Enhanced HFC-134a Systems with Refrigerant Permeation Rates Less than 20 Grams per Year

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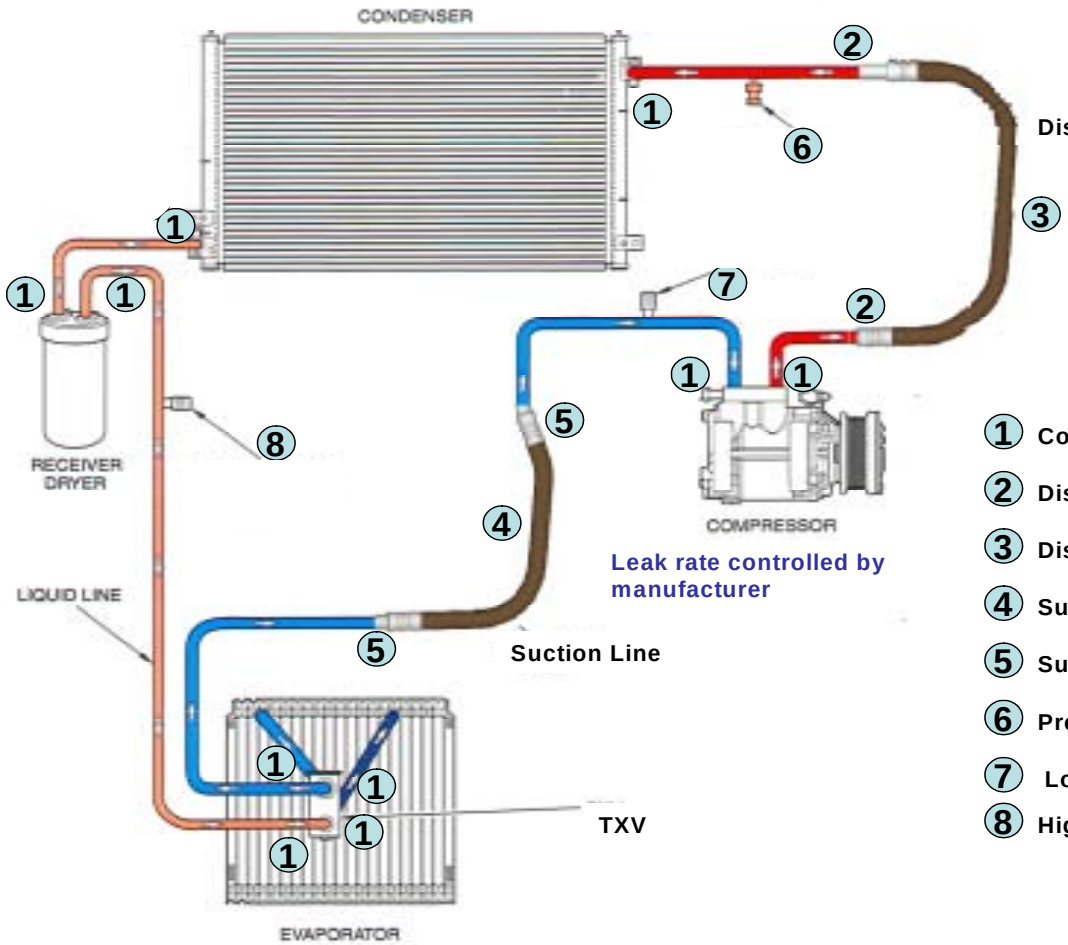
Overview

- Assumptions
- Seal designs evaluated
- Hoses evaluated
- Other leakage points
- Compare most robust seal designs to typical designs
- Conclusions
- Limitations

Assumptions

- All hose / tube assemblies contain non-brazed mechanically locked connection blocks
- Heat exchangers do not leak
- Transducer, charge / service port braze joints do not leak
- Vehicle A/C system operates 3% of the time. An additional 2% was added to consider system off time. Therefore, 5% was used for grams/yr calculation

System Schematic



Key:

1. Connection point
2. Discharge hose coupling
3. Discharge hose
4. Suction hose
5. Suction hose coupling
6. Pressure Transducer
7. Low Side Charge Port
8. High Side Service Port

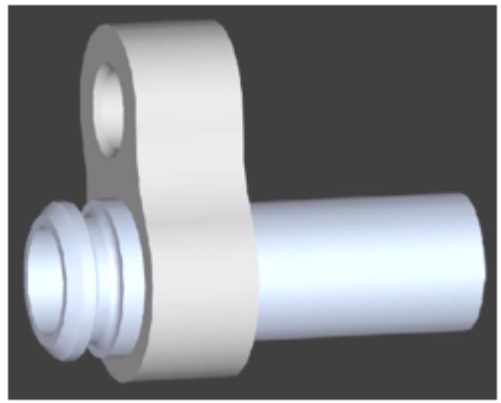
Seals Evaluated

- Typical O-ring (5/8” joint – 0.70” seal material cross section)
- Slim line seal (5/8” joint)
- Dual Seal
  - 5/8” o-ring
  - 5/8” slim line

O-Ring Design

- Mating geometry critical for proper compression/fill of rubber material
- Requires lubrication for assembly to prevent damage. Lubrication attracts contamination.
- Axial groove or captured design options
- Seal is exposed to full system refrigerant pressure
- Refrigerant permeation occurs either tangentially or through the seal

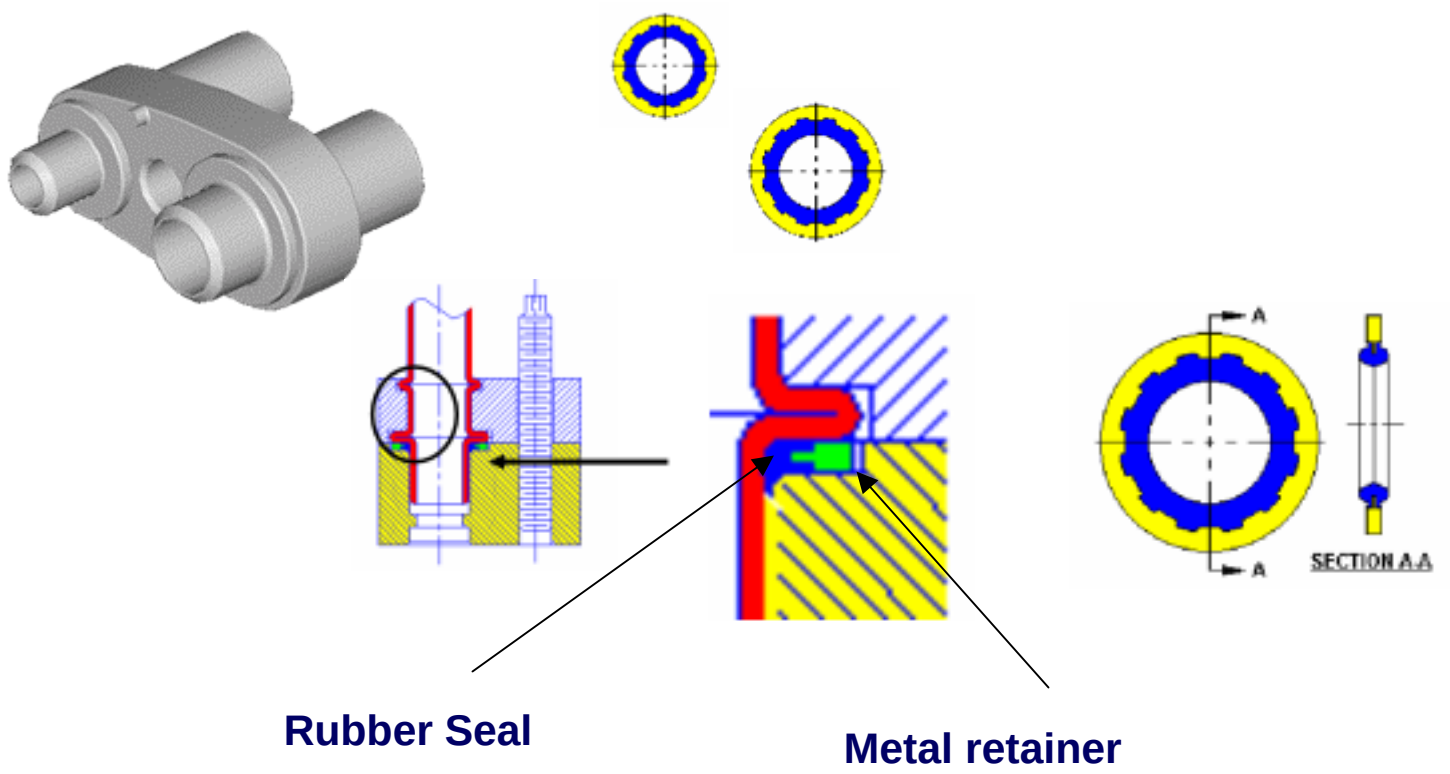
O-Ring Design



Slim Line Design

- No machined groove required on tube end. Flow passage increased through tube ID
- Once the joint is assembled (torqued), compression of rubber seal material is controlled by metal washer
- Does not require lubrication, is less likely to be damaged or attract contamination
- Double acting seal (face and radial)
- Seal is exposed to full system refrigerant pressure
- Refrigerant permeation occurs either tangentially or through the seal material. Metal washer is an additional barrier reducing refrigerant permeation

Slim Line Design



Rubber Seal

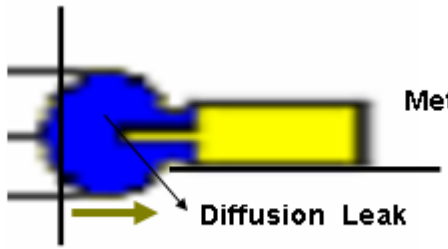
Metal retainer

Dual Seal Design

- Same features as slim line
- Addition of o-ring isolates system pressure from slim line seal
- Slim line exposed only to refrigerant which permeates through o-ring seal

Dual Seal

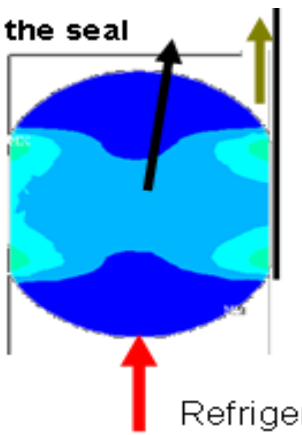
Diffusion Leak



Metal Retainer to reduce Permeation

Diffusion Leak Through the seal

Through the seal



Tangential Leak past the seal

Refrigerant Pressure

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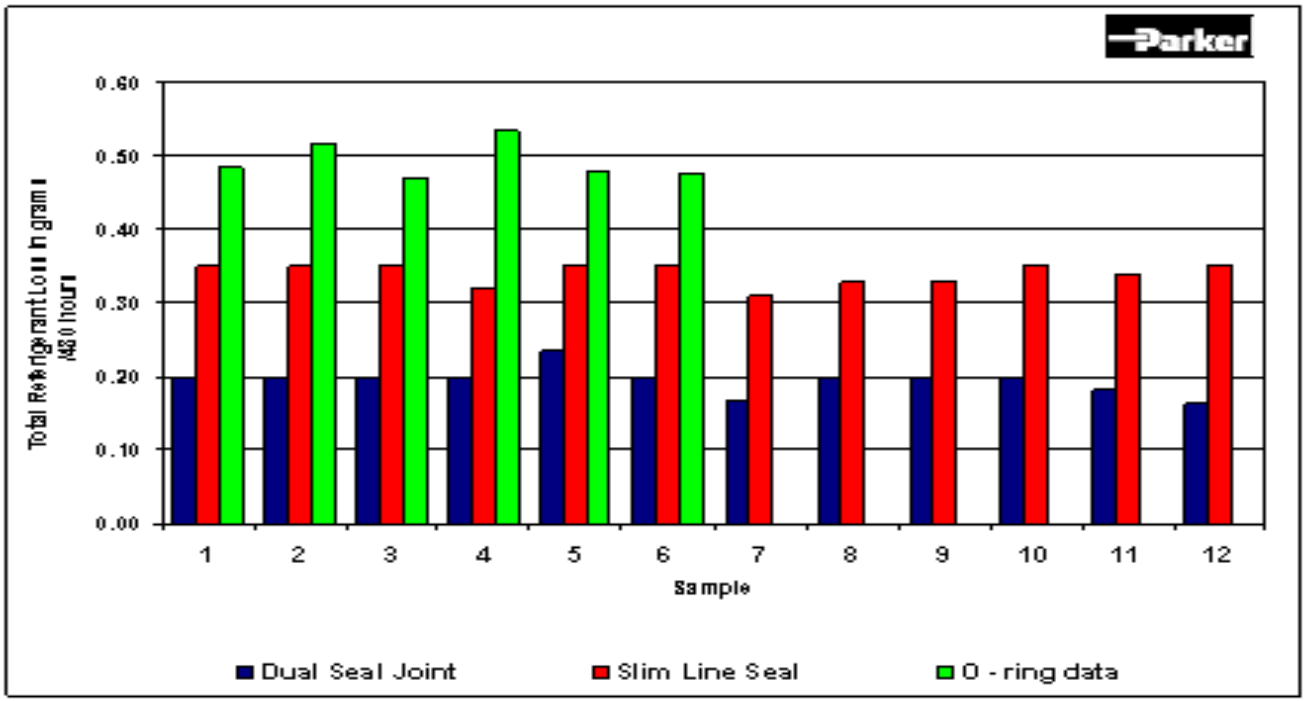
Thermal / Pressure Cycle Test

- Test samples are charged with charged refrigerant bottle attached to test parts
- Joints are exposed to 160 thermal cycles between -40 C to 110 C for 480 hours (20 days).
- One complete cycle duration is 3 hours

Seal Leakage



Annual Grams/Yr Calculation

(Grams / 480 hours) / 480 hours x 8,760 hours per year x 0.05

Fitting Leak Summary

Connection	O-Ring Design Thermal Cycle Test Leakage	O-Ring Design Grams/yr 5% System Operation	Slim Line Design Thermal Cycle Test Leakage	Slim Line Design Grams/yr 5% System Operation	Dual Seal Design Thermal Cycle Test Leakage	Dual Seal Design Grams/yr 5% System Operation
Compressor Inlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Compressor Outlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Condenser Inlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Condenser Outlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
R/D Inlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
R/D Outlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
TXV Inlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Evaporator Inlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Evaporator Outlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
TXV Outlet	0.5 Grams/480 hours	0.46	0.33 Grams/480 hours	0.30	0.20 Grams/480 hours	0.18
Pressure Transducer	0.5 Grams/480 hours	0.46				

Hose/Coupling Thermal / Pressure Test

Discharge Barrier Hose Assembly

- 42” 13/32” ID hose with 2 couplings
- Charged with 85 grams HFC-134a
- Tested at 90 C for 28 days

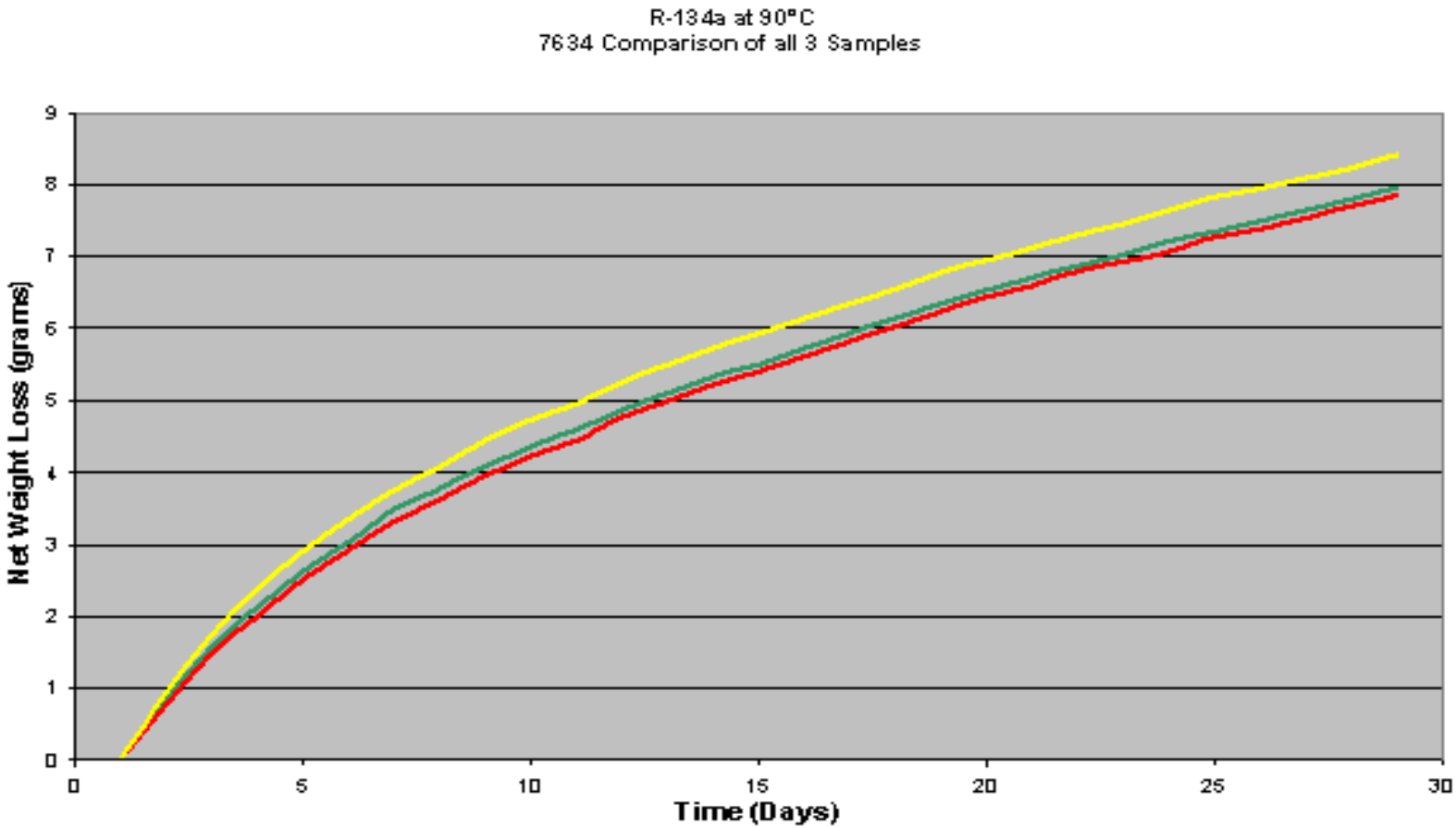
Suction Rubber Hose Assembly

- 42” 5/8” ID hose with 2 couplings
- Charged with 210 grams HFC-134a
- Tested at 50 C for 28 days

Annual Grams/Yr Calculation

(Grams / 28 days) / 28 days x 365 days per year x 0.05

Parker 7634 HOSE



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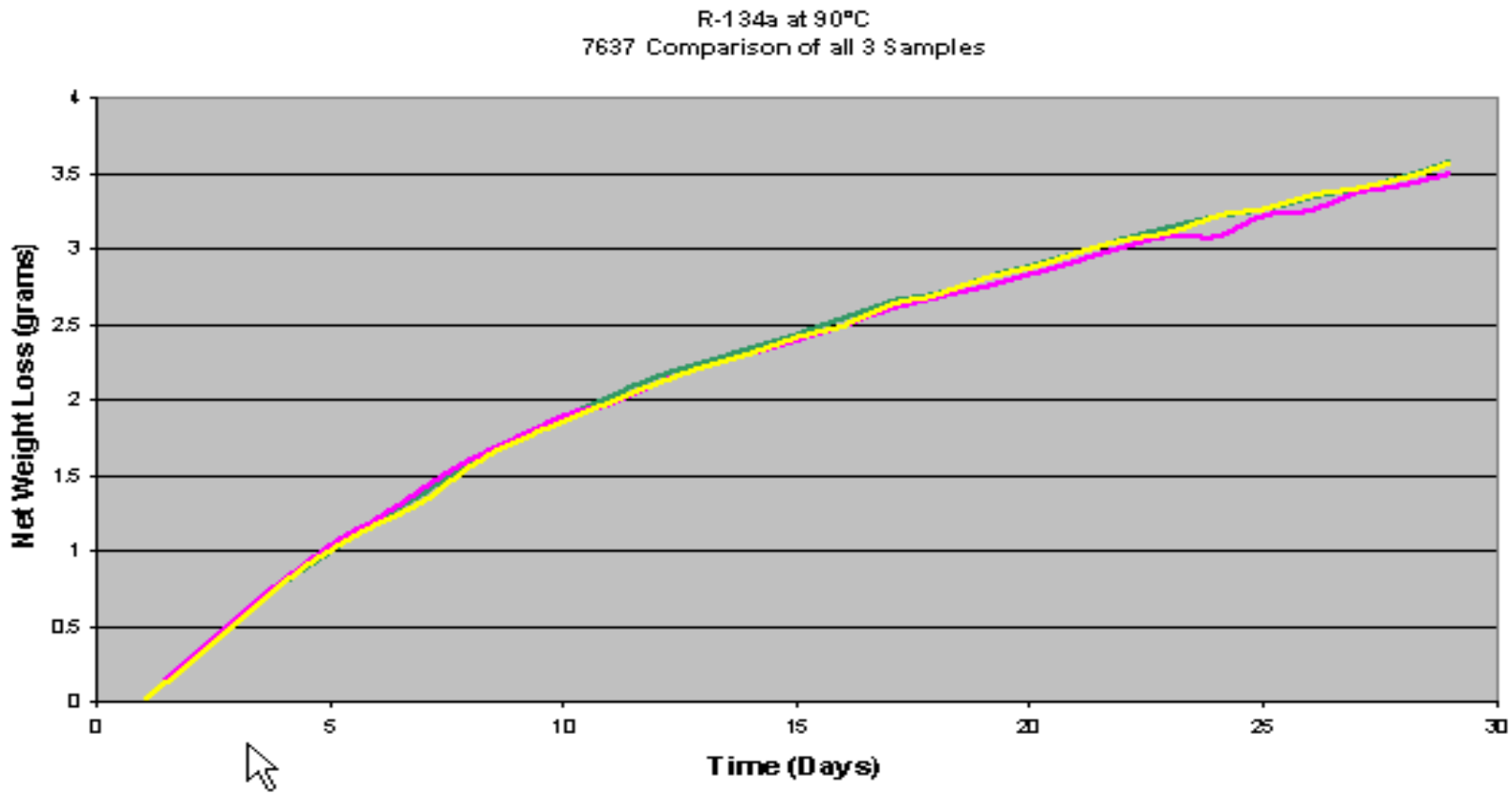
Parker Low Permeation 7637 HOSE



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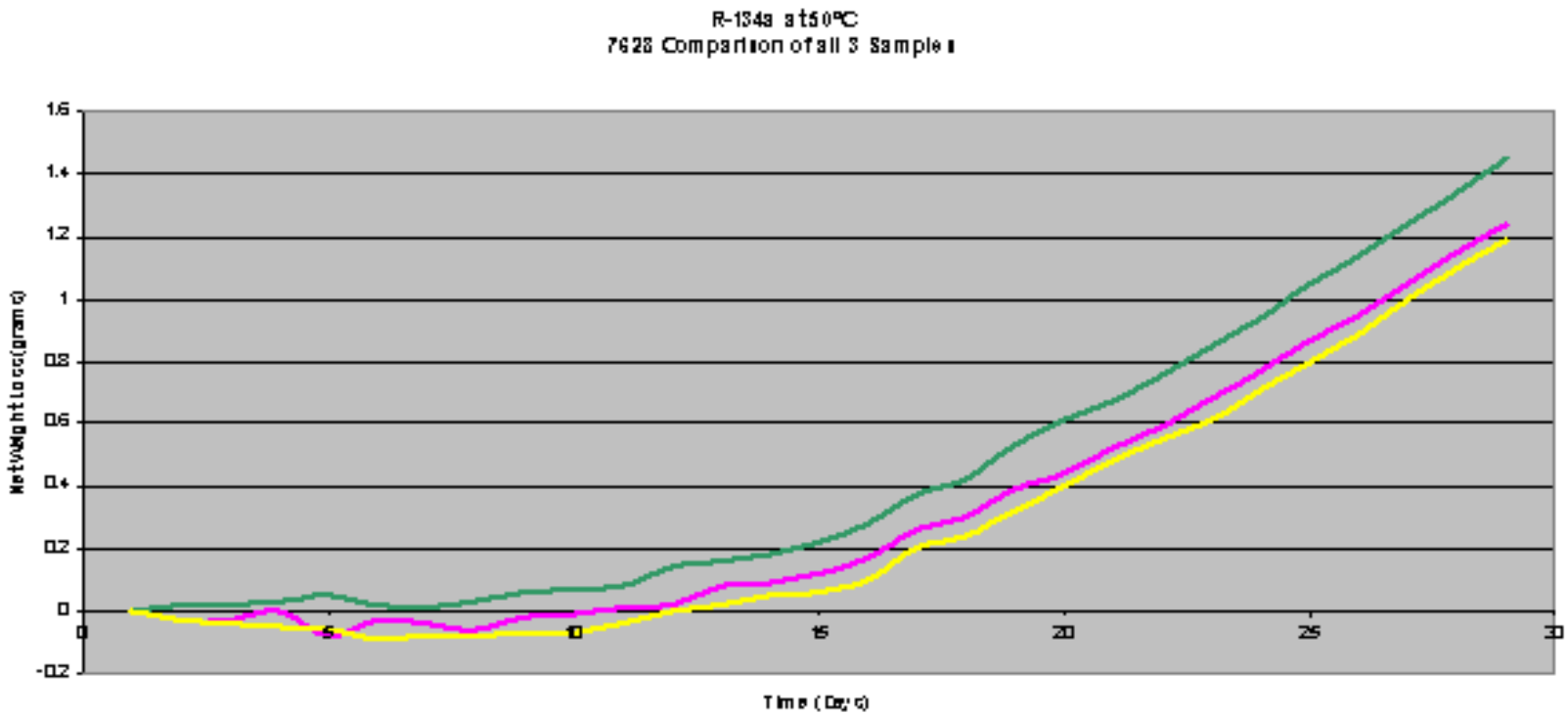
Parker 7628 HOSE



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Hose Comparison Summary

Hose Assembly	*Comments*	*Thermal Cycle Test Leakage*	*Grams/yr 5% System Operation*
Discharge Hose Assembly	Standard Barrier Hose Parker 7634	8.5 Grams/28 days	5.54
Discharge Hose Assembly	Low Permeation Hose Parker 7637	3.5 Grams/28 days	2.28
Suction Hose Assembly	Rubber Hose Parker 7628	1.24 Grams/28 days	0.81

Charge / Service Port Leakage

Fitting	*Comments*	*Leakage Grams/yr*
Low Side Charge Port	Manufacturer Specification	7 .0
High Side Service Port	Manufacturer Specification	7.0

Item	*O-Ring Design Grams/yr*	*Slim Line Design Grams/yr*	*Dual Seal Design Grams/yr*
End connections (10 Total)	**4.6**	**3.0**	**1.8**
Transducer	**0.46**	**0.46**	**0.46**
Suction Hose Assembly	**0.81**	**0.81**	**0.81**
Charge/Service Ports (2)	**14.0**	**14.0**	**14.0**
Standard Parker 7634 Discharge Hose Assembly	**5.54**	**5.54**	**5.54**
Total Leakage	**25.41**	**23.81**	**22.61**

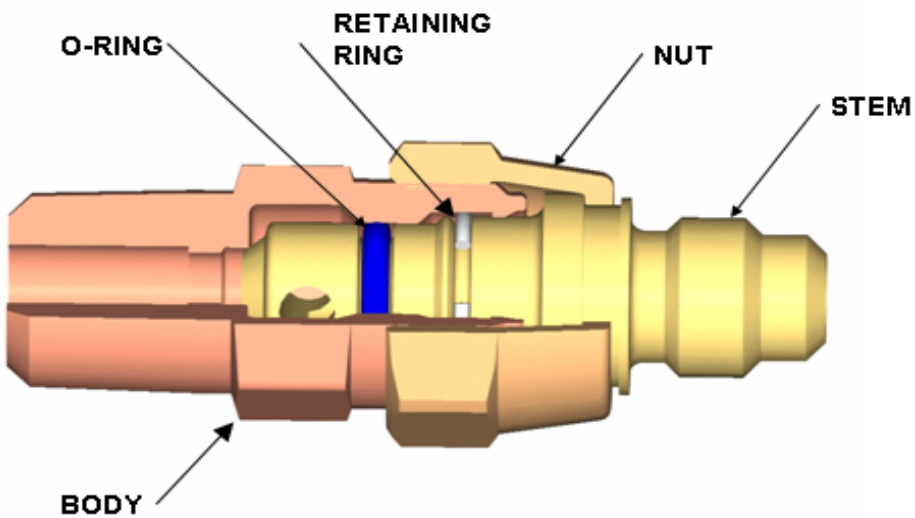
Item	*O-Ring Design Grams/yr*	*Slim Line Design Grams/yr*	*Dual Seal Design Grams/yr*
End connections (10 Total)	4.6	3.0	1.8
Transducer	0.46	0.46	0.46
Suction Hose Assembly	0.81	0.81	0.81
Charge/Service Ports (2)	14.0	14.0	14.0
Parker 7637 Low Permeation Discharge Hose Assembly	2.28	2.28	2.28
Total Leakage	22.15	20.55	19.35

Isolated Charge Port

Low refrigerant permeation rate

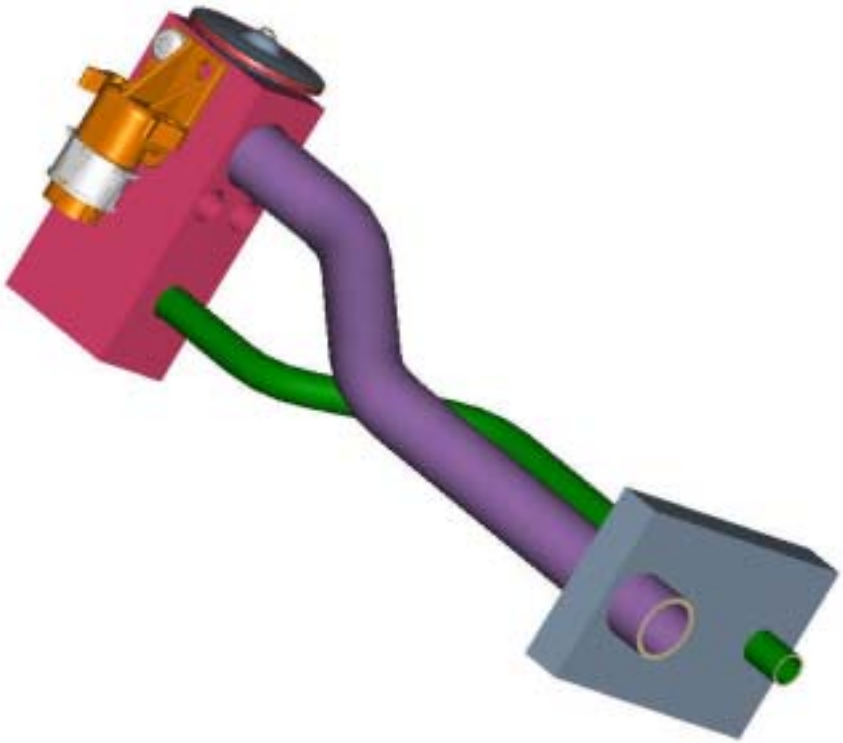
- 2.8 grams/yr max without a valve core
- Improved evacuation and refrigerant fill time

Self-Contained Isolated Port Design



Item	*O-Ring Design Grams/yr*	*Slim Line Design Grams/yr*	*Dual Seal Design Grams/yr*
End connections (10 Total)	4.6	3.0	1.8
Transducer	0.46	0.46	0.46
Suction Hose Assembly	0.81	0.81	0.81
Parker Isolated Charge/Service Ports (2)	5.6	5.6	5.6
Parker 7637 Low Permeation Discharge Hose Assembly	2.28	2.28	2.28
Total Leakage	13.75	12.15	10.95

TXV with Integrated tubes



Item	*O-Ring Design Grams/yr*	*Slim Line Design Grams/yr*	*Dual Seal Design Grams/yr*
End connections (8 Total) with Integrated TXV	3.68	2.4	1.44
Transducer	0.46	0.46	0.46
Suction Hose Assembly	0.81	0.81	0.81
Parker Isolated Charge/Service Ports (2)	5.6	5.6	5.6
Parker 7637 Low Permeation Discharge Hose Assembly	2.28	2.28	2.28
Total Leakage	12.83	11.55	10.59

Conclusions

- Removing direct refrigerant pressure from the primary seal significantly reduces refrigerant permeation of a connection point. Dual seal reduces refrigerant permeation 60% vs. o ring only joint.
- The most robust design of this study is the dual seal, low permeation discharge hose, isolated charge / service ports and an integrated TXV. A 58% reduction in permeation was achieved vs. typical systems.

Limitations

Study used typical industry static temperature / pressure cycling tests for connections and hose coupling integrity tests but did not consider correction factors for vehicle dynamics.

A to B comparisons do illustrate improvement potential of various designs.

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