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SURFACE VEHICLE RECOMMENDED PRACTICE

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RECOMMENDED PRACTICES FOR DESIGN AND EVALUATION OF PASSENGER AND LIGHT TRUCK COOLANT HOSE CLAMPED JOINTS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

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1. Scope—This SAE Recommended Practice covers recommended practices for design and evaluation of hose clamped joints primarily in automotive applications. It is intended to: (a) evaluate current joint designs, (b) compare existing designs, (c) aid in the development of new designs, (d) give objective results once weights are set, (e) rate the overall design and individual sections of design, and (f) encourage future research by industry and the OEM's.

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2. References

2.1 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1508—Hose Clamp Specifications
SAE J1610—Test Method for Evaluating the Sealing Capability of Hose Connection with a PVT Test Facility

3. *Abstract*—Design of hose-clamped coolant joints is not an exact science, therefore precise formulas and methods cannot accurately predict performance. However, theoretical and philosophical constructs based on empirical data and industry experience can be used to develop standard practices for evaluating automotive hose-clamped coolant joints. This document allows individual users to define key parameters that are important to their products and educate the industry about hose clamped coolant joints.

Five major components of designing a robust hose-clamped joint are: (a) sealability, (b) hose assembly, (c) hose blow-off, (d) assembly of clamps over hose/fitting, and (e) serviceability of the clamp. Depending on the function of the joint and the priority of the design, one category may be more important than another. In automotive coolant joint designs, sealability and hose assembly are the main concerns. Since most of the coolant joints are "low" pressure, hose blow-off ranks third. To satisfy the end customer, coolant joints must not leak. In addition the hose must be able to be assembled. In other words, the effort to push the hose fully on the joint must not be higher than is consistently manageable by the assembly operator. Therefore both sealability and hose assembly conditions must be met. Until recently it was thought that either one or the other of the criteria could be met while sacrificing the other.

Assembly and serviceability are also legitimate concerns when variation and proliferation exist. Variation in the clamp assembly as well as the type of clamp is inversely related to the robustness of the joint. As the variation of the assembly decreases, the potential for the joint to seal increases. Serviceability is important because the clamping mechanism must be accessible to the general public or easily substituted with other standard products.

4. *Methodology*—A weighting system is used to rank choices in the design process. The weights are arbitrarily set by the user to target key system requirements for that particular user. The process works best with a computer program but is not required to use the procedure. The design choices are ranked from 1 to 5 where 1 is the worst choice and 5 is the best choice for that particular section. In the event that a given design does not match any of the listed choices, the most applicable match should be chosen.

a. 1 Poor Design—20% (1/5)
b. 2 Average to Poor Design—40%
c. 3 Average Design—60%
d. 4 Average to Good Design—80%
e. 5 Good Design—100%

NOTE—It must be noted that some sections may indicate excellent designs but due to the interactions and dependencies, the total joint will suffer. In the following example it is suggested that the designer has only two concerns: sealability and hose assembly. A 40% weight is assigned to sealability and a 60% weight is assigned to hose assembly. Therefore hose assembly is the most important joint design criterion.

For the sealability part of this example, only interference and residual load are considered important with weights of 30% and 70%, respectively. Therefore with the weights chosen it is understood that residual load is felt to contribute the most towards sealing a coolant joint.

For the hose assembly part of this example, only interference to the fitting and wall thickness are considered important with 60% and 40% weights, respectively. Therefore it is similarly understood that interference to the fitting plays the largest part in hose assembly.

In the first design iteration sealability of the joint is rated at 54% while hose assembly is rated at 56%. In the second design it is shown that both sealability and hose assembly ratings have been increased to 57% and 72%, respectively.

The conclusion is that the second design is better in preventing leaks and is easier to assemble than the prior design. **However, keep in mind that most coolant joints are more complex than in the following example**.

4.1 Example

.4 **Sealability**

.3 Interference

1 Line to Line
2 0 < 2.5% Interference
3 2.5 < 5.0 Interference
4 5 - 10% Interference
5 > 10 % Interference

Design 1 selection: 2
Design 2 selection: 2

.7 System Pressure (PSI)

1 > 80 PSI
2 51 - 80 PSI
3 31 - 50 PSI
4 16 - 30 PSI
5 0 - 15 PSI

Design 1 selection: 3
Design 2 selection: 4

.6 **Hose Assembly**

.6 Interference to Fitting

1 > 10% Interference
2 5 - 10 % Interference
3 2.5 < 5% Interference
4 0 < 2.5% Interference
5 Line to Line

Design 1 selection: 4
Design 2 selection: 4

.4 Wall Thickness

1 6.0 mm
2 5.3 mm
3 4.8 mm
4 4.3 mm
5 3.8 mm

Design 1 selection: 1
Design 2 selection: 3

Calculations Design 1
Rating for Sealability = .4x.3x2 + .4x.7x3 = 1.08/2.0 = **54%**
Rating for Hose Assembly = .6x.6x4 + .6x.4x1 = 1.68/3.0 = **56%**
Total Joint Rating = 1.08 + 1.68 = 2.76/5.0 = 55.2%

Calculations Design 2
Rating for Sealability = **57%**
Rating for Hose Assembly = **72%**

FIGURE 1A—EXAMPLE OF SEALABILITY AND HOSE ASSEMBLY

.40	**SEALABILITY**	
	.30	- Interference
	.20	- Pressure
	.17	- Surface Finish
	.16	- Roundness
	.07	- Sealing Length
	.06	- Temperature
	.02	- Adhesion
	.02	- Bead Geometry and Diameter
.25	**HOSE ASSEMBLY**	
	.26	- Bead Diameter
	.20	- Interference to Fitting
	.10	- Hose Durometer
	.08	- Wall Thickness
	.08	- Angle of Installation
	.08	- Reach to Install
	.06	- Lead End Diameter of Fitting
	.05	- Ramp Angle
	.05	- Column Strength of Hose
	.04	- Lubrication
.20	**HOSE BLOW-OFF**	
	.30	- Pressure
	.20	- Interference Fit
	.15	- Bead Diameter
	.15	- Bead Design
	.12	- Clamp Type
	.08	- Type of Assembly Lubrication
.10	**ASSEMBLY OF CLAMPS OVER HOSE/FITTING**	
	.30	- Number of Different Assembly Tools
	.30	- Operator Sensitivity
	.20	- Calibration of Tools
	.15	- Rpm of Air Tools
	.05	- Stray Assembly Lubricant (Slip Agents)
.05	**SERVICEABILITY OF CLAMP**	
	.40	- Tool Availability
	.20	- Clamp Reuse
	.20	- Clamp Availability
	.15	- Adjustability
	.05	- Corrosion

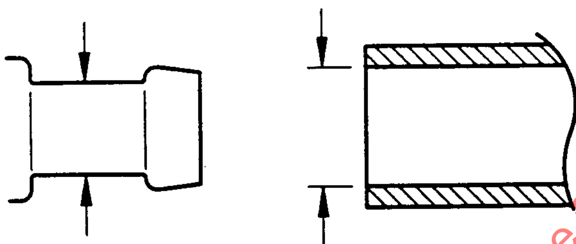
FIGURE 1B—EXAMPLE OF SEALABILITY AND HOSE ASSEMBLY (CONTINUED)

5. *Sealability*

5.1 Interference—Interference of the inside diameter of the hose to the sealing surface (shank) of the fitting is one of the most important criteria in designing a sealed system. There is a direct relationship between hose to fitting interference and push-on force. As the interference increases so will the push-on force. The relationship between interference and push-on will also change with hose material, reinforcement type and construction. Minimum design requirements should always have a line to line fit between inner diameter of the hose and the shank of the fitting. Clearance fits of any magnitude can lead to joint leaks. More interference has been proven to provide better sealing than less interference or a clearance fit. The greater the interference (provided the joint can still be assembled), the better probability of the sealed joint. Interference is calculated as shown in Equation 1:

$$((\text{Shank OD} - \text{Hose ID})/\text{Hose ID})*100 \qquad \text{(Eq. 1)}$$

5.1.1 HOSE/SHANK INTERFERENCE (% OF INSIDE DIAMETER)—(See Figure 2.)



1 Line to Line
2 $0 < 2.5\%$ Interference
3 $2.5 \leq x < 5\%$ Interference
4 $5 \leq x \leq 10\%$ Interference
5 $>$ 10 Interference

FIGURE 2—SEALABILITY—INTERFERENCE

5.2 Clamp Force Throughout Temperature Range (Residual Load)—Residual pressure, along with hose to fitting interference, is one of the most important factors in designing a leak-free joint. Load around the diameter of the clamp (pressure) is required after the system has come to equilibrium. As the pressure increases the higher the clamping force needs to be to prevent leakage. Products that can maintain continuous pressure on the hose, even after the hose has set, will have a greater potential to seal. The impact of clamping pressure on sealing will be reduced if imperfections in the fitting exist. Initial load is not a complete indicator of how the joint will behave over time. Note that excessive clamp pressures can damage some hoses and fitting.

Incorrect sizing of the clamp can result in lower initial and residual loads. Development testing should determine the minimum pressure from the clamp required to seal the joint taking into consideration production processes.

5.3 Pressure—System operating pressures define the type of clamping system the joint requires. Low pressure systems will allow the most flexibility in the design of the joint and will be easier to seal. As the pressure increases the hose design requirements may also change. Higher pressure applications will require different reinforcements and constructions. Pressure is also important with respect to the friction between the hose and the fitting and the hose and the clamp.

5.3.1 MAXIMUM JOINT PRESSURE (PSI)

a. 1 > 80 PSI
b. 2 51 to 80 PSI
c. 3 31 to 50 PSI
d. 4 16 to 30 PSI
e. 5 0 to 15 PSI

5.4 Surface Finish—The surface finish of the fitting is important in the sealing process. Although rough finishes can contribute to a joint leak under some conditions, a certain degree of "grabbiness" by the fitting is required to prevent blow-off. Finishes that are too smooth will be harder to push on the fitting. Similarly if a boundary layer of fluid is allowed between the hose and a "too smooth" fitting, a blow-off condition is likely to occur. The more consistent the sealing surface, the better the chance the joint has to seal.

5.4.1 SURFACE FINISH OF FITTING (RA)

a. 1 Sand Cast (50 - 25)
b. 2 Sand Cast (24 - 6.3)
c. 3 Die Cast (6.2 - 2.1)
d. 4 Molded Plastic (2.0 - 0.8)
e. 5 Machined, Tubing, (0.8 - 0.2)

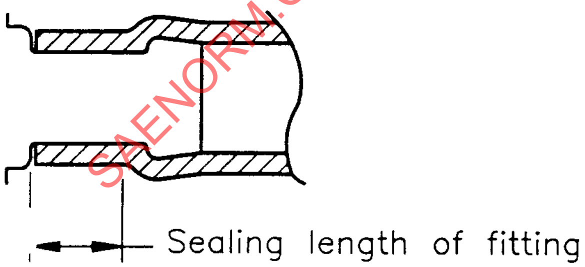
5.5 Roundness—Parting lines are direct leak paths. Larger parting lines have a higher probability of causing a joint leak than joints with smaller, faintly visible parting lines. Depressions or crevices below the contact surface will also cause leaks. Mismatch of dies or molds may create a leak path at low temperatures.

5.5.1 ROUNDNESS OF FITTING SEALING SURFACE

a. 1 > 0.50 mm Major Surface Imperfection
b. 2 0.28 to 0.50 mm Machined Imperfections
c. 3 0.178 to 0.254 mm No visual as produced imperfections
d. 4 0.076 to 0.152 mm Radial Removal of Discontinuities
e. 5 < 0.076 mm Turned Surfaces

5.6 Sealing Length—Longer sealing lengths provide a more robust design and assembly process. If the sealing length is not long enough, there is a greater potential that the clamp will be mis-aligned. In production settings, where accurate placement of the clamp cannot be guaranteed (assuming loose assembly), there is a greater possibility that the clamp will be placed either on the bead of the fitting or the hose stop. If the clamp is "tilted" a leak may develop.

5.6.1 SEALING LENGTH OF FITTING—See Figure 3.



1 < 1 : 1 (Land Length: Clamp Width)
2 1.25 : 1
3 1.5 : 1
4 1.75 : 1
5 > 2 : 1

FIGURE 3—SEALABILITY—SEALING LENGTH

5.7 Temperature—Systems with a constant ambient or higher temperature will seal better than joints that have a constant cold temperature or fluctuating cold/hot temperatures. Greater rates of temperature changes may promote system leaks.

5.7.1 TEMPERATURE

a. 1 Constant Cold
b. 2 Fluctuating Cold Environment
c. 3 Fluctuating Cold/Hot Environment
d. 4 Constant Ambient Temperature
e. 5 Constant Hot Temperature

5.8 Adhesion—Any adhesion of the hose to the fitting aids in the sealing process and reduces the responsibility of the clamp. Joints that do not adhere over time rely more heavily on the clamp, hose interference, etc., to seal the joint. Not all EPDM hose bonds to copper brass.

5.8.1 ADHESION OF HOSE TO FITTING

a. 1 Paint/other that forms a lube
b. 2 Non-Dissipating Lubricant
c. 3 Clean/Smooth surface
d. 4 Paint that forms a bond
e. 5 Copper-Brass fitting to EPDM Hose

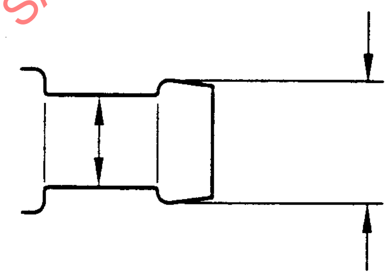
5.9 Bead Geometry and Diameter

a. 1 < 360 Degree Bead
b. 2 360 bead, 0 < 3% Interference
c. 3 360 bead, 3 to 5% Interference
d. 4 360 bead, 5 to 10% Interference
e. 5 360 bead, > 15% Interference

6. Hose Assembly

6.1 Bead Diameter—As the bead height increases the push-on force over the bead also increases. Although the larger bead aids in blow-off forces, it makes the joint more difficult to assemble.

6.1.1 BEAD DIAMETER OF FITTING—See Figure 4.

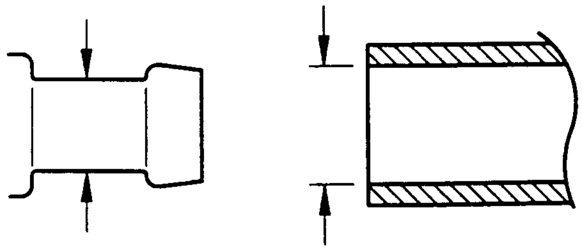


1 115% of Nominal Shank Diameter
2 110% of Nominal Shank Diameter
3 105% of Nominal Shank Diameter
4 103% of Nominal Shank Diameter
5 No Bead

FIGURE 4—HOSE ASSEMBLY—BEAD DIAMETER

6.2 Interference to Fitting—Greater interference between the hose and the sealing surface of the fitting provides a better seal; however, the push-on forces (and efforts) increase also. In general, the greater the interference the greater the push-on forces.

6.2.1 INTERFERENCE TO FITTING—See Figure 5.



1 > 10% Interference
2 5 to 10% Interference
3 0 to 5% Interference
4 0 to 10% Clearance
5 > 10% Clearance

FIGURE 5—HOSE ASSEMBLY—INTERFERENCE TO FITTING

6.3 Hose Durometer—Higher durometer hose is less compliant than lower durometer hose and will have higher push-on forces. Lower durometer materials will allow the translation of the pressure of the clamp directly to the sealing surface. Lower durometer hose will allow the joint to be designed with more interference. Note that hose column strength may be reduced by using lower durometer rubbers and consequently lead to more difficult installation.

6.3.1 HOSE TUBE DUROMETER (SHORE A)

a. 1 71 to 80
b. 2 61 to 70
c. 3 51 to 60
d. 4 40 to 50
e. 5 < 40*

6.4 Wall Thickness—The wall thickness variation of a hose can affect the distribution of pressure as applied by the clamp and the push-on force required to assemble the joint. Smaller wall thicknesses will allow easier installation and better transmission of load to the sealing surface.

6.4.1 WALL THICKNESS (FOR 15 TO 46 MM ID HOSES)

a. 1 6.0 mm
b. 2 5.3 mm
c. 3 4.8 mm
d. 4 4.3 mm
e. 5 3.8 mm

6.5 Angle of Installation—The angle of installation of the hose to the fitting will affect the push-on effort of the operator. The straighter the angle of installation the easier the joint is to assemble.

6.5.1 ANGLE OF INSTALLATION—See Figure 6.

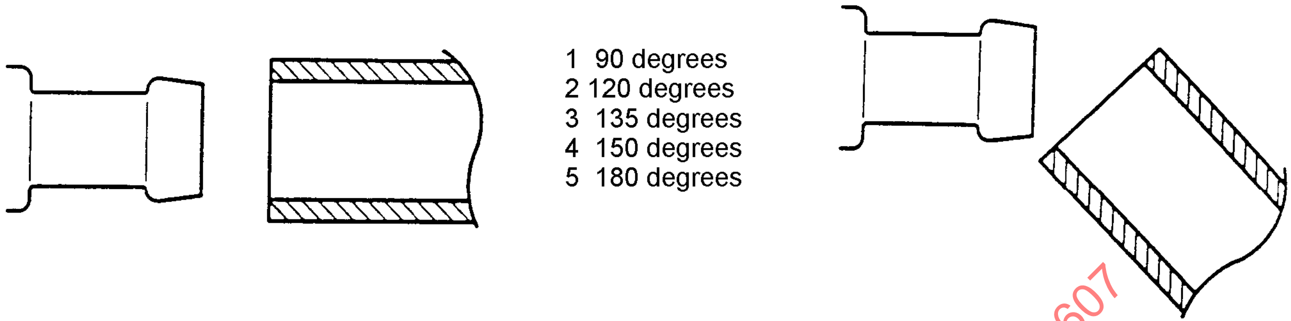


FIGURE 6—HOSE ASSEMBLY—ANGLE OF INSTALLATION

6.6 Reach to Install—Long overhead reaches to install hoses are more difficult than short horizontal reaches. Difficult to install joints have a higher probability of being assembled incorrectly.

6.6.1 REACH TO INSTALL

a. 1 Long Reach, Overhead
b. 2 Long Reach, Horizontal
c. 3 Average Reach, Horizontal
d. 4 Short Reach, Overhead
e. 5 Short Reach, Horizontal

Long Reach is > 1 foot from body

Short Reach is < 1 foot from body

6.7 Lead End Diameter of Fitting—See Figure 7.

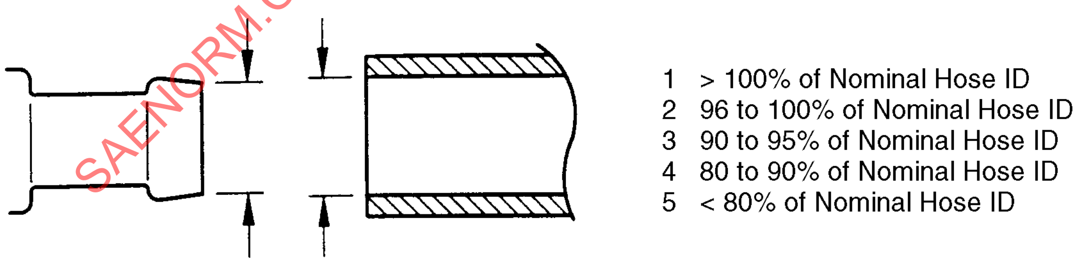
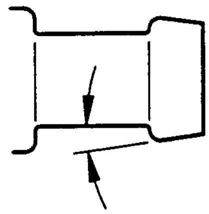


FIGURE 7—HOSE ASSEMBLY—LEAD END DIAMETER OF FITTING

6.8 Ramp Angle—Steep sloping ramp angles make assembly of the hose to the fitting more difficult. However, ramp angles that increase the bead length also increase the surface area and may increase the hose push-on force.

6.8.1 RAMP ANGLE OF BEAD—See Figure 8.



1 90 degrees
2 61 to 89 degrees
3 46 to 60 degrees
4 31 to 45 degrees
5 0 to 30 degrees

FIGURE 8—HOSE ASSEMBLY—RAMP ANGLE

6.9 Column Strength—For a given material and construction, hoses with a larger wall thickness will have a greater tendency to resist buckling during the installation of the hose. Reinforcement type (i.e., braid, spiral, knit, etc.) and configuration (i.e., angle, loops-needles, etc.) are very important parameters in push-on forces required to install the hose.

6.9.1 COLUMN STRENGTH OF HOSE

a. 1 3.8 mm
b. 2 4.3 mm
c. 3 4.8 mm
d. 4 5.3 mm
e. 5 6.0 mm

6.10 Type of Assembly Lubrication—Lubrication aids in the assembly of the hose to the fitting in some cases. Typically lubricants are used because the interference between the hose and the fitting causes a high installation (push-on) force. Although interference is good for the seal of the joint, the related push-on forces must be kept manageable for production environments. Time and temperature will affect the dissipation of lubricants. Use of any type of nondissipating lubricant may increase the potential for hose blow-off.

6.10.1 LUBRICATION

a. 1 None
b. 2 Water
c. 3 Water and Glycol
d. 4 Partially Dissipating
e. 5 Dissipating

7. Hose Blow-Off

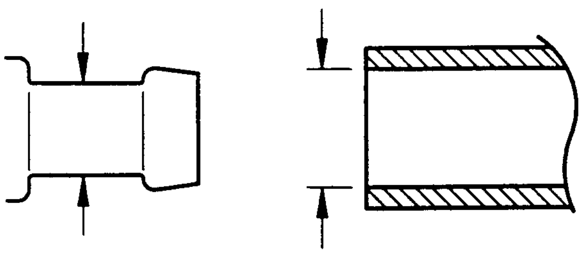
7.1 Pressure—Joints with higher system pressures will have a greater probability of blowing off than joints with lower pressures.

7.1.1 SYSTEM PRESSURE (PSI)

a. 1 > 80 PSI
b. 2 51 to 80 PSI
c. 3 31 to 50 PSI
d. 4 16 to 30 PSI
e. 5 0 to 15 PSI

7.2 Interference Fit—Greater interferences will require higher pressures to blow the hose off of the fitting (assuming no clamp). Proper hose to bead interference along with the proper clamp will give increased resistance to hose blow-off. Reinforcement type (i.e., braid, spiral, knit, etc.) and configuration (i.e., angle, loops-needles, etc.) are very important parameters in push-on forces required to install the hose.

7.2.1 INTERFERENCE FIT TO SHANK DIAMETER—See Figure 9.

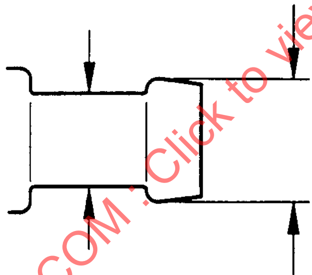


1. 103% of Nominal
2 105% of Nominal
3 107% of Nominal
4 110% of Nominal
5 115% of Nominal

FIGURE 9—HOSE BLOW-OFF—INTERFERENCE FIT

7.3 Bead Diameter—Larger bead heights are better than smaller bead heights in resisting hose blow-off. However, as the bead height increases the force to assemble the joint also increases.

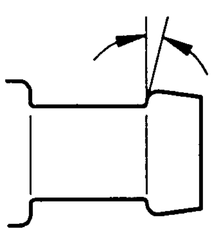
7.3.1 BEAD DIAMETER—See Figure 10.



1. No Bead
2 103% of Nominal
3 105% of Nominal
4 110% of Nominal
5 115% of Nominal

FIGURE 10—HOSE BLOW-OFF—BEAD DIAMETER

7.4 Bead Design (Back Angle)—See Figure 11.



1. No Bead
2 150 Degrees
3 135 Degrees
4 120 Degrees
5 90 Degrees

FIGURE 11—HOSE BLOW-OFF—BEAD DESIGN (BACK ANGLE)