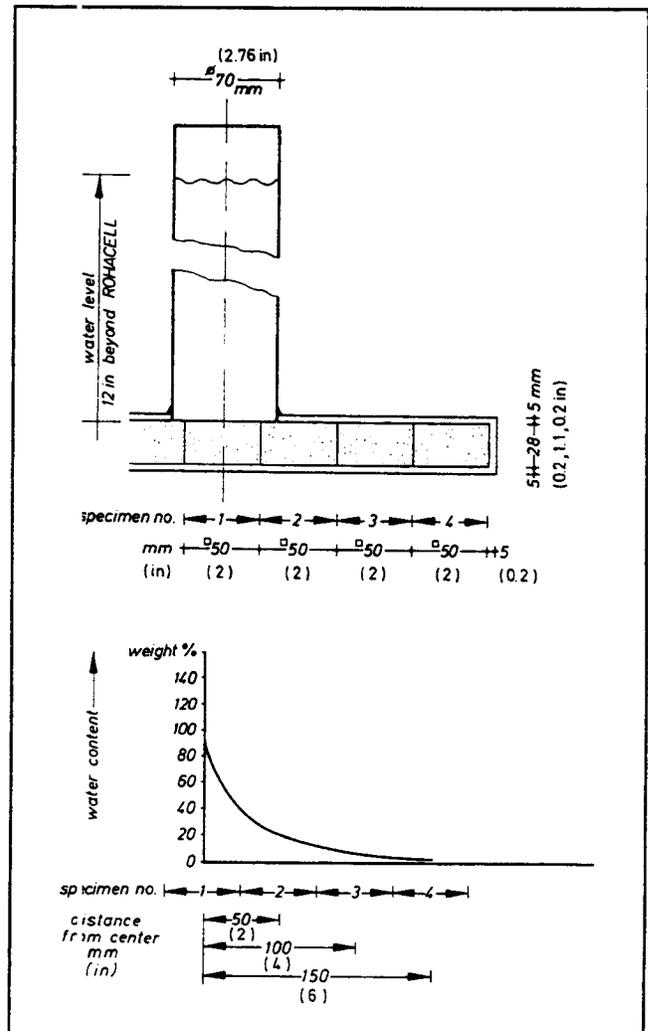


Fig. 13: Sandwich with ROHACELL P 170 kept in water for 40 months:

Material behavior upon simultaneous exposure to moisture and heat

Even when ROHACELL is kept for a prolonged period at 100% rel. humidity and 158 °F (70 °C) the compressive strength, for example, is only slightly affected. When the specimen is subsequently kept under normal conditions (73.4 °F, 23 °C, 50% r.h.), the original values are recovered. The table also gives the changes in weight and volume under these conditions with respect to the original weight and volume.

Compressive strength of ROHACELL after 500 h at 158 °F (70 °C) and 100% r.h.

ROHACELL	Test conditions	Change in weight*		Volume change*		Compressive strength	
		(weight %)	(vol. %)	(vol. %)	psi	(N/mm ²)	
31	A	—	—	—	56.9	(0.40)	
	B	4.4	0.13	-4.1	55.9	(0.39)	
	C	1.8	0.06	-5.2	55.5	(0.39)	
	D	0.7	0.03	-5.5	55.5	(0.39)	
51	A	—	—	—	127	(0.89)	
	B	4.1	0.20	-2.8	112	(0.79)	
	C	1.9	0.09	-3.7	121	(0.85)	
	D	1.0	0.05	-4.3	127	(0.89)	
71	A	—	—	—	213	(1.5)	
	B	3.8	0.27	-2.3	185	(1.3)	
	C	1.7	0.13	-2.9	199	(1.4)	
	D	1.2	0.10	-3.0	213	(1.5)	

*) versus initial values

Test conditions

A = material as supplied

B = after 500 h at 158 °F (70 °C) and 100% r.h.

C = as B and another 500 h in a standard climate of 73.4 °F (23 °C) and 50% r.h.

D = as B and exposure to standard climate of 73.4 °F (23 °C) and 50% r.h. until approx. constant weight

the properties of ROHACELL

The electrical properties

Dielectric constant and loss tangents of ROHACELL

ROHACELL	Frequency, GHz			
	2.0	5.0	10.0	26.0
Dielectric constant				
31	1.08	1.05	1.05	1.06
51	1.07	1.09	1.06	1.11
71	1.08	1.11	1.13	1.10
Loss tangent				
31	.0001	.0004	.0008	.0034
51	.0002	.0004	.0011	.0050
71	.0003	.0007	.0018	.0076

Measured by: Seavey Engineering Associates, Inc.

Surface resistance

ROHACELL	31	51	71
ohm	2×10^{13}	9×10^{12}	5.5×10^{12}

The excellent dielectric values of ROHACELL are a major advantage for its use in radomes and antenna engineering.

The moisture pick-up of ROHACELL without skins does not really influence the remarkable specific properties of ROHACELL in antenna applications since the water molecules are fixed in the imide groups and are unable to oscillate freely. When ROHACELL is covered with skins as usual, the skin material influences the properties of the antenna more than ROHACELL itself. The change of the antenna properties by water absorption of the skins must also be taken into account as the water molecules may oscillate freely here.

X-ray transmission

Aluminium-equivalent measurements were carried out with 100 kV X-rays on various ROHACELL specimens. The graph shows curves measured for ROHACELL grades 31, 51 and 71. Only the given readings for the indicated thicknesses were measured for ROHACELL 110, P 170 and P 190.

ROHACELL	Thickness in. (mm)	Al-equivalent in. (mm)
110	1.9 (48)	0.17 (0.44)
P 170	1.1 (28)	0.16 (0.39)
P 190	0.9 (23)	0.15 (0.35)

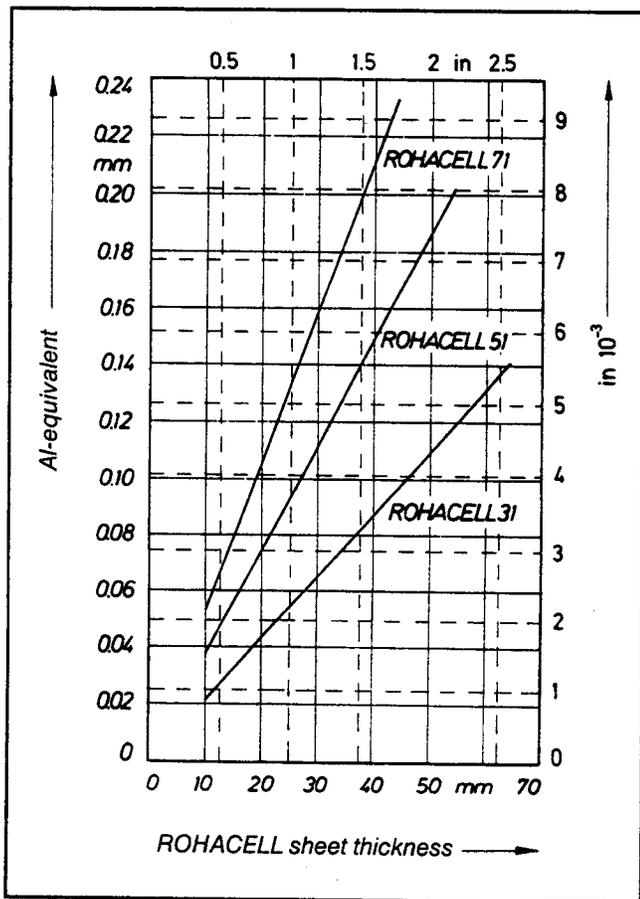


Fig. 14: X-ray transmission of ROHACELL (100 kV)

Chemical resistance

Resistance table for ROHACELL 31, 51, 71, 110

At 68 °F (20 °C)

Acetone	+	Methyl isobutyl ketone	+
Ether	+	Petroleum ether	+
Benzene	+	Sulphuric acid (10%)	+
Dibutyl phthalate	(+)	Soda solution (5%)	-
Diesel fuel	+	Styrene	+
Glacial acetic acid	-	Super petrol	+
Ethyl acetate	+	Carbon tetrachloride	+
Isopropyl alcohol	+	Tetrahydrofuran	-
Paint solvent I	+	Toluene	+
Paint solvent II	+	Trichloroethylene	+
Methyl alcohol	-		

At the boiling point

Carbon tetrachloride	(171 °F) (77 °C)	+
Benzene	(176 °F) (80 °C)	+
Trichloroethylene	(190 °F) (88 °C)	+
Chlorobenzene	(270 °F) (132 °C)	-
Xylene	(282 °F) (130 °C)	+
O-Dichlorobenzene	(356 °F) (180 °C)	-

+ resistant (+) limited resistance - not resistant

Bearing in mind the special behavior under heat, this table also holds for ROHACELL P 170 and P 190.

Among the outstanding characteristics of ROHACELL is its resistance to organic solvents. This is equally true for benzene, xylene and monostyrene as for the usual paint and adhesives solvents, fuel constituents and most other industrial solvents. ROHACELL **does not** resist **alkaline** media.

Fire behavior

ROHACELL burns with a slightly smoky flame. The fumes contain no corrosive decomposition products.

The toxicity of the smoke fumes was determined by the mortality of rats after inhaling the thermal decomposition products of ROHACELL for half an hour, decomposition was according to ASTM D 1929. In the temperature range up to 1112 °F (600 °C) the decomposition products of ROHACELL are less toxic than the decomposition products of pinewood.

From .4 in. (10 mm) material thickness upwards, the grades ROHACELL 31, 51 and 71 are "normally flammable" (class B2) within the meaning of DIN 4102 and have a "non-drip" rating. According to ASTM D 1692-59 T, they are classified as "Burning by this Test". The burning rate differs from grade to grade and depends on the material thickness. For ROHACELL 51, .4 in. (10 mm) thick, it amounts to .9 in./min (2.4 cm/min).

When provided with suitable skins, sandwich parts not covered at the edges meet the conditions of FAR, paragraph 25.853 (a) and (b). The specifications of Airbus Industrie for smoke density and toxicity are also met.

According to VDE 0471-3 (incandescent wire method), the ignition temperature of ROHACELL 51 is 1,310 °F (710 °C) when the specimen is .2 in. (5 mm) thick.

According to DIN 51794, the ignition temperature of all ROHACELL grades is about 1,112 °F (600 °C) without flame and about 662 °F (350 °C) with flame.

The calorific value of ROHACELL, measured according to DIN 51708, is about $26000 \frac{Ws}{g}$ ($2817 \times 10^3 \frac{cal}{pound}$).

The LOI (Limiting Oxygen Index) of ROHACELL 31, 51 and 71 is 19 to 20.

Comparison with other foam plastics

The majority of the values for the following graphs are derived from our own measurements. However, comprehensive literature values were also included so as to be able to form the best possible averages for the different makes of foam plastics. Neither the composition nor the manufacture of the types of foam plastics included in the comparison is uniform. As a result, there may be deviations from the given values, depending on the make. The properties are not rated. It is only intended to show where ROHACELL is to be classified.

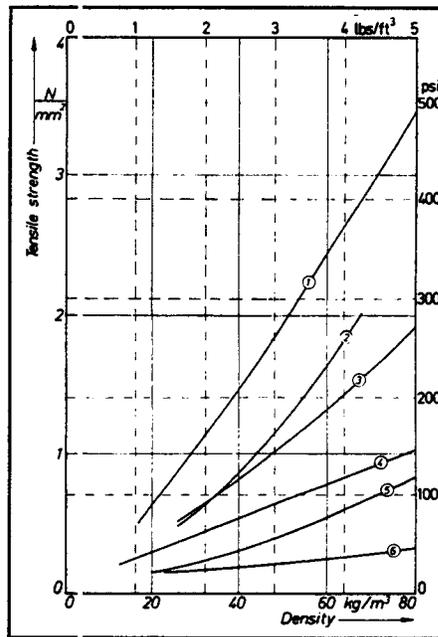


Fig. 15: Tensile strength according to ASTM D 638-68 of various rigid foams as a function of density at 68 °F (20 °C)

- 1 = ROHACELL
- 2 = PS (extruded)
- 3 = PVC (cross-linked)
- 4 = PS (foamed in a mold)
- 5 = PUR
- 6 = PF

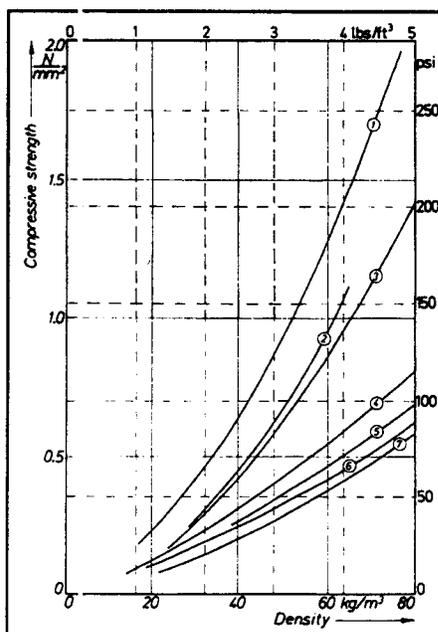


Fig. 16: Compressive strength according to ASTM D 1621-64 of various rigid foams as a function of density at 68 °F (20 °C). For PS foamed in a mold the compressive strength at 10% compression was included for comparison's sake

- 1 = ROHACELL
- 2 = PS (extruded)
- 3 = PVC (cross-linked)
- 4 = PS (foamed in a mold)
- 5 = PF
- 6 = PUR

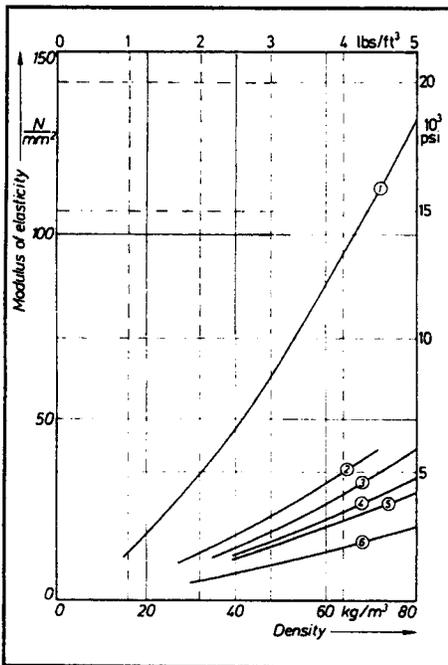


Fig. 17: Modulus of elasticity according to ASTM D 638-68 of various rigid foams as a function of density at 68 °F (20 °C)

- 1 = ROHACELL
- 2 = PS (extruded)
- 3 = PVC (cross-linked)
- 4 = PVC (not cross-linked)
- 5 = PF
- 6 = PUR

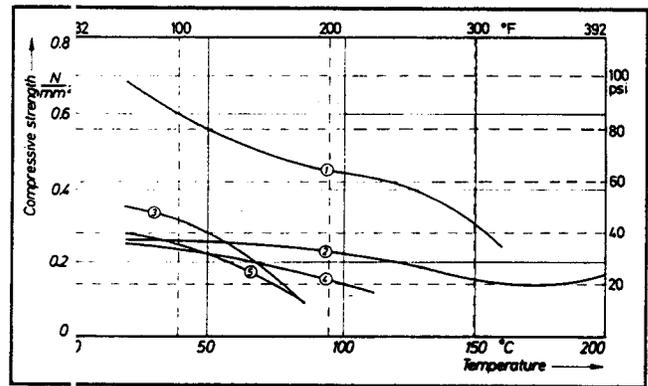


Fig. 20: Compressive strength according to ASTM D 1621-64 of various rigid foams with a density of 2.5 lbs/ft³ (40 kg/m³) as a function of temperature. For PS foamed in a mold the compressive strength at 10% compression was included for the sake of comparison.

- 1 = ROHACELL
- 2 = PF
- 3 = PVC (cross-linked)
- 4 = PUR
- 5 = PS (foamed in a mold)

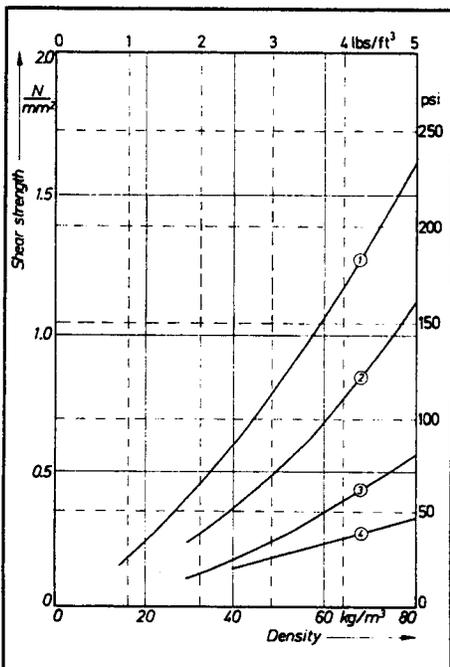


Fig. 18: Shear strength according to ASTM C 273-61 of various rigid foams as a function of density at 68 °F (20 °C)

- 1 = ROHACELL
- 2 = PVC (cross-linked)
- 3 = PUR
- 4 = PVC (not cross-linked)

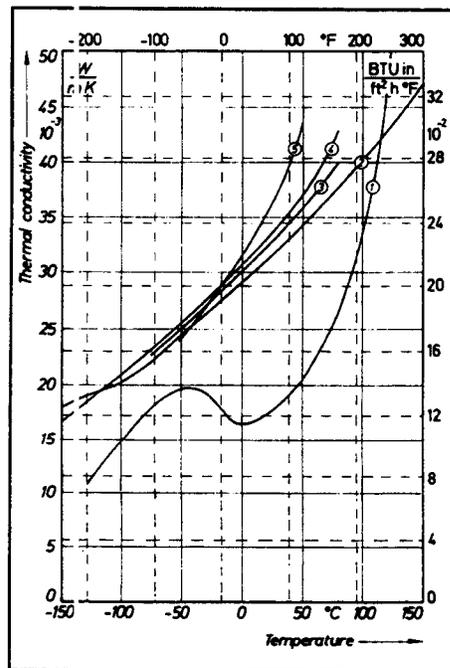


Fig. 21: Thermal conductivity according to ASTM C 177-63 of various rigid foams as a function of temperature

- 1 = PUR (density 2.5 lbs/ft³ / 40 kg/m³, foamed with fluorotrichloromethane)
- 2 = ROHACELL (density 2.2 lbs/ft³ / 35 kg/m³)
- 3 = PS (density 2.5 lbs/ft³ / 40 kg/m³, foamed in a mold)
- 4 = PF (density 2.5 lbs/ft³ / 40 kg/m³)
- 5 = PVC (density 3.1 lbs/ft³ / 50 kg/m³, cross-linked)

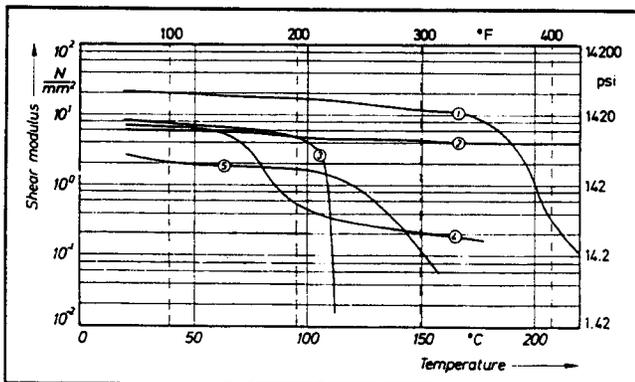


Fig. 19: Shear modulus according to ASTM D 2236-69 of various rigid foams with a density of 2.5 lbs/ft³ (40 kg/m³) as a function of temperature

- 1 = ROHACELL
- 2 = PF
- 3 = PS (foamed in a mold)
- 4 = PVC (cross-linked)
- 5 = PUR

Comparison with other foam plastics

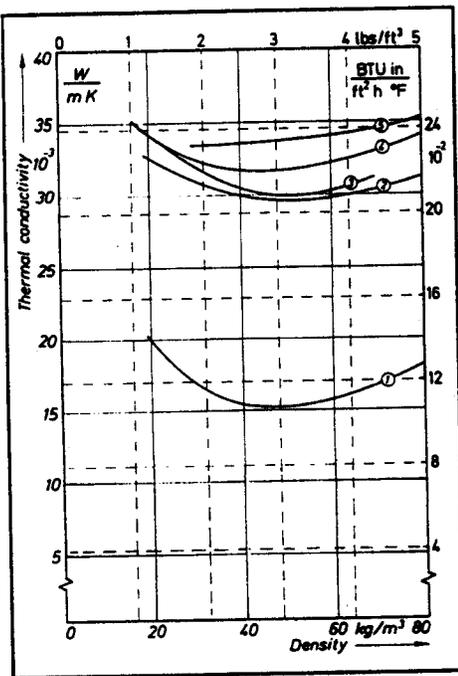


Fig. 22: Thermal conductivity according to ASTM C 177-63 of various rigid foams as a function of density

- 1 = PUR foamed with fluorotrichloromethane
- 2 = PF
- 3 = ROHACELL
- 4 = PS (foamed in a mold)
- 5 = PUR (foamed with CO₂)

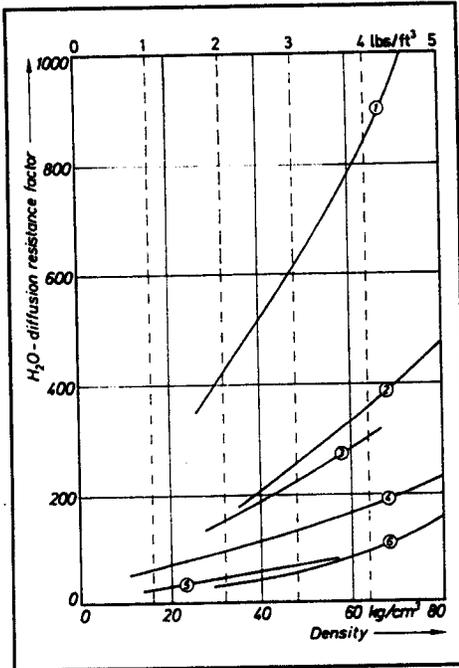


Fig. 23: H₂O diffusion resistance factor of various rigid foams as a function of density, measured in a 0 - 85% r.h. gradient

- 1 = ROHACELL
- 2 = PVC (cross-linked)
- 3 = PS (extruded)
- 4 = PS (foamed in a mold)
- 5 = PUR
- 6 = PF

Explanation of the abbreviations

The foam plastics consist of:

- PS = polystyrene
- PVC = polyvinyl chloride
- PUR = polyurethane
- PF = phenol formaldehyde

Test methods for ROHACELL

The gross density of ROHACELL in lbs/ft³ (kg/m³) is determined according to ASTM D 1622. The specimens are taken from a ROHACELL sheet 4 in. x 4 in. x 1 in.

The compressive strength of ROHACELL in psi (N/mm²) is determined according to ASTM D 1621. The dimensions of the test specimens are given in the table below.

ROHACELL	Specimen size in.	(mm)
31	2 x 2 x 2	(50 x 50 x 50)
51	2 x 2 x 2	(50 x 50 x 50)
71	2 x 2 x 1.77	(50 x 50 x 45)
110	2 x 2 x 1.9	(50 x 50 x 48)
P 170	2 x 2 x 1.1	(50 x 50 x 28)
P 190	2 x 2 x .9	(50 x 50 x 23)

The elastic modulus from the tensile test in psi (N/mm²) is determined according to ASTM D 638. The specimens have a cross-section of 10 x 10 mm according to specimen type M.

The shear strength and the shear modulus are determined as per ASTM C 273 and stated in psi (N/mm²). Specimen size is 7.87 x 1.97 x .78 in. (200 x 50 x 19.8 mm).

Fabricating ROHACELL

Cutting and stamping

Cutting

Thin sheets are cut with a knife. Thicker sheets can be scored half-way through and then broken. A particularly clean fracture is obtained by breaking the sheet at the edge of a table.

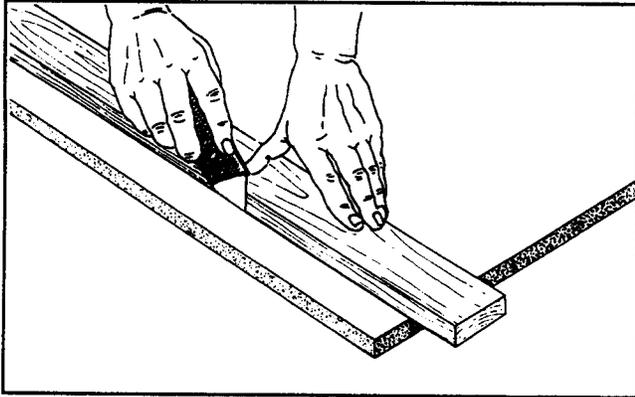


Fig. 24: Cutting

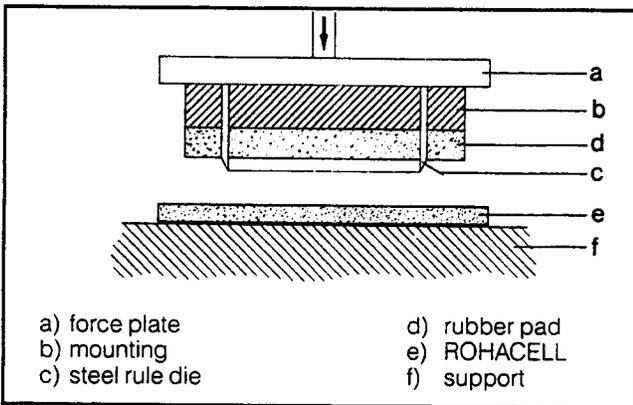


Fig. 25: Steel rule die for ROHACELL

Stamping

Parts can be stamped out of thin sheets (max. .4 in. [10 mm] thick) in this way. The maximum sheet thickness depends on the ROHACELL grade used.

Machining

ROHACELL is machined without lubricants on high-speed wood or plastics processing machines employing tools common to this field. Common machining methods include: drilling, planing (including cutting to thickness), milling, sawing and sanding. Make sure that the resultant dust is thoroughly removed by suction.

Sawing

Circular saws are used for cutting sheets to size. Band and compass saws can be used for cutting shapes.

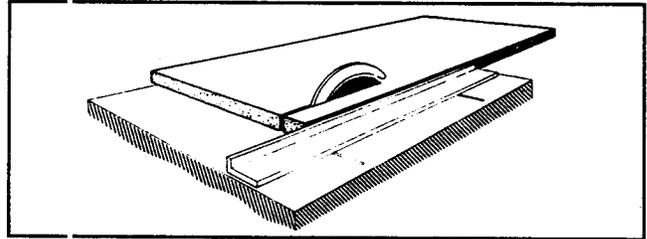


Fig. 23: Cutting-to-size by circular saw

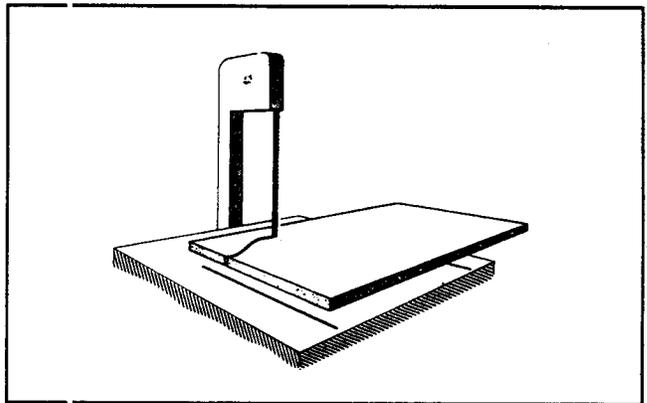


Fig. 27: Cutting shapes by means of a band saw

Sanding

The foam sheet can be shaped by sanding, using a steel template fixed to the sheet. Sanding is either done with an abrasive belt or by hand on a grinding stand. For large parts a board covered with abrasive paper is used, which is drawn across the template by hand. Plane ROHACELL sheets with close thickness tolerances are treated on grinding machines with vacuum table.

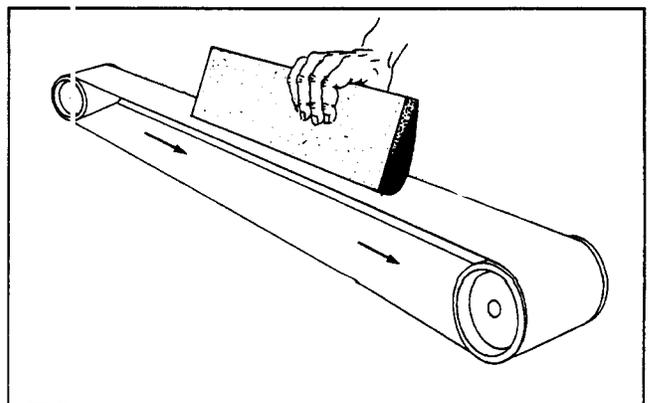


Fig. 28: Shaping by sanding with an abrasive belt

Machining

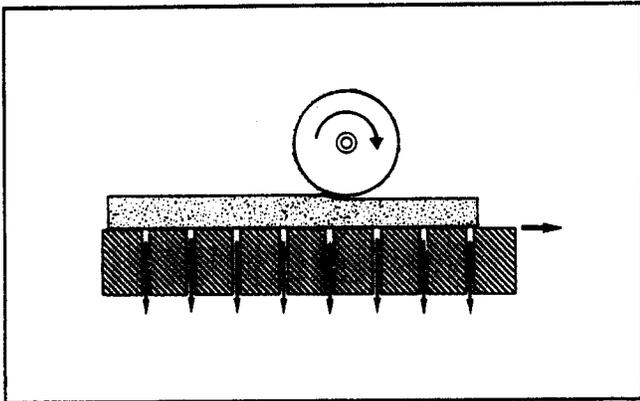


Fig. 29: Plane grinding on a face grinding machine

Planing

The common planing machines used for wood are also used to plane edges and surfaces. It is equally possible to work with a thickening machine. Since the foam is more easily crushed than wood, the profile of the feed rollers may be reproduced. Chip removal should therefore be sufficiently deep for the impression to disappear. The contact pressure of the rollers should be matched to the compressive strength of the foam plastic, too. If the roller pressure is too high, the outer parts of the cells are most likely to be destroyed. This is noticeable through the "feltlike feel" of the foam surface. Rubber-covered rollers have also proved useful.

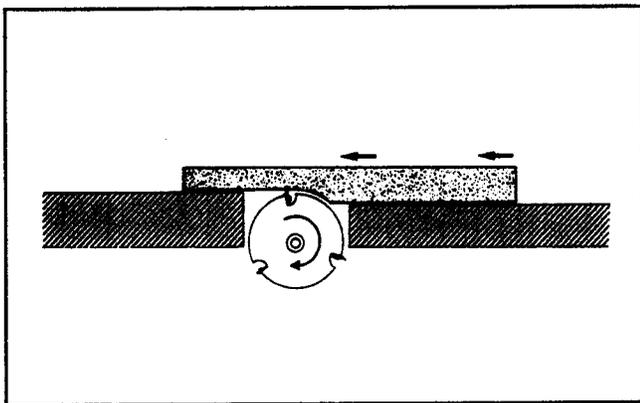


Fig. 30: Trueing on the planing machine

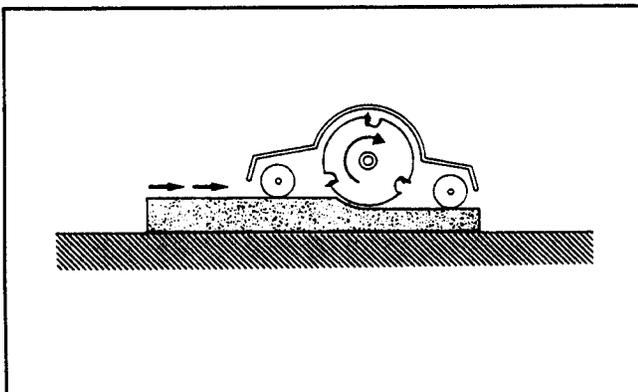


Fig. 31: Cutting to thickness

Milling

Grooves, rabbet and other profiles can be cut with a routing cutter. With due care, the material can be cut to web widths of .08 in. (2 mm).

Parts matching the contours of a template can be produced with a suitable milling cutter.

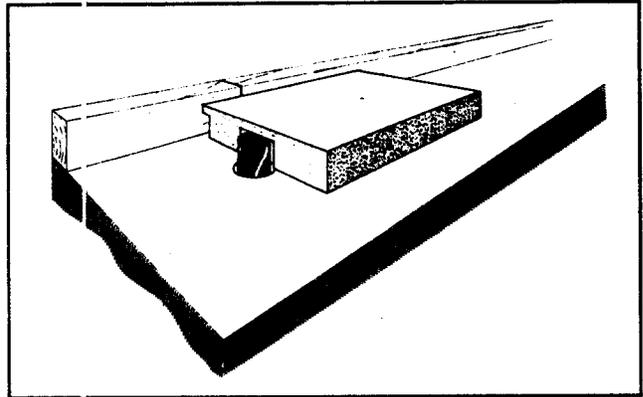


Fig. 32: Cutting grooves and rabbets with a routing cutter

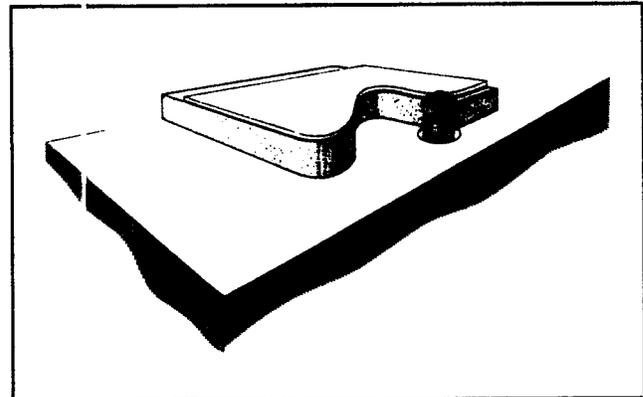


Fig. 33: Contour milling using a template

Machining

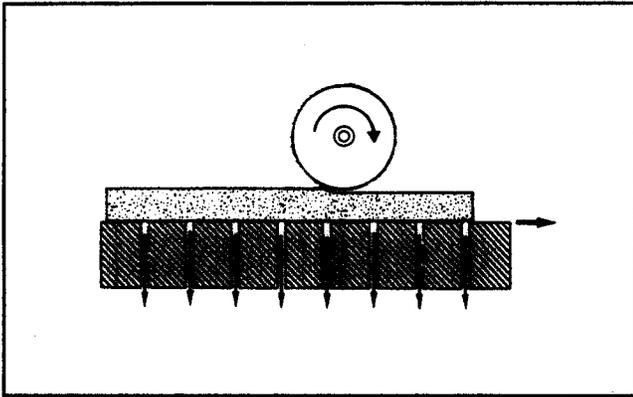


Fig. 29: Plane grinding on a face grinding machine

Planing

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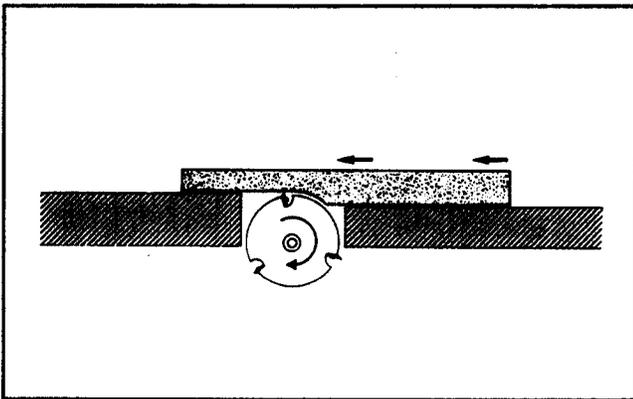


Fig. 30: Trueing on the planing machine

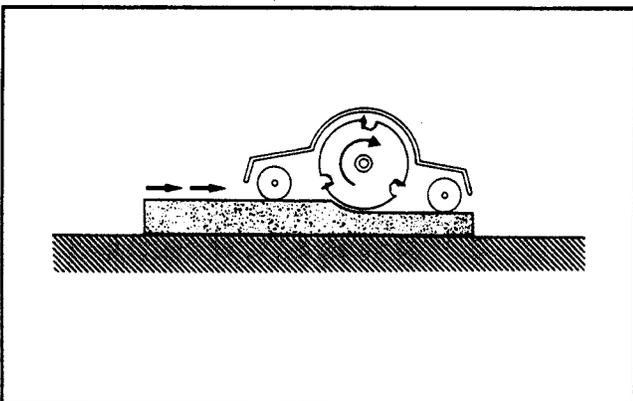


Fig. 31: Cutting to thickness

Milling

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Parts matching the contours of a template can be produced with a suitable milling cutter.

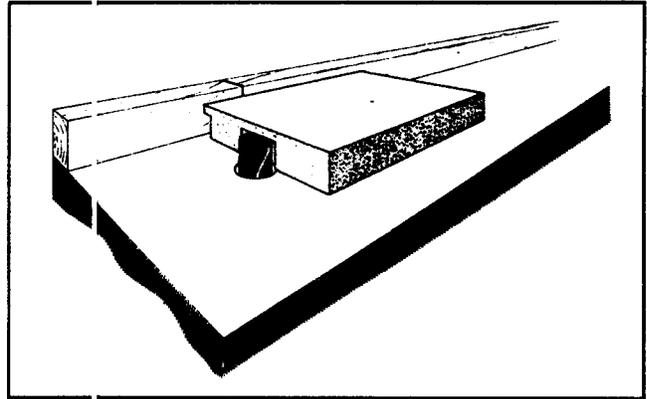


Fig. 32: Cutting grooves and rabbets with a routing cutter

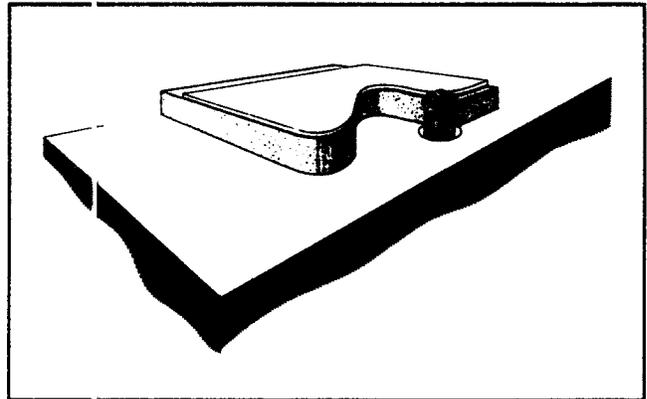


Fig. 33: Contour milling using a template

Compressing ROHACELL

Surface compression

ROHACELL sheets with an integral structure are produced in a press which can be cooled and heated. A cold, suitably oversized ROHACELL sheet is placed between heated platens at 320–356 °F (160–180 °C) and then the press closed immediately. The specific molding pressure should be about 30% less than the compressive strength of the particular ROHACELL grade at 68 °F (20 °C). As the heat penetrates into the ROHACELL sheet, the outer cells correspondingly give way and are squeezed flat. The procedure gives a higher density in this layer. The molding time depends on the desired degree of compression until the thickness stop is reached. The sheet must now be cooled to about 176 °F (80 °C) before it can be taken out of the press. This prevents the flattened cells from recovering their original shape (Fig. 34). The method also serves for partial compression of molded articles (Fig. 35).

In practice, this procedure is also utilized for sandwich parts with thin skins in order to increase the bending stiffness of the sandwich. Another important fact is that the indentation resistance is considerably improved through the higher density of the edge zones. During hot curing of the adhesives or resins, the outer surface is compressed until the desired thickness stop is reached.

Moldings with complex exterior contours

After heating the ROHACELL part to be molded to the forming temperature (338–374 °F [170–190 °C], depending on material grade), it is placed in a heated mold and brought to the required geometrical form by compression. The molding must be cooled down to about 176 °F (80 °C) before it can be taken out of the mold.

The described method is far more cost-effective than other techniques, because there is no machining to a precise exterior contour.

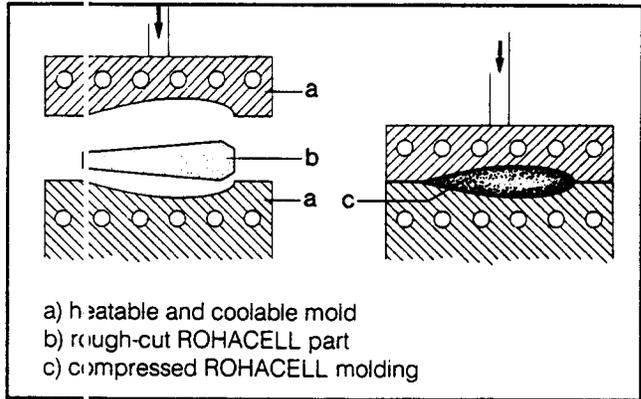


Fig. 36: Manufacture of moldings with complex exterior contours

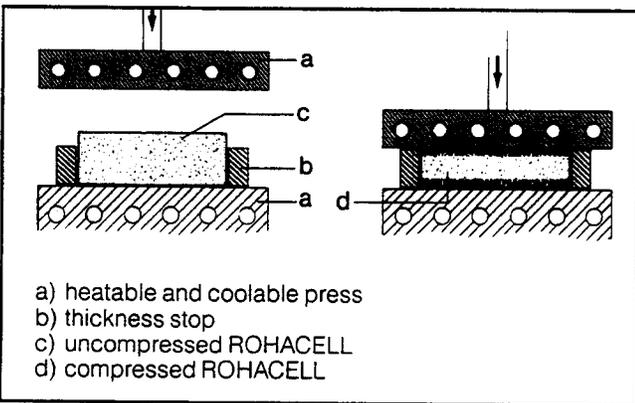


Fig. 34: Surface compression

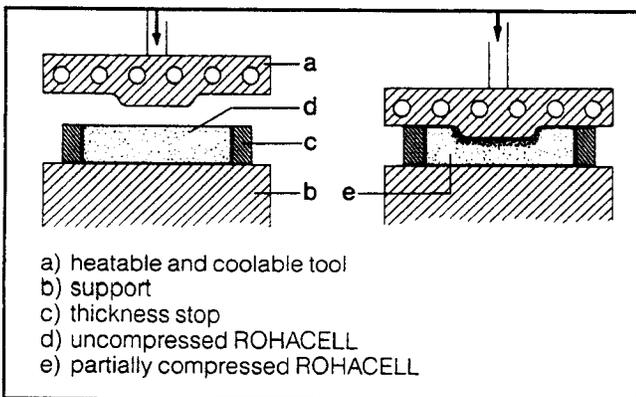


Fig. 35: Partial compression

Forming

Moldings can be relatively simply produced from ROHACELL sheets. The smallest attainable bending radius is about twice the sheet thickness.

Heating the ROHACELL sheets

Before heating the ROHACELL sheets, they should be dried for 2 hrs. at 248 °F (120 °C), using a heating cabinet with air circulation. ROHACELL becomes thermoelastic and can therefore be formed at a temperature of 338 to 374 °F (170 – 190 °C). The required forming temperature depends on the degree of shaping, the pretreatment and the density.

The heating time for ROHACELL sheets in a heating chamber with air circulation that has been brought to forming temperature is about 1 min/0.04 in. (1 min/mm) sheet thickness. Care must always be taken so see that the hot air sweeps uniformly over both sides of the foam plastic sheets and that no heat is allowed to accumulate (Fig. 37). This method is particularly suitable for the manufacture of prototypes. Heating is much simpler and more dependable between heating plates, which you can easily make yourself (Fig. 38). This method can be recommended for series production.

Radiant heaters can be used to warm up thin sheets of ROHACELL up to 0.24 in. for line bending (Fig. 39). A vacuum forming machine may be used to mold these same sheets.

Caution: The forming temperature is close to the foaming temperature, so that it must be accurately controlled in order to prevent post-foaming. This is particularly important when warming up the ROHACELL sheet by means of radiant heaters.

Avoiding unduly fast cooling

Since the heat capacity of the rigid foam is low because of its small mass and the sheet surfaces cool quickly because of the multitude of cut cells which act as "cooling vanes", the blanks must be protected against cooling while they are moved from the heating cabinet or the heating plates to the forming device. Unduly fast cooling is avoided by covering the ROHACELL sheets on all sides with cotton cloth, thin aluminium foil, glass fabric or silicone rubber. The foam plastic is heated and formed together with this cover. The cover is intended to keep the ROHACELL sheet just long enough at the necessary forming temperature until forming is finished.

With simple moldings a cover on one side is often sufficient if the work is done fast. The cover must be applied to that side of the ROHACELL sheet which is subject to tensile stress during forming (Fig. 41).

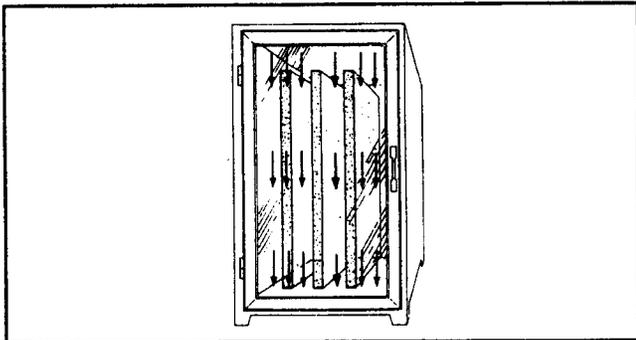


Fig. 37: Heating in a cabinet with air circulation

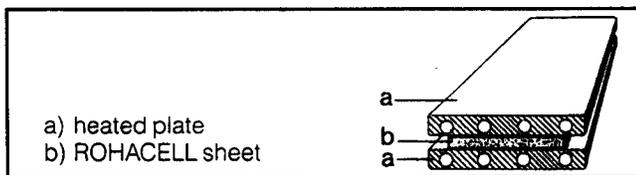


Fig. 38: Heating between plates

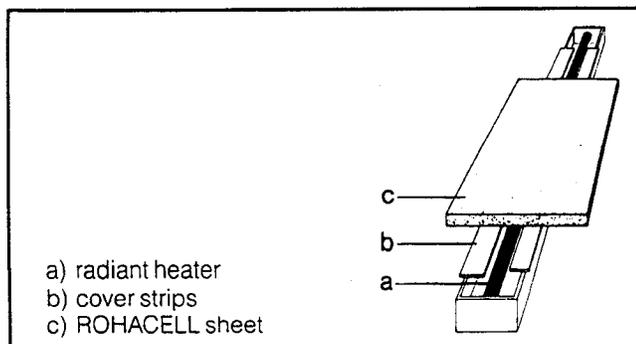


Fig. 39: Line bending of thin ROHACELL sheets

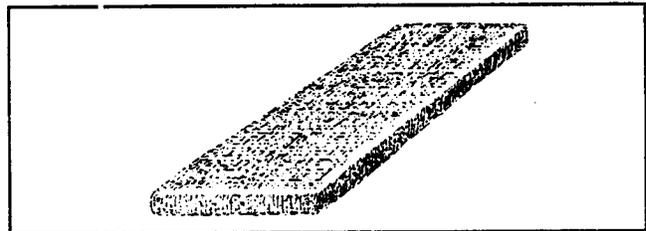


Fig. 40: ROHACELL sheet covered all around

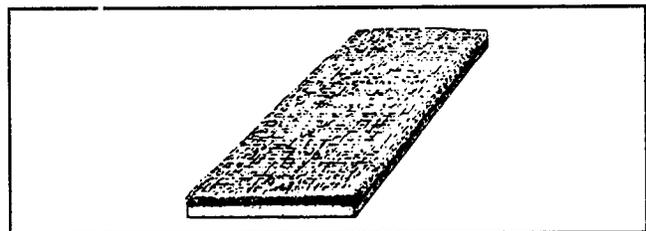


Fig. 41: ROHACELL sheet covered on one side only

For series production, the heating plates and the forming tool can be put in such a position that, when the heated ROHACELL blank is quickly and automatically taken from the heating plates to the forming tool, there is often no need for any cover.

Design of the forming tools

Tools which are not heated can be used for simple parts when the degree of forming is small. Tool temperatures of 176 to 212 °F (80 – 100 °C) may be necessary when more complex parts have to be formed.

The foam plastic cools quickly because of its low heat capacity, and once the formed part has cooled down to c. 176 °F (80 °C) it may be removed from the tool. With simple parts, the molds are not subjected to a substantial amount of heat, so that hardwood molds are adequate. Polyester and epoxy resin molds are also used. The advantage of these non-metallic molds is that the ROHACELL surfaces do not cool down so quickly during forming because of the relatively poor heat conductivity. Metal molds should be thermostatically controlled.

In order to ensure that the ROHACELL sheet can be drawn into the mold without much resistance, the edges should have large radii. If the radii are too small, the edge is squeezed into the heated foam at the start of forming and impedes further sliding. Cracks at these points will then be unavoidable. Forming itself should be done uniformly and quickly. Abrupt forming must be avoided.

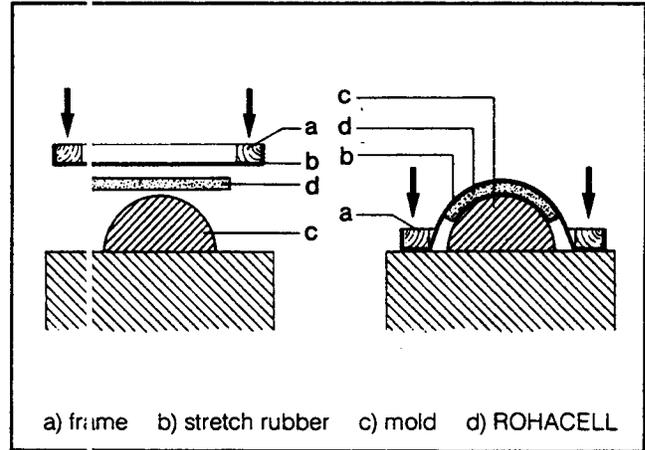


Fig. 44: Forming ROHACELL with stretch rubber

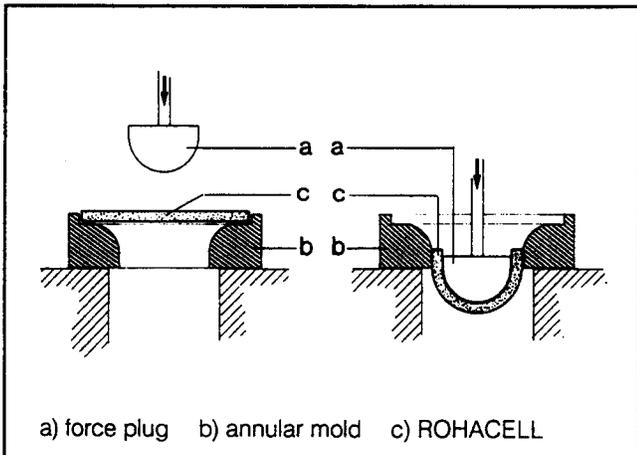


Fig. 42: Forming of a hemisphere from ROHACELL

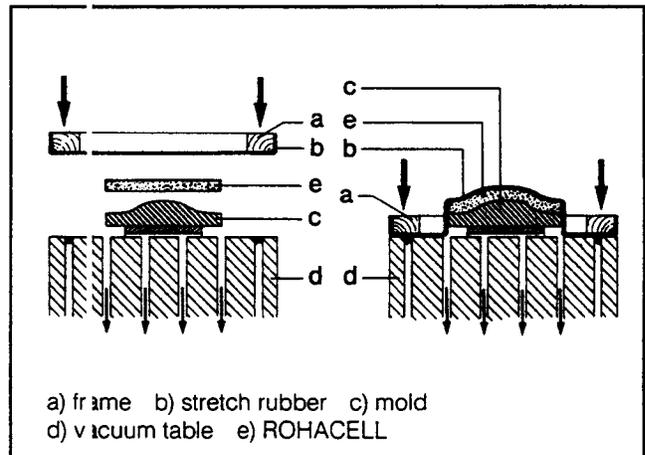


Fig. 45: Forming ROHACELL with stretch rubber

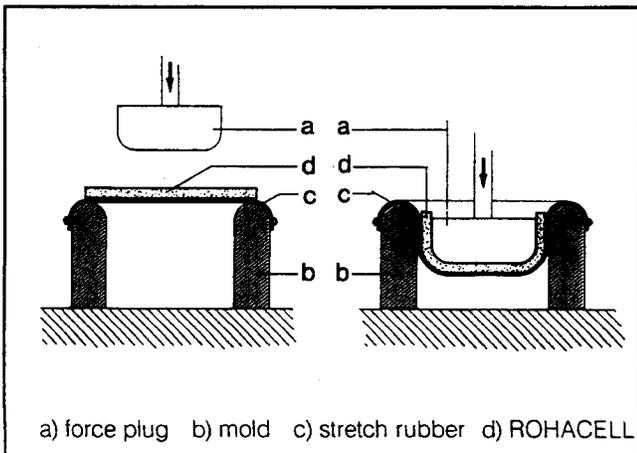


Fig. 43: Forming ROHACELL with stretch rubber

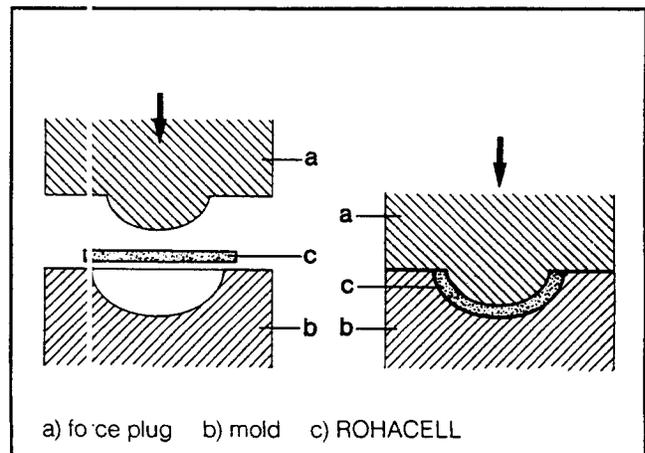


Fig. 46: Forming in the tool

Bonding

Owing to the large number of available adhesives and the multitude of materials which may be bonded to ROHACELL, it is difficult to provide complete information on the application methods and amounts of adhesives, as well as on the drying and curing times. However, in case of special problems we will be glad to look for a practical solution together with the adhesive manufacturers. For most bonding problems ROHACELL offers the decisive advantages of solvent resistance and heat distortion resistance for hot curing up to 320 °F (160 °C).

Practically all commercial adhesives can therefore be used.

The bond between the adhesive and ROHACELL is much improved through mechanical anchoring in the cut cells.

It is essential that the ROHACELL surfaces are freed from dust by suction or blowing with oil-free compressed air before bonding.

Since ROHACELL is highly impervious to solvent diffusion, great care must be taken, when large areas of ROHACELL are to be bonded to ROHACELL or other diffusion-tight materials by solvent-based adhesives, that the adherends are well devolatilized after the adhesive has been applied to both sides before they are joined together under pressure.

Joints made with these adhesive systems (generally rubber-based) normally remain somewhat elastic and have good peel strength. When it is possible to hot-cure the joint, the quality of the bond can be greatly improved.

Owing to the good heat transfer which is required, heat-sealing can only reasonably be done where thin material layers are to be bonded to ROHACELL; e.g. for laminating with metal sheets or decorative paper sheeting.

Emulsion adhesives are not recommended.

The solvent-free systems include hot-melt adhesives, reactive adhesives and adhesive films. Reactive adhesives like epoxy and polyester resins should be allowed to cure under sufficient pressure (1.25 – 43.5 psi/0.05 – 0.3 N/mm²) or be very fluid during application so that the cells of the foam are well filled. The cure can be accelerated by heat (up to 320 °F/160 °C). The joints become very hard and rigid.

Adhesive films and hot-melt adhesives need heat for bonding and can therefore normally be heat-cured. Adhesive films must be sufficiently thick (.02 – .04 lbs/ft²/100 – 200 g/m²) in order to anchor them firmly in the cut ROHACELL cells.

Some adhesive films such as phenolics give off volatile constituents while curing. Therefore they should be warmed-through with gentle pressure. Before pressing for bonding, the press should be briefly opened again to allow the volatile constituents to escape.

When hot-melt films are used, it has frequently proved useful to perforate them before bonding in order to avoid air bubbles.

For the purpose of better deaeration in difficult cases, prior grooving of the ROHACELL sheet surfaces will help. Grooves about .04 – .06 in. (1 – 1.5 mm) deep and .08 in. (2 mm) wide have proved useful.

When ROHACELL is to be bonded to other materials, the adhesive may generally be selected according to its suitability for these materials.

To obtain perfectly straight sandwich panels, it is important for both sides of the ROHACELL sheet to be simultaneously bonded to the skin. Both skins must be of the same material and have the same thickness. Equally important are uniform heating and cooling on both sides.

To prevent core compression during hot press bonding we recommend starting out with a ROHACELL core .02 – .04 in. (0.5 – 1 mm) over thickness and closing the press to stops.

The application of laminates

The usual laminating methods like hand lay-up and molding techniques can be used. In order to obtain good peel strengths, pressures of at least 1.25 psi/0.05 N/mm² are desirable. Hot curing is recommended for the short cycle times. ROHACELL tolerates up to 320 °F (160 °C), but in that case the press should be run to a stop (see also "Bonding"). When polyester resins are used there is no need to seal the foam plastic surface, because it is resistant to styrene.

If the molding pressure is to be applied with a vacuum bag, the ROHACELL sheet may, for the sake of better venting, be perforated with holes about .08 in (2 mm) in diameter at intervals of about 2 in. (5 cm). Before laminating, the ROHACELL surfaces must be completely free from dust in order to ensure good adhesion of the resins. Sandwich parts are also made with the prepregs usual in aircraft construction. Pressing-on and curing is either done in an autoclave or in a mold. The first layer on ROHACELL should be a resin-rich prepreg in order to have sufficient resin for anchoring in the cut cells and thus to achieve good bond strength.

Before applying the prepregs, the ROHACELL surfaces should be freed from dust by suction or by blowing with oilfree compressed air.

When prepregs are used which release volatile constituents during the curing process, e.g. water from phenolic resin prepregs, the removal of the volatiles, e.g. from an autoclave, must be ensured by suction. If curing takes place in a molding tool, the press must be briefly opened again when the prepregs are warmed through, so that the bulk of the volatile constituents can escape. In the case of matrix systems, which are cured at very high temperatures, the ROHACELL core may yield excessively when curing takes place in an autoclave or a press without a stop. Better results are then achieved with ROHACELL WF.

In any case it is recommended whenever possible to run the tool against a stop, particularly when curing takes place in molding tools, in order to avoid exceeding the lower tolerance limit through thermoelastic creep.

When relatively brittle skins are used, e.g. phenolic resin prepregs, the bond strength can be considerably increased by applying an elastic primer or hot-melt adhesive film to the ROHACELL core. ROHACELL is a foam plastic with closed cells. During bonding or when a laminating resin is applied, the resins only penetrate the open pores of the cut surface. The bond strength obtained in this way is very good for ordinary purposes.

A peel test is often performed to provide information on the bond strength of a skin on the core, although this test does not really resemble practical conditions. A peel force generally only acts on the sandwich after the skins have failed for reasons of stability (e.g. creasing or wrinkling) or strength (cracking or compression), which is most likely to occur in practice.

Painting

ROHACELL can be painted or sprayed with most commercial paints (including nitrocellulose lacquers). Most emulsion paints of the kind used in the building trade are chemically basic. These paints are unsuitable, because ROHACELL does not resist alkaline media. For smooth and glossy surfaces the foam plastic is first filled and sanded. Spraying fillers, e.g. polyester fillers, are also suitable for this purpose. If a paint with grain effect is to be applied, spray-filled surfaces need not be sanded before painting.

When joints or damaged areas on ROHACELL parts have to be filled and then sanded, the filler should have about the same sanding behavior as the ROHACELL grade in order to get a perfect transition from the filled area to the adjoining foam plastic. You can prepare such a filler yourself according to the following formulations:

Formulation 1:

90 parts by wt. filler

20 parts by wt. thinner

15 parts by wt. microballoons

The amount of added microballoons depends on the ROHACELL grade to be filled. The more microballoons are added the easier is the sanding. The thinner is used to vary the consistency so that the filler can be smoothly applied.

Formulation 2:

100 parts by wt. pore filler

25 parts by wt. microballoons.

The amount of added microballoons again depends on the ROHACELL grade to be sanded.

For the sake of better adhesion, the ROHACELL area to be filled is first brushed once with pore filler before the filling compound is knifed on. Filling greatly raises the compressive strength of the foam plastic surface.

Particularly decorative and resistant surfaces are obtained by metal flame spraying. Aluminium, bronze, copper and iron may be sprayed on.

The production of prepreg (SMC) moldings with ROHACELL 71

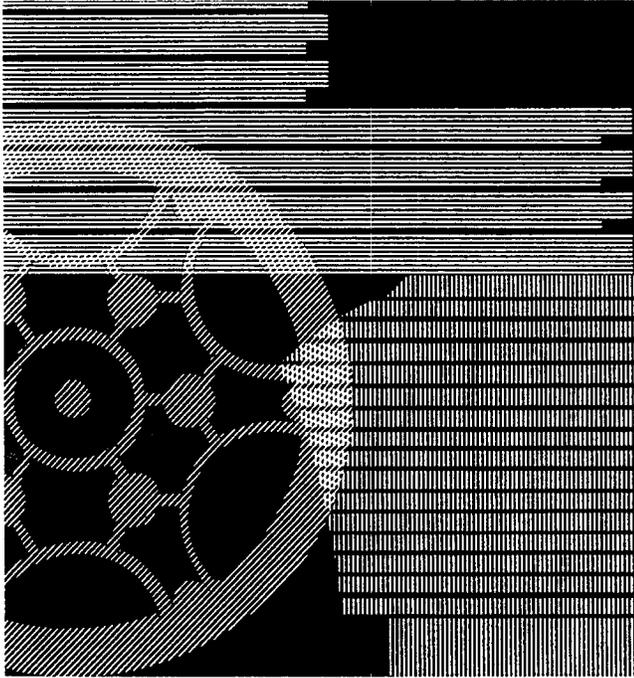
Prepregs are SMC's. Their main constituents are unsaturated polyester resins, textile glassfiber, fillers and auxiliaries. They are applied in steel tools at 248 – 320 °F (120 – 160 °C).

For the manufacture of sandwich parts with SMC skins and ROHACELL 71 as the core material, a molding pressure of about 116 psi/0.8 N/mm² has proved beneficial. This specific molding pressure should only be applied until the mold cavity is filled by the flowing prepreg. Afterwards it is reduced to about 58 psi/0.4 N/mm² and kept constant until the end of the curing cycle. The press temperature should be 248 – 266 °F (120 – 130 °C).

This processing technique has proved useful where normally reactive and free-flowing SMC resins are used.

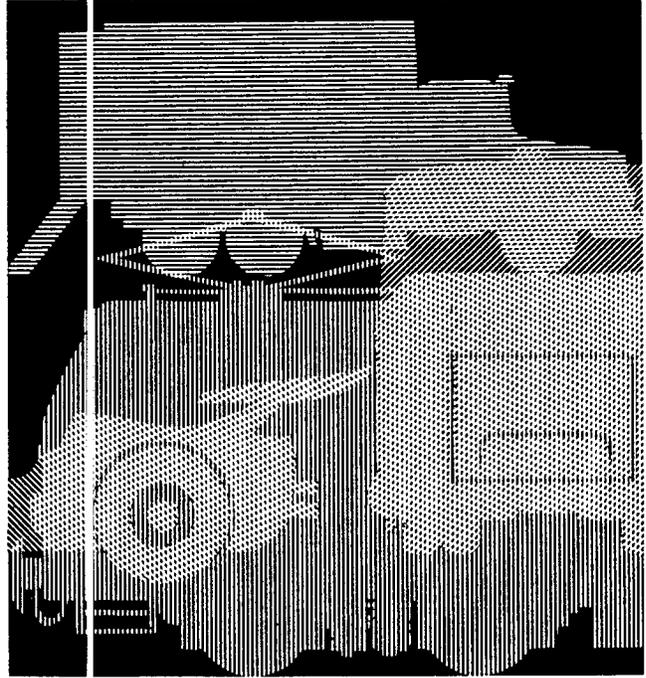
Practical examples of ROHACELL

Model building



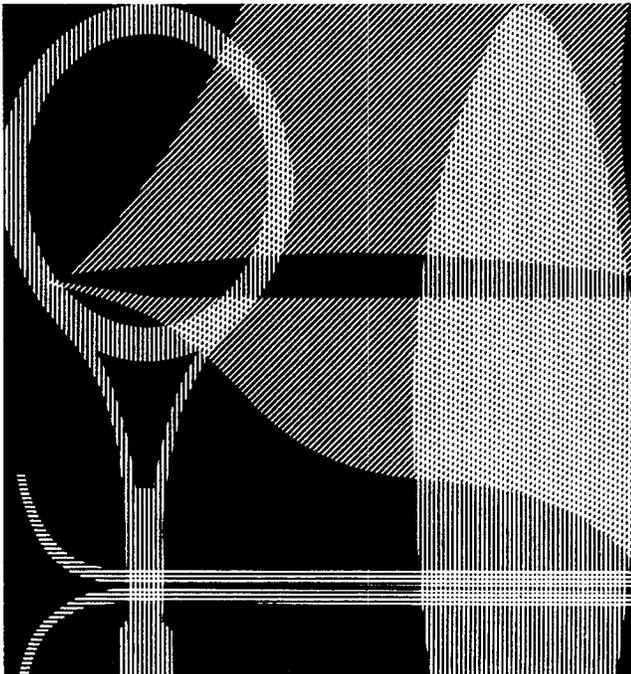
- easy machining
- readily painted
- good dimensional stability
- easy handling

Vehicle construction



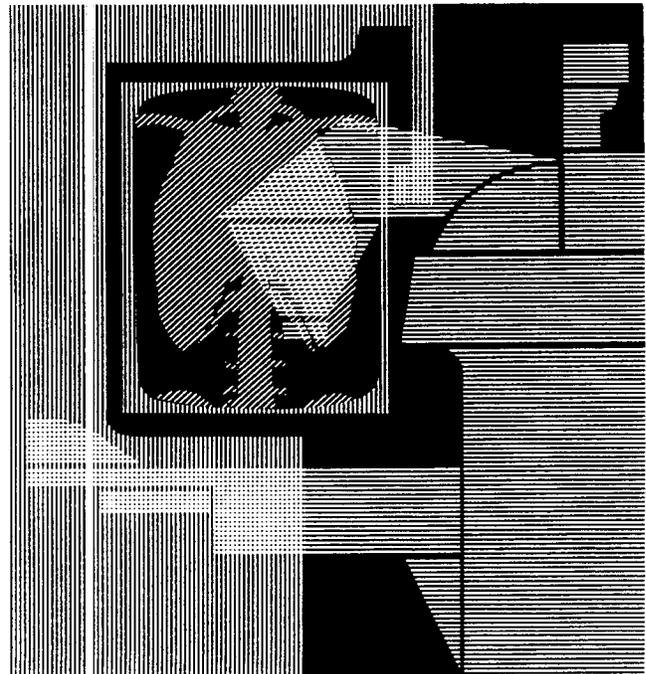
- high rigidity
- low weight
- self-supporting sandwich structures
- extreme stresses are tolerated
- short cycle time for polyester moldings with ROHACELL core
- can be painted with bake on coatings

Sports equipment



- can be highly stressed dynamically
- good damping
- low weight
- simple manufacture

Medical engineering



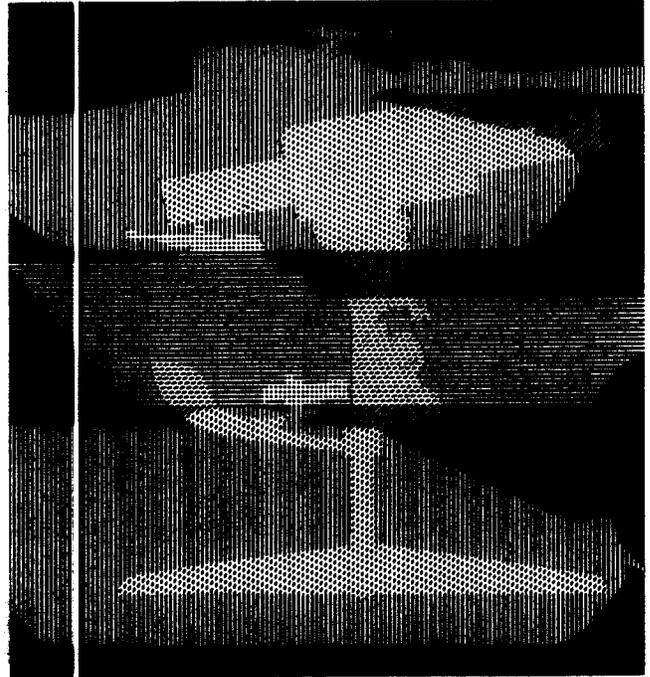
- outstanding radiation transmission
- minimum radiation scatter
- smaller doses are therefore required

Antennae, radomes



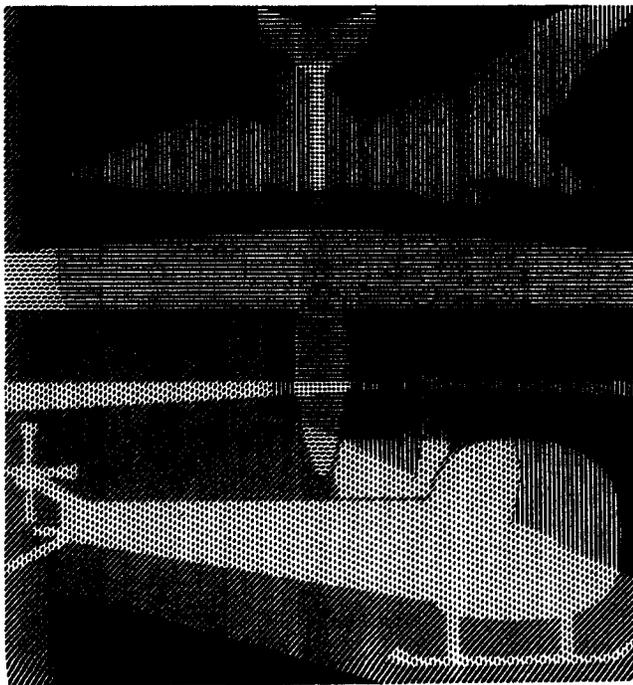
- excellent radiation transmission
- minimum radiation scatter
- good forming properties
- can be highly stressed dynamically
- high heat resistance

Arms technology



- can be extremely highly stressed

Aircraft construction



- can be extremely highly stressed dynamically
- self supporting structures
- high specific strengths
- low weight
- simple forming
- simple machining
- core material with closed cells

Polymethacrylimide **rigid** foam

Important notice

The information and statements herein are believed to be reliable but are not to be construed as a warranty or representation for which we assume legal responsibility. Users should undertake sufficient verification and testing to determine the suitability to their own particular purpose of any information or products referred to herein. NO WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE IS MADE.

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