6 Sep 99

PROCEDURE FOR FINISHING THE SEGMENT PROPELLANT CASINGS

These are student recollections of the RRS Solid Propellant Rocket Propulsion Course (May 99) for review and rewrite by more experienced RRS members.

1. Put on a pair of disposable rubber gloves.

2. Carefully remove the wax paper from the ends of the cured segment propellant casings. Clean off the excess propellant from the exterior phenolic surface of the casings using a paper towel and acetone.

3. Inspect the ends of the casings for propellant voids. Show suspect propellant areas to the instructor.

4. Take casings to end of line at Station #1 for end grinding. The instructor will do the end gringing. When in Station #1 area remain upwind of airborne propellant dust from the grinder.

5. Inspect the ends of the casings again for propellant voids. Show suspect propellant areas to instructor.

6. Proceed to end of line at Station #2 for segment propellant drilling.

7. Pull the drill bit back to allow space to insert the segment into the fixture.

8. Slide casing horizontally into fixture leaving about 1 inch protruding from front of fixture. 'Snug' both nuts on the top of the fixture to hold casing in place.

9. BEFORE cutting any propellant, determine amount of 'drill-trigger-squeeze' necessary to obtain about 3 to 5 rotations per second.

10. DO NOT start drill with bit touching propellant. Start drill then move drill bit to the propellant end face. Push the rotating bit into the propellant about 1 to 2 inches, keeping the bit turning. With the drill bit turning, pull the bit out expelling cored propellant.

11. Repeat this process 3 or 4 times. When near the back end face of the propellant DO NOT poke thru the back end face. Keep the drill turning and cut thru the back end face.

12. Pull the drill bit back to allow space to remove the drilled segment. Loosen both nuts and remove drilled segment.

13. Repeat drilling process for remaining casings.

14. Inspect the interior surface of the propellant for voids. Show suspect propellant areas to the instructor.

15. Proceed to the end of the line at Station #3.

16. Insert the 'end-preparation-tool' into the drilled hole. With the cutting edge of the tool against the end face of the propellant, twist the tool and casing in opposite directions 'curling' the propellant from the face. This process should result in a 5 degree flat, concave surface. Repeat this process for the other end of the casing.

17. Inspect the ends of the casing for propellant voids. Show suspect propellant areas to the instructor.

18. The instructor will sand a 'round' in the edge of the drilled hole on the concave surface at each end of the casing and make a final inspection of the propellant segment casings.

6 Sep 99

PROCEDURE FOR LOADING THE SEGMENT PROPELLANT CASINGS

These are student recollections of the RRS Solid Propellant Rocket Propulsion Course (May 99) for review and rewrite by more experienced RRS members.

1. Put on a pair of disposable rubber gloves.

2. Check the condition of the empty phenolic segment propellant casings. Make sure the inner and outer surfaces are smooth and undamaged. Make sure the end rims are square to the tube wall and that the rims have no nicks and that the end cuts are clean.

3. Clean the phenolic residue from the inside and the outside of the casings using a paper towel and acetone.

4. Put on a new pair of disposable rubber gloves.

5. Place the square aluminum plate on the table.

6. Place a wax paper square in the center of the aluminum plate.

7. Place the casing in the vertical position in the center of the wax paper.

8. The 'karate chop' method for packing the top of the casing should be demonstrated before continuing to the next step.

9. While loading the propellant, hold the casing firmly down on the wax paper and aluminum plate.

10. Take a 'tennis-ball-size-glob' of propellant from the pile on the table and put it into the cylinder. Push the propellant to the bottom with one finger. Pack the propellant into the bottom of the casing by 'poking' your finger down thru the propellant several times, continuing to hold the casing firmly down on the wax paper.

11. Repeat this process with another 'tennis-ball-size-glob' of propellant, packing the propellant by poking a finger down into the propellant.

12. With a small amount of propellant protruding out the top of the casing use the 'karate chop' method to pack the top of the casing. To pack the top of the casing it may be necessary to 'lightly' push on the top of the casing with the palm of your hand, while continuing to hold the casing firmly down on the wax paper.

13. DO NOT put propellant contaminated with sand, dirt or debris back into the pile on the table. Collect the excess propellant from and around the aluminum plate and place it back onto the pile on the table.

14. Continue to hold the casing firmly down onto the wax paper so that the propellant does not 'ooze-out' from the bottom of the casing. Pick

up the aluminum plate and carry the packed casing to the wooden oven shelf.

15. Place one edge of the metal plate against the oven shelf at a slight angle from the horizontal. Pulling the wax paper, slide the loaded casing from the aluminum plate to the oven shelf.

16. With the loaded casing on the oven shelf, hold the casing down and twist slightly to ensure that the casing rim is resting squarely and firmly against the wax paper and the oven shelf surface.

PROCEDURE FOR ASSEMBLYING THE ROCKET MOTOR

These are student recollections of the RRS Solid Propellant Rocket Propulsion Course (May 99) for review and rewrite by more experienced RRS members.

1. You may or may not want to wear rubber gloves for assembly.

2. This is a 2 person job. One person will hold the aluminum motor case and place RTV on the phenolic rim of one end of each segment propellant casing. The other person will grease the outside of the components and install the components into the aluminum motor case.

3. Layout the following parts:
   - a. 1 aluminum motor casing
   - b. 1 nozzle
   - c. 1 nozzle retainer
   - d. 1 nozzle spacer
   - e. 1 test bulkhead
   - f. 2 large diamter O-rings
   - g. 1 small diameter O-ring
   - h. 2 snap rings
   - i. 5 finished segment propellant casings

4. Put grease into the large diameter O-ring groove around the outside of the nozzle. Insert one large diameter O-ring into the groove on the side of the nozzle. With both thumbs push the O-ring over the edge of the nozzle and into the groove around the outside of the nozzle.

5. With the O-ring in place fill the groove with grease. Moderately grease the outside cylindrical wall of the nozzle, keeping grease from getting into the aft exhaust, throat and forward interior (combustion chamber) nozzle areas.

6. With the motor casing held vertically on the table, note the snap ring groove just inside the end of the motor casing. Insert the greased nozzle (the aft exhaust end UP) and push down until it stops. Now push down and twist the nozzle slightly to move the O-ring past the end of the motor case then push down until it stops a second time.

7. Again push down and twist the nozzle slightly to move the O-ring past the snap ring groove inside the motor casing. Slide the nozzle just past the snap ring groove and look for O-ring material in the groove. If O-ring material is found the O-ring may be damaged. Show the instructor.

8. With the motor casing in the horizontal position, install the nozzle retainer just behind the nozzle and push both the retainer and nozzle about 1/2 inch past the snap ring groove.

9. Put the snap ring on the snap ring pliers. Lightly squeezing the pliers, move the snap ring and pliers to the end of the motor casing where the nozzle was inserted. With your hand 'cupped' around the snap

ring and the end of the motor casing, squeeze the pliers and move the snap ring into the motor casing.

10. The snap ring seats 'SNUGLY' into the groove. Fit the side of the snap ring which is away from the pliers into the groove first, then move the other side into position and SLOWLY let the ring open into the groove.

11. Remove the pliers, tug on the ring to ensure that it is in place. Have the other person examine the snap ring for proper installation.

12. Rotate the motor casing 180 degrees so that the installed nozzle is away from you.

13. Have the other person put several small drops of RTV around the phenolic edge of one end of a segment propellant casing. Smear the RTV thin, keeping RTV from getting onto the end face of the propellant and place the nozzle spacer onto it.

14. Moderately grease the outside of the segment casing, keeping grease from getting onto the spacer or propellant face. Insert the segment casing, SPACER END FIRST, into the motor casing and push the segment casing flush to the end of the motor casing.

15. Have the other person put several small drops of RTV around the phenolic edge of one end of another segment propellant casing. Smear the RTV thin, keeping RTV from getting onto the end face of the propellant. Moderately grease the outside of the segment casing keeping grease from getting onto the smeared RTV or propellant face. Insert the segment casing, RTV END FIRST, into the motor casing, up against the first segment casing, and push the second segment casing flush to the end of the motor casing.

16. Repeat step 15 for the remaining 3 segment propellant casings. Push the last segment casing in until it stops.

17. Put a thin coat of grease on the small diameter O-ring and install against the phenolic rim of the last segment casing in the motor casing.

18. Put grease into the large diameter O-ring groove around the outside of the test bulkhead. Insert one large diameter O-ring into the groove on the side of the test bulkhead. With both thumbs push the O-ring over the edge of the test bulkhead and into the groove around the outside of the test bulkhead.

19. Fill the groove, with the O-ring in place, with grease. Moderately grease the outside, cylindrical wall of the test bulkhead.

20. The test bulkhead end with the threaded hole sticks OUT OF the top of the motor casing. Smear a thin layer of grease onto the bulkhead face to be inserted INTO the motor casing. Wipe this layer one time to make sure the grease layer is very thin.

21. With the motor casing held vertically on the table insert the greased test bulkhead (WITH the threaded hole up) and push down until it stops. Now push down and twist the bulkhead slightly to move the O-ring past the end of the motor case, then push down until it stops.

22. Again push down and twist the bulkhead slightly to move the O-ring past the snap ring groove inside the motor casing. Slide the bulkhead

just past the snap ring groove and look for O-ring material in the groove. If O-ring material is found show the instructor.

23. Examine the position of bulkhead surface adjacent to the snap ring groove. If the surface is not past the groove you may have to push down on the test bulkhead as the snap ring is inserted.

24. Put the snap ring on the table. Put the snap ring pliers prongs into the snap ring holes so that the prongs are flush with the back surface of the snap ring. Lightly squeezing the pliers, move the snap ring and pliers to the end of the motor casing where the test bulkhead was inserted.

25. While inserting the snap ring ensure that the snap ring holes and pliers are adjacent to the longitudinal flat area of the test bulkhead, this provides space for the pliers. With your hand 'cupped' around the snap ring and the end of the motor casing, squeeze the pliers and move the snap ring into the motor casing.

26. The snap ring seats 'SNUGLY' into the groove. Fit the side of the snap ring which is away from the pliers into the groove first, then move the other side into position and SLOWLY let the ring open into the groove. If necessary, push on the test bulkhead to provide clearence for the snap ring.

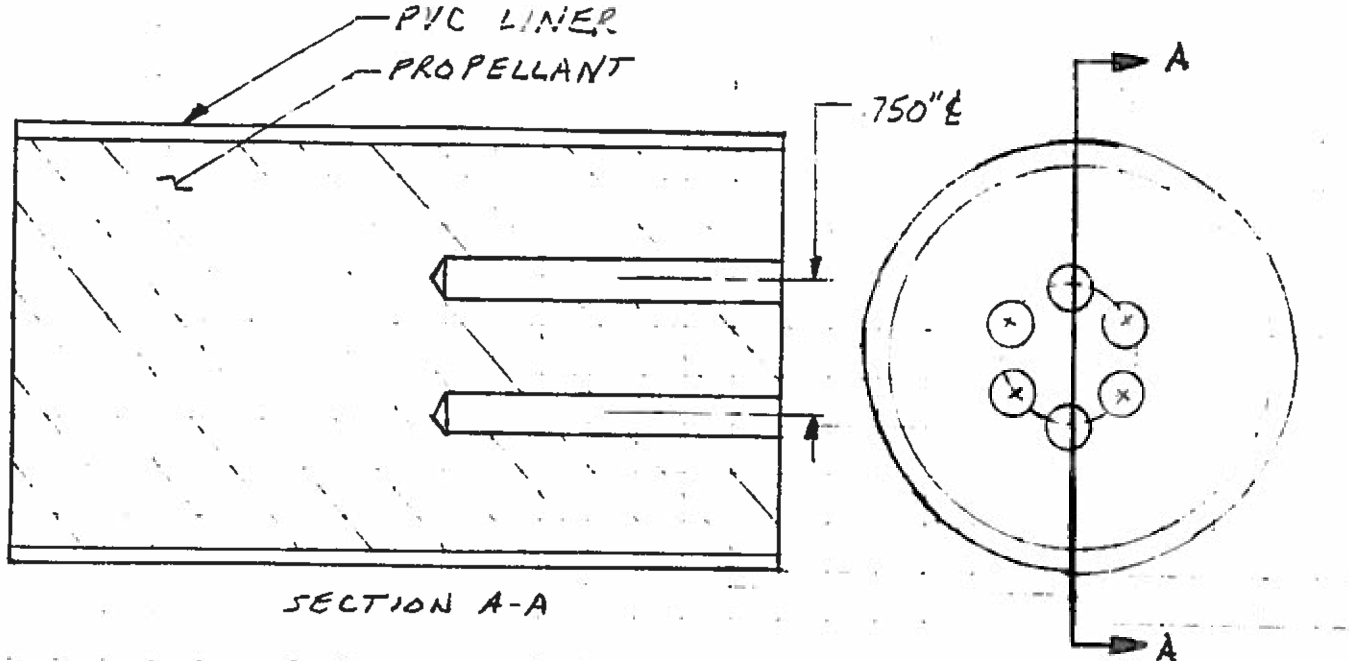
27. Remove the pliers, push on the ring to ensure that it is in place. Have the other person examine the snap ring for proper installation.

28. Have the instructor examine the two snap rings for proper installation.

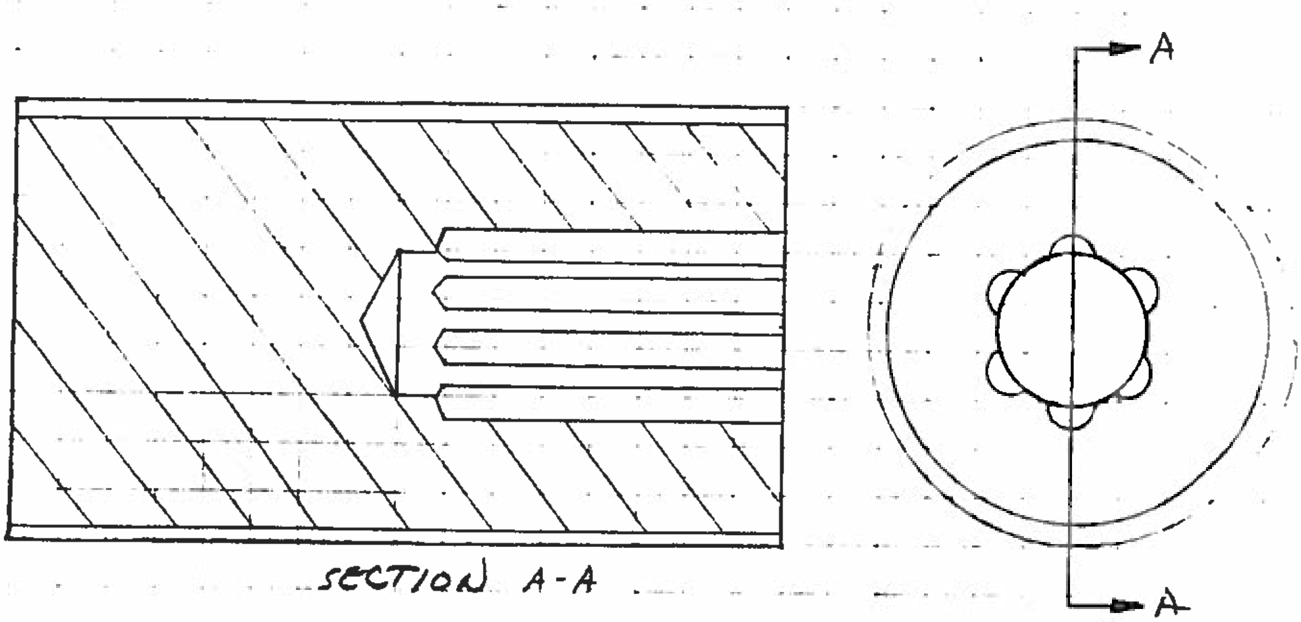
29. Clean your hands, then remove excess grease from the nozzle and test bulkhead ends and motor casing exterior surface.

30. Tape an aluminum foil cover over the test bulkhead end of the motor casing. Write your initials or name and date on the aluminum motor casing. Clean up the assembly area.

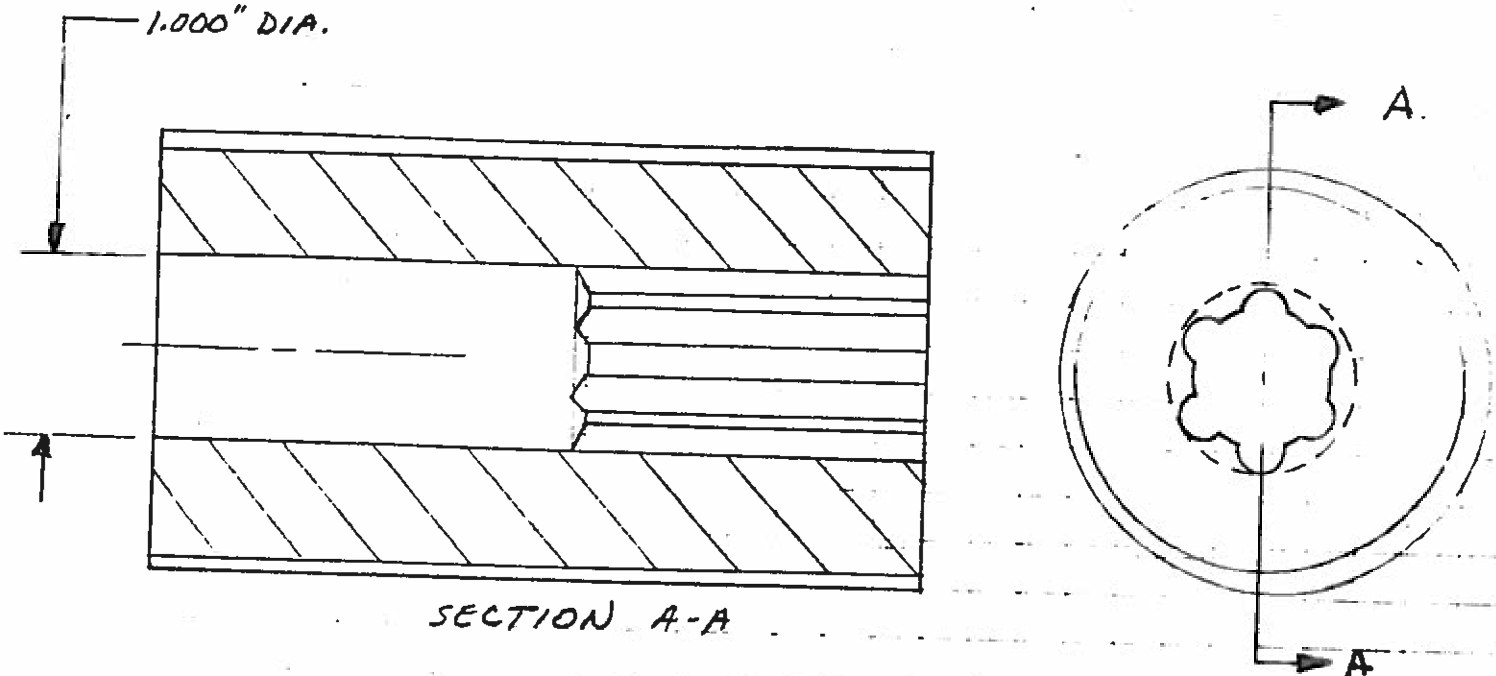
RRS COMPOSITE "BETA" DESIGN IMPROVEMENT IDEA#



DRILL SIX EQUALLY SPACED .250" DIA. HOLES CENTERED ON A .750" CIRCLE.



NEXT, DRILL A .750 DIA. HOLE CONCENTRIC WITH THE CENTER LINE CIRCLE OF THE .250" DIA HOLES. DRILL THE .750" DIA HOLE ABOUT .250 DEEPER THAN THE .250" DIA. HOLES.



LAST, DRILL THE 1.000 DIA. GRAIN BORE HOLE TO THE BOTTOM EXTENT OF THE .250 DIA. HOLES.

BY THIS METHOD, USING ONLY SIMPLE TOOLS AND MACHINING TECHNIQUES, A "STAR GRAIN" CAN BE CREATED. PLACE THIS GRAIN WITH "STAR" AGAINST THE BULKHEAD FOR IMPROVED IGNITION RELIABILITY AND SPEED

ADDITIONAL POLYURETHANE NOTES

Assume that the hydroxyl value of R45M is 75 mg KOH / 100 gm of resin. Dividing 75 by 100 gives 0.75 mg KOH / gram of resin. Now, divide 1000 by 0.75 and you will get 1333.3 gm of resin per equivalent. This is known as the Equivalent Weight, not the Molecular Weight

Assume that the isocyanate percentage on the label of the I143L is 29.1% Then, divide 4200 by the isocyanate percentage and you will get 143.3 gm of I143L per equivalent. This is the isocyanate's Equivalent Weight, not its Molecular Weight. Often, the manufacturer will show the Equivalent Weight directly on the label, making this calculation unnecessary.

Finally, for a theoretically-perfect match-up of the two chemicals so that no reactive groups on either ingredient are left over after curing is complete, you want to use the weights of these two ingredients in the ratio of the two Equivalent Weights, calculated above, that is:

1333.3 gm of R45M : 143.3 gm of Isonate 143L

If you express the ratio in terms of 100 gm of R45M, then it is a linear proportion calculation:

$100/1333.3 = X/143.3$; Rearranging and solving gives:

X=Wt. of I143L needed for 100 gm of R45M = $(143.3) * (100/1333.3) = 10.748$ gm I143L,

or, $X \sim 10.75$ gm I143L for 100 gm of R45M

Typically, in order to ensure that the curing reaction is complete, an excess, if any, of only 2-10% of isocyanate is used. The vast majority of the time, the excess is between 1% and 5%, with the most-used excess being about 2%. So, for the case shown, you would probably want to use

$10.748 * 1.02 = 10.963$ gm of I143L.

Rounded off, this would give about 11.0 gm of I143L for every 100 gm of R45M. Some of this excess will react with the small amount of moisture that inevitably is present, even after extreme drying conditions have been done. In fact, if you want, you can actually add this excess amount separately to pre-react with moisture and then add the remainder later. Although it will produce some carbon dioxide bubbles, they will be small in number and size and should, especially if you do any vacuum degassing or vacuum casting, come completely out of the mixture before it gels, leaving a nice dense, bubble-free, rubbery product.

If too much isocyanate is used, initially the inside will be soft, but after the mass has been exposed to moisture in the air which diffuses into the mass over a long period of time, it will set up to be as hard as the pressed black powder that Estes uses in its engines. The reason is that the moisture produces urea-type compounds which crosslink extensively to produce a non-flexible, very hard grain. Also, if aluminum powder is used, with a correctly-formulated mixture, then too much high-speed mixing can abrade the surfaces of the particles and causes the aluminum to react with the hydroxyl groups on the ends of the R45M molecules. The effect is one of having too much curing agent present even though it was correctly formulated to begin with. This has been known to happen with BIG motors, where the external surface is cured but the interior mass is still gelatinous, gooey, too-soft, etc. This is referred to as a "soft-center" cure. Upon cutting it open, the soft, sticky interior surfaces are now exposed to the "excess" isocyanate and proceed to cure due to contact with atmospheric moisture, still leaving the interior in an excess-isocyanate state.

Please note that an "over-isocyanated" mixture will not cure properly any more than one without enough isocyanate. (Usually (but not always), the plasticizer is inert, so no curing agent is needed for it.) There is a huge excess of isocyanate in the final product, and it reacts with the moisture in the ingredients first, to produce carbon dioxide bubbles. This results in foaming (or "puffing"), which gives a porous propellant. The excess isocyanate also causes the bulk of the material to "skin over" with a firm, tough film of a urea-type product, that also results from the reaction with water, leaving the inside still over-isocyanated. This skin can also trap bubbles that didn't have enough time to get out before the propellant mass has gelled. Finally, the excess isocyanate can act, believe it or not, like a plasticizer!

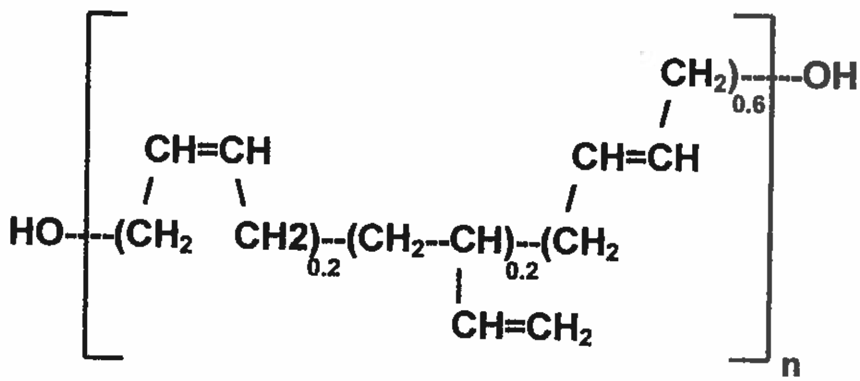
L. G. Teebken 5/20/99

For isocyanate

If NCO percentage is given: $\left(\frac{4{,}200}{\text{NCO percentage}}\right)$ = Equivalent weight of Isocyanate

Additional Notes

- The hydroxyl functionality of R45M polymer is typically in the range of 2.2 to 2.4, whereas that of R45HT is somewhat higher, typically 2.4 to 2.6.
- Optimum cure closely corresponds to an --NCO/--OH ratio of 1.0.
- If a catalyst is used, concentrations are usually in the range of 0.05 – 0.5 %, by weight.
- Organo-tin-based catalysts are preferred for fast cures at elevated temperatures, with minimum side effects.
- **HTPB: Simplified structure:**



n = 50

Polymer:	**R45HT**	**R45M**
Viscosity @ 30 C, centipoises	**5,000**	**5,000**
Hydroxyl Value, meq/gm resin	**0.83**	**0.75**
Hydroxyl Number, mg KOH/gm resin	**46.6**	**42.1**
Approx. Molecular Weight	**2,800**	**2,800**
Approx. Moisture Weight, %	**0.05**	**0.05**
Specific Gravity @ 30 C	**0.901**	**0.899**

$\left(\frac{1000}{\text{OH value}}\right)$ = Equivalent weight of Polyol

$\left(\frac{56{,}100}{\text{OH number}}\right)$ = Equivalent weight of Polyol (~~Functionality~~)

$\left(\frac{\text{Molecular weight}}{\text{Functionality}}\right)$ = Equivalent weight (in general