Material Selection Guide for Vacuum/Pressure Control Tubing

Executive Summary

Good - Neoprene, Shore 80A Durometer hardness (softer would be better)

30 feet of 1/8" ID 1/16" wall thickness

10 feet of 1/4" ID 1/8" wall thickness

Source: McMaster-Carr < http://www.mcmaster.com/pdf/106/0075.pdf>

Total Tubing Cost $14.10

Use heat stabilized Nylon cable ties $0.03 each

Source: McMaster-Carr < http://www.mcmaster.com/pdf/106/0678.pdf>

Better - Silicone tubing, Shore 70A Durometer hardness (the widely available 50A is less desirable)

30 feet of 4mm ID 2mm wall thickness

10 feet of 1/4"ID,1/8"wall thickness (appx. 6mm ID, 3mm wall)

Source: McMaster-Carr < http://www.mcmaster.com/pdf/106/0076.pdf>

Total Tubing Cost $35.70

Use Tefzel cable ties $0.51 each

Source: McMaster-Carr < http://www.mcmaster.com/pdf/106/0678.pdf>

Best -Viton tubing

30 feet of 1/8" ID 1/8" wall thickness (Shore 60A Durometer hardness, 1/8" (3.2mm) wall is very thick so the softer Viton is easier to stretch over the fittings)

10 feet of 1/4"ID,1/8"wall thickness (Shore 75A Durometer hardness)

Source: McMaster-Carr < http://www.mcmaster.com/pdf/106/0075.pdf>

Total Tubing Cost $306.00

Use wide-band spring steel hose clamps

Source: Home Depot $0.40 each

The Problem

The third generation Mazda RX-7 has over 33 feet of small control hoses (<1/4 inch id) under the hood. These hoses connect the solenoids and actuators that control the twin sequential turbo charging system, various emission control systems, and engine management systems. These hoses can carry vacuum (up to 24 inHg) or pressure (up to 12 psi) or both (not at the same time of course). On later cars Mazda secured some of the more failure prone connections with small wide-band spring steel hose clamps. Many of these hoses are buried deep within the engine and are not easily accessible or visible.

Failure of one of these hoses, in the form of a leak, usually at a connection, can be difficult and time consuming to diagnose.

Compounding this situation are two things. First, the under-hood temperatures on a third generation RX-7 are significantly higher than typically found in piston engine cars. This is due to the elevated exhaust temperatures of the rotary engine combined with the complex exhaust flow paths for the turbochargers and the presence of an exhaust pre-catalyst in the engine compartment. After driving on surface streets for 10 minutes, running at 70 mph on the freeway for 15 minutes, then driving on surface streets for 10 minutes (back to my house), shutting down and allowing a 10-minute heat soak, the following temperatures were measured with a thermocouple (Table 1).

Table 1. Under-Hood Temperatures

Location	Temperature °F
Y Pipe (just above the exhaust manifold)	263 °F
Under intake plenum (where most of the solenoids are)	168 °F
Turbo Control Actuator (directly underneath the turbos)	248 °F

These temperatures were collected when the ambient air temperature was 65 °F. As you can imagine if it was 102 °F that day, or I drove fast enough to bring the turbochargers fully online, the temperatures would be higher.

Another unique attribute of the third generation RX-7 is the presents of significant amounts of oil in the intake system. This oil has two origins. The first is a design flaw, the crankcase ventilation system allows large amounts of oil into the intake system during hard cornering. It has been reported that cars under track conditions can loose a quart of oil into the intake system during several laps. The other source of oil in the intake system is leakage of the turbocharger bearing seals. As the turbocharger bearing seals wear, they will allow the pressurized oil, which cools and lubricates the bearings, to leak into the intake system.

Oil in the control hoses was enough of a concern to Mazda that they equipped most of the factory check valves in the system with built in filters to prevent entrained oil droplets from entering the check valves. While stopping entrained oil droplets, they do not prevent the more volatile constituents of the oil (oil vapor) from entering the control hoses.

The Requirement

Here in the US, third generation RX-7s are 5-7 years old. Due to the presence hot oil vapor in the control tubes and elevated under-hood temperatures most of the original equipment hoses have lost their elasticity and are prone to leaking. Replacement of the original equipment hoses will soon be necessary. Paying to have all the control hoses replaced is an expensive and non-trivial job ($400 - $700). Doing it yourself for the first time typically takes several days.

If you plan on keeping your car for less that 5 years after replacing the control hoses, it probably doesn't matter what hose material our hose clamping system you use. All the automotive vacuum hoses on the market, even the cheap hose from the automotive discount chain stores will last that long. Think about that, a typical 5 year old third generation RX7 has 60,000 miles on the odometer, in 5 more years it will have 120,000 miles, are you still going to want to be driving it?

If the answer is yes, then you want to replace the original hoses with a hose material that will last the rest of the life of the engine. Along with the hose material, you must select a method of securing the hose to the fittings. Currently, all commercially available hose replacement kits for the RX7 use silicone hose and the most common method of securing the hose is 6/6 Nylon cable ties. The selection of silicon hose for the replacement material is probably historical. Since the 60's high-performance shops have offered silicon hose replacement kits for many types of cars. Silicone is a relatively cheap material with an excellent ability to resist high temperatures. Unfortunately, given the unique under-hood environment of the third generation RX7 this traditional high performance hose material may not necessarily be the best choice for long term durability.

To summarize, if you plan on keeping your car for 5 years or less material selection is unimportant. If you plan on keeping your car for 10 or more years and don't want to replace the control hoses again, proper material selection is critical. If you plan on keeping your car 5-10 more years you need to select a material that is a step above the original equipment.

A Guide to Selection

Ok, this is purely conjecture on my part since no one has 10 years experience with any hose on the thrid generation RX-7. So, carefully read all the details, study the tables and footnotes, and reach your own conclusions.

Less than 5 years of ownership left. Your choice is the easiest of all. Depending on your priorities, cost or looks should be your guide. If cost is paramount, a good grade of tubing such as Neoprene (Table 3) purchased from a quality auto parts store (not a discount chain) is acceptable. Heat stabilized Nylon zip ties (Table 2) can be used to secure the hose. A step up would be to use wide-band spring steel clamps, which can be purchased in the US at Home Depot relatively cheaply.

If looks are a priority, then silicone is your choice. It comes in an assortment of colors, but beauty does have it's price (Table 3). If you're really into looks, pick a contrasting or coordinating zip tie color, otherwise stick to the heat stabilized type.

5 to 10 years of ownership left. This is the gray area. Under *normal* driving conditions silicone tubing with high temperature Tefzel zip ties would be sufficient. If you drive in extreme conditions, high temperatures in mostly stop and go driving, you may want to consider upgrading to Viton hose. Silicone's lack of chemical resistance to the ever present oil vapor in the intake system will significantly reduce the mechanical properties of silicone tubing under these conditions in spite of it's initially higher temperature rating. This is a judgment call. If you're in a high temperature area, drive stop and go, but will be selling the car closer to 5 years rather than 10 choose silicone. If you're planning on owning the car with this type of use for closer to 10 years use Viton. However, if you do use silicone tubing wide-band spring steel hose clamps may not be a good long term clamping solution. This is because the sharp edges of the steel band can cut into silicone over time (remember silicone has poor cut resistance).

10 or more years of ownership. Without a question you need to use the best materials available. The cost of materials amortized over 10 years is small compared to the cost of redoing the hoses for a second time. Viton or similar floropolymer hose with wide-band spring steel hose clamps is the best choice. Although silicone has a slightly higher maximum operating temperature it's long term resistance to oil is not good which could

result in significant degradation in physical properties over time. Although not listed on the tables, silicone also has a lower tear and abrasion resistance. The longer you own the car the more likely the hose is to get nicked or the longer it will rub on any wear spots.

Table 2. Material Properties of Hose Clamps					
Material Property	**Nylon 6/6**	**Heat stabilized Nylon 6/6**	**Heat stabilized Nylon 4/6**	**Tefzel**	**Spring Steel**
Max Operating temp	185°F	220°F	275°F	302°F	600°F
Color Availability	Wide Range	Black	Black	Dark Aqua	Black Silver
Life Expectancy	1-2	4-5	7-9	>15	>30
Typical Cost /100	$2.00	$2.00	$2.00	$51.00	$40.00

Table 3. Material Properties of Tubing			
Material Property	**Neoprene**	**Silicone**	**Viton**
Max. Cont. Operating Temp.[1]	212 °F	460 °F	400 °F
Durometer hardness	80 (Shore A)	50 (Shore A)	75 (Shore A)
Chemical Resistance[2]			
Motor Oil	2	3	1
Gasoline	4	4	1
Toluene (an ingredient in many carburetor cleaners)	4	4	1
Working Pressure[3]	19 psi	14 psi	25 psi
Working Vacuum[3]	29 inHg	29 inHg	29 inHg
Typical Cost per foot[4]	$0.29	$0.63	$2.29

Conclusion

So there you have it. These are my opinions and are not necessarily applicable to your car. I collected the data from various sources all of which caution against using the data for your specific application. None of this data exactly fits the engine environment of third generation RX-7. So, your mileage will definitely vary. If you disagree with what I wrote, write your own paper. If you find a mistake drop me a line at <mike_putnam@hotmail.com>. Let me know in 10 years what your results were. 8)

Acknowledgments

The data for the tie-wraps was shamelessly ripped-off from Max Cooper's web site < http://www.maxcooper.com/rx7/>

Footnotes and References

The devil, they say, is in the details. Here is where we answer the question "If in Table 1 the maximum temperature measured is under 270 °F and the cheaper hose is rated for over 270 °F continuous use, why use the more expensive tubing?"

Table Footnotes

1. The maximum continuos operating temperature is determined by heating a test specimen in a oven for 1,000 hours and then testing its material properties. The maximum temperature at which there is no appreciable loss of material properties is then listed as "the maximum operating temperature". This laboratory test does not take into account many factors that will significantly reduce the tubing's ability to withstand high temperatures including pressure, chemical attack, stress, pulsation, heat cycling and the attachment to fittings. What this means is that choosing a material with maximum operating temperature near the under-hood temperatures would be an invitation to eventual failure. It is best to use these numbers for comparison i.e. silicone is slightly more resistant to heat than Viton which is much more resistant than Neoprene.

2. The criteria used for the chemical resistant ratings were primarily volume swell resistance, compression set resistance, and aging resistance. In some cases they are the considered opinion of experienced compounders. Several factors must always be considered when using a rubber part in service. The most important are:

a. The temperature of service. Higher temperatures increase the effect of all chemicals on polymers. The increase varies with the polymer and the chemical. A compound quite suitable at room temperature might fail miserably at elevated temperatures.

b. Conditions of service. A compound that swells badly might still function well as a static seal yet fail in a dynamic application.

c. The grade of polymer. Many types of polymers are available in different grades that vary greatly in chemical resistance.

d. The compound itself. Compounds designed for other outstanding properties may be poorer in performance in a chemical than one designed especially for fluid resistance.

Each polymer is rated for use in individual chemicals at room temperature. Where multiple chemicals are in use, refer to the rating of the most aggressive fluid when evaluating polymer performance. Polymers are rated as:

1 Recommended. Little or minor effect, 0-5% volume swell where applicable.

2 Minor to moderate effect. Rubber parts probably still useful in most applications, 5-10% volume swell where applicable.

3 Moderate to severe effect. Rubber parts useful in some static applications only. 10-20% volume swell where applicable.

4 Not recommended.

3. The values listed for working pressures are derived from tests conducted under controlled laboratory conditions. The tubing tested was 1/8"ID, 1/16" wall thickness. Working pressure is 1/5 burst pressure. Many factors will reduce the tubing's ability to withstand pressures including temperature, chemical attack, stress, pulsation and the attachment to fittings. It is imperative that the user conduct tests simulating the conditions of the application prior to specifying the tubing for use. What does this mean for your RX-7? Since a control hose failure will not result in a catastrophic injury-causing failure, a safety factor of 5 is a little excessive. None of the hoses mentioned will probably ever burst. They will usually fail at a connection at a pressure below the burst pressure. Unfortunately, there is no standardized test for that, so use these working pressures for comparisons, not gospel, on how they will perform in your car.

4. From the McMaster-Carr Catalog (1/8" ID, 1/16" wall), your price may vary.

Resources

http://207.106.32.244/crg/ - DuPont's chemical resistant guide, more information on rubber products than you can shake a stick at (you have to register to use the site).

http://www.tygon.com/sitefrset.html - Tygon Tubing's site. They make Viton (trade name Fluron F-5500-A) and Silicone (trade name Sanitary Silicone 3350) tubing. This site is a good source of physical properties for both tubing materials.

http://www.maxcooper.com/rx7/how-to/hose/tools_materials.htm - Max Cooper's info on tie-wraps, tubing, and check valves.

http://robrobinette.com/hoses.htm - Rob's site on how to replace the control hoses

http://www.pfsupercars.com/ - Source for high quality and high price silicone hose kits.

http://www.hosetechniques.com// - Source for high quality and high price silicone hose kits in every color you could want. On the questions page of Hose Techniques

Web site they state that their silicone hose is "Not for use with gasoline or oil or other liquids".

http://www.mcmaster.com/pdf/106/0075.pdf - McMaster-Carr is the place to buy metric and/or english Viton hose by the foot. They will sell to anyone with a credit card.

http://www.mcmaster.com/pdf/106/0076.pdf - McMaster-Carr has silicone tubing by the foot. They have silicone tubing with Shore 70A Durometer hardness in English and Metric sizes. If you are getting silicone tubing, 70A is better than 50A. 50A is the most widely available and is just too soft. If your supplier doesn't know what the Durometer hardness rating is for the silicone tubing he is selling, assume it's 50A.

http://www.mcmaster.com/pdf/106/0678.pdf - McMaster-Carr has heat stabilized Nylon and Tefzel cable clamps in 100 and 25 count bags.

http://www.m-tech-inc.com/tubing4.html - source for thick wall (2-4mm) metric sized silicone and Viton tubing. There are minimum purchases, usually 100 ft., so it is best to make a group buy with three other people.

http://www.omega.com/tubing/flexibletubing/viton.html - expensive, but extensive source for Viton tubing (English sizes only). There are minimum purchases, usually 100 ft., so it is best to make a group buy with three other people.

Your local rubber or tubing supplier - look in the yellow pages under "tubing" or "hose-rubber". Ask if they can get silicone or Viton "tubing". Don't ask for "hose". In the trade, a hose has many constituents to it, braiding, lining etc., tubing is made from a single material.