COMMERCIAL
REFRIGERATION

RETROFIT POSITIVE & MEDIUM REFRIGERATING SYSTEMS

Tecumseh

www.tecumseh.com

Recommendations to retrofit positive existing installations running with HFCs (R404A & R507)

1-HCFCs & HFCs Retrofit Context

This guide aims to provide practical information and recommendations, to retrofit some existing R404A & R507 positive & medium refrigerating systems.

Low back pressure application leads to unacceptable compressor temperatures, according to reliability criteria for hermetic technology. The necessary additional compressor cooling would require its redesign.

R407series were initially introduced to retrofit installations running with R22, mainly for High Back Pressure racks running in supermarkets.

HFC fluids are covered by Kyoto protocol. For Refrigerators and freezers […] intended to commercial use into hermetically sealed systems, R407A & R407F are considered as a temporary/transitional solution regarding the coming F gas regulation (EC) N°842/2006.

To issue performance comparisons, Tecumseh carried out some tests with every compressor family.

Here under some extracts of F gas regulation to be voted into 2014.

New Equipment		Prohibition Date
11. Refrigerators and freezers […] for commercial use (hermetically sealed systems)	that contain HFCs with GWP of 2500 or more	1 January 2020
	that contain HFCs with GWP of 150 or more	1 January 2022
11a. Stationary refrigeration equipment, that contains, or that relies upon for its functioning HFCs with GWP of 2500 or more except equipment intended for application designed to cool products to temperatures below -50°C		1 January 2020

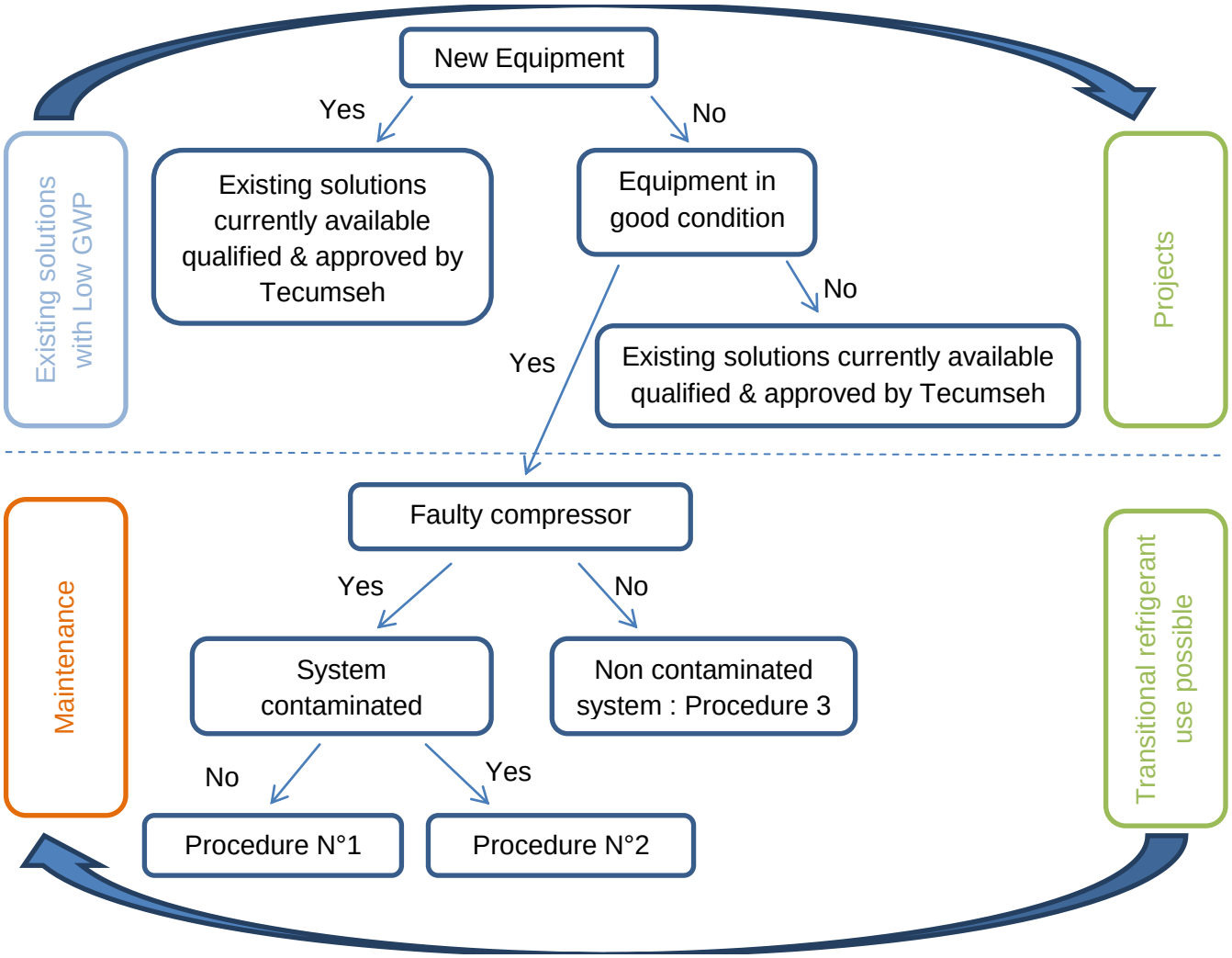
Maintenance	Prohibition Date
The use of fluorinated greenhouse gases, with a global warming potential of 2500 or more, to service or to maintain refrigeration equipment with a charge size […] of 40 tonnes (tons) of CO_2 equivalent Estimation of fluids' mass having 40 tonnes (tons) of CO_2 equivalent ➔ 10,36 Kg of R-404A ➔ 19,04Kg of R-407A ➔ 22,59Kg of R-407C ➔ 21,97Kg of R-407F	1 January 2020
The use of reclaimed fluorinated greenhouse gases, with a global warming potential of 2500 or more, to service or to maintain refrigeration equipment with a charge size […] of 40 tonnes (tons) of CO_2 equivalent or more, provided that they have been labelled in accordance with Article 10 (4a).	1 January 2030

2-New Projects & Maintenance - Retrofit

The reading of the terms and deadlines proposed by F- Gas leads us to a double approach: one for the new applications and the other one for the extension of life of existing applications. And in the respect for the criteria of performance, reliability, and security which characterize our ranges of products.

New projects or new installations: the use of R134a could be an option for most medium and high-temperature applications. This refrigerant (GWP=1430) is usable until the second term on new applications and for maintenance until 2030. The ranges exist; the refrigerant is known and recognized by users. In comparable cooling capacity, R134a brings coefficients of performance from 8 to 20% superior to those of R404A. The dimensions of the condensing units will most of the time be unchanged.
Tecumseh also proposes solutions for applications using natural refrigerants (GWP<150). Several product lines have been developed for the use of refrigerants like hydrocarbon which meet most of current safety standards (EN378). Those solutions serve specific applications where eco-design is the core of their customer's strategy.

To maintain or to retrofit existing installations with R407A and R407F: Tecumseh has also evaluated the possibility of using HFC alternatives. Our results concern hereafter the R407 series for existing installations as a replacement of R404A commercial refrigeration applications.



3- Environmental Data

R407 series are blends with the same R32, R125 and R134a molecules. They all require some POE synthetic lubricants.

Fluid compositions & GWP of their constituents are detailed hereunder:

	R143a	R32	R125	R134a
GWP	**4470**	**675**	**3500**	**1430**
	Percentage of each substance (%)			
R404A	52	0	44	4
R507	50	0	50	0
R407A	0	20	40	40
R407C	0	23	25	52
R407F	0	30	30	40

The total global warming potential (GWP) calculation of a mixture sums the weight fractions of the individual substances multiplied by their GWP:

Σ (Substance X % x GWP) + (Substance Y % x GWP) + … (Substance N % x GWP)

R32 is chlorine free, and flammable. Fluid R125 counteracts it.
We will remind R407 series are classified A1 by EN378-1 & AHSRAE, as is R404A. They refer to the same relevant standards. A1 means substance is classified not dangerous:

A = Low toxicity,
1= no flame propagation à 18°C, 101300 Pa.

Listed below are some properties of R404A transitional alternatives:

		ODP	GWP	Boiling P (°C)	Critical temperature (°C)	Critical Pressure (abs bars)	Security Class
R404A	Quasi azeotrope blend	0	3860	-46.5	72.1	37.35	A1
R507	Azeotrope blend	0	3885	-47.1	70.7	31.15	A1
R407A	Azeotrope blend	0	2100	-38,9	82.3	46,2	A1
R407C	Azeotrope blend	0	1770	-43.8	86.05	46.3	A1
R407F	Azeotrope blend	0	1820	-46	82.6	47.5	A1

Global Warming Potential(s) should be calculated in terms of the 100-year global warming potential of one kilogram of a gas relative to one kilogram of CO_2.

Carbon footprint reduction, cost & efficiency will be some criteria to consider prior to plan a retrofit.

4- Enthalpy Diagram Learning & Fluid Comparisons vs. R404A

Glide & heat exchanger performances:

R404A is a quasi azeotrope blend with its glide lower than 1K. On the other side, R407A, R407C & R407F display 4 to 7K of glide.

Sub cooling will refer to bubble point and superheat to dew point.

Fluid / Tdew (°C)	-35	-10	0	45
R404A	0.7	0.6	0.5	0.3
R407A	6.4	5.9	5.7	4.2
R407C	7.1	6.5	6.3	4.9
R407F	6.3	5.9	5.7	4.3

We note several glide effects:

A Proper fluid composition is needed to operate the systems efficiently. To properly feed the expansion device and to reach the expected capacity delivered by the evaporator, technician will check appropriate sub cooling at the condenser outlet.

Temperature will slightly increase during the evaporation phase and decrease during the condensation phase. Counter flow heat exchanger technology developed and installed within the last 10 years will be less sensitive to this physical phenomenon than former ones.

Also, average temperature during the evaporating phase, named “middle” saturated temperature, increases the temperature difference (TD) between the primary & secondary fluid.

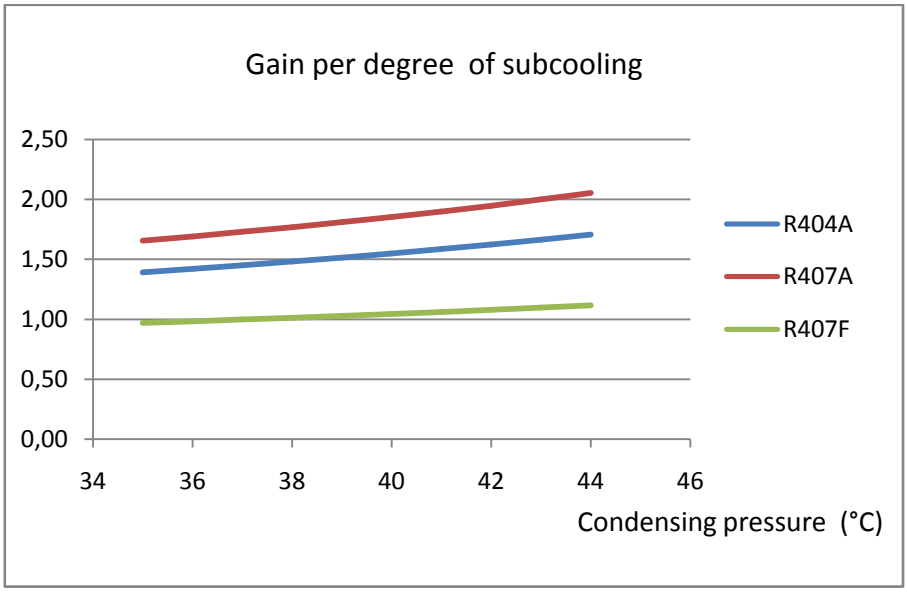
- Those two facts may counteract heat exchanger possible capacity losses.

One remaining risk is evaporator ice-up, according to secondary fluid type and flow across exchangers.

- Timer & temperature of defrost command device could be adjusted and/or reset.

Sub cooling effect according to fluids:

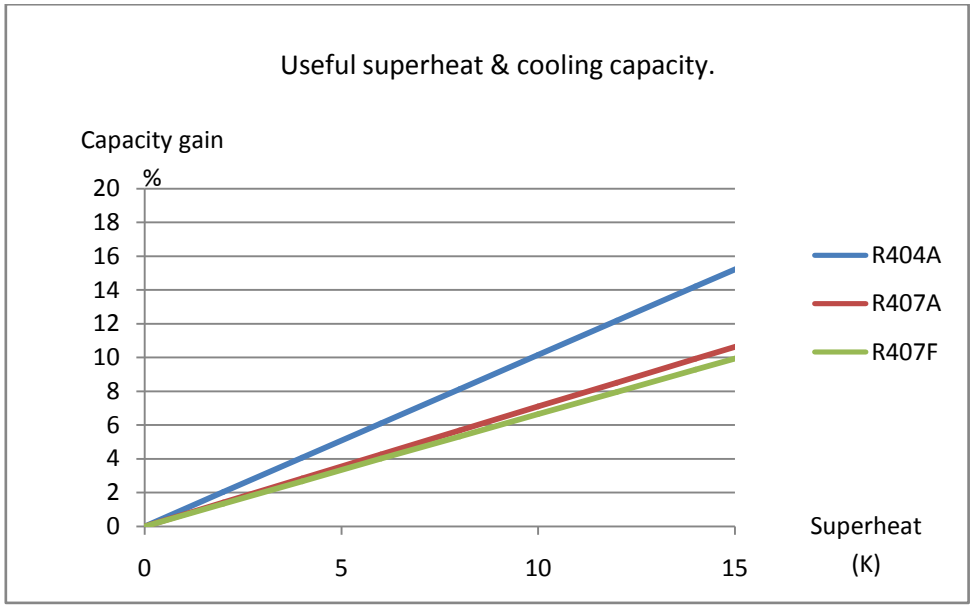
According to thermo dynamical fluid properties, a same subcooling value provides different cooling capacity gain for each fluid. Curves shown here display gains per degree of subcooling at various condensing pressures.



Curves are plotted at saturated pressures To/Tc = -10/45°C, Dew /Dew.

Superheat and cooling capacity:

Return gas and liquid temperature are constant.



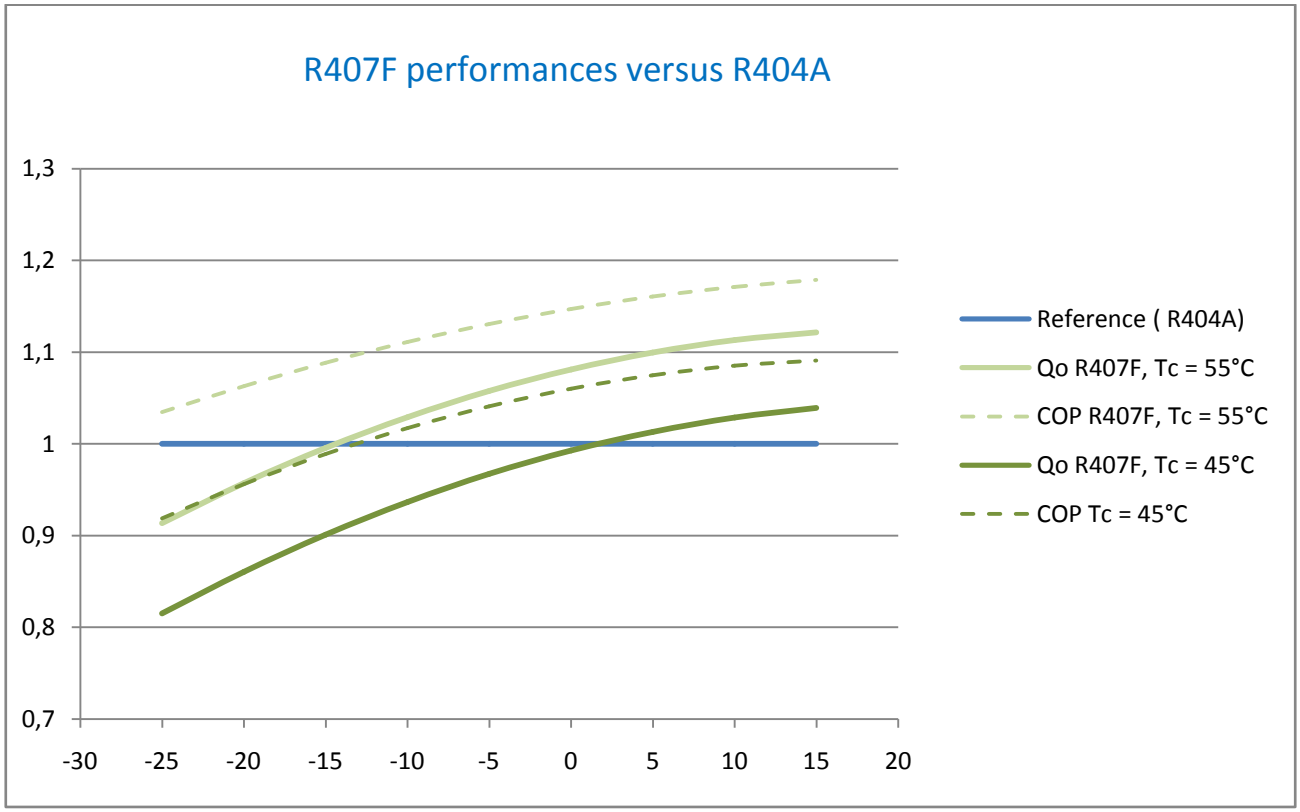
Vapor enthalpy effect is lower with R407A and R407F than with R404A.

Eg: with R407A and R407F, 10K of useful superheat provides 7% of capacity gain versus 10% with R404A.

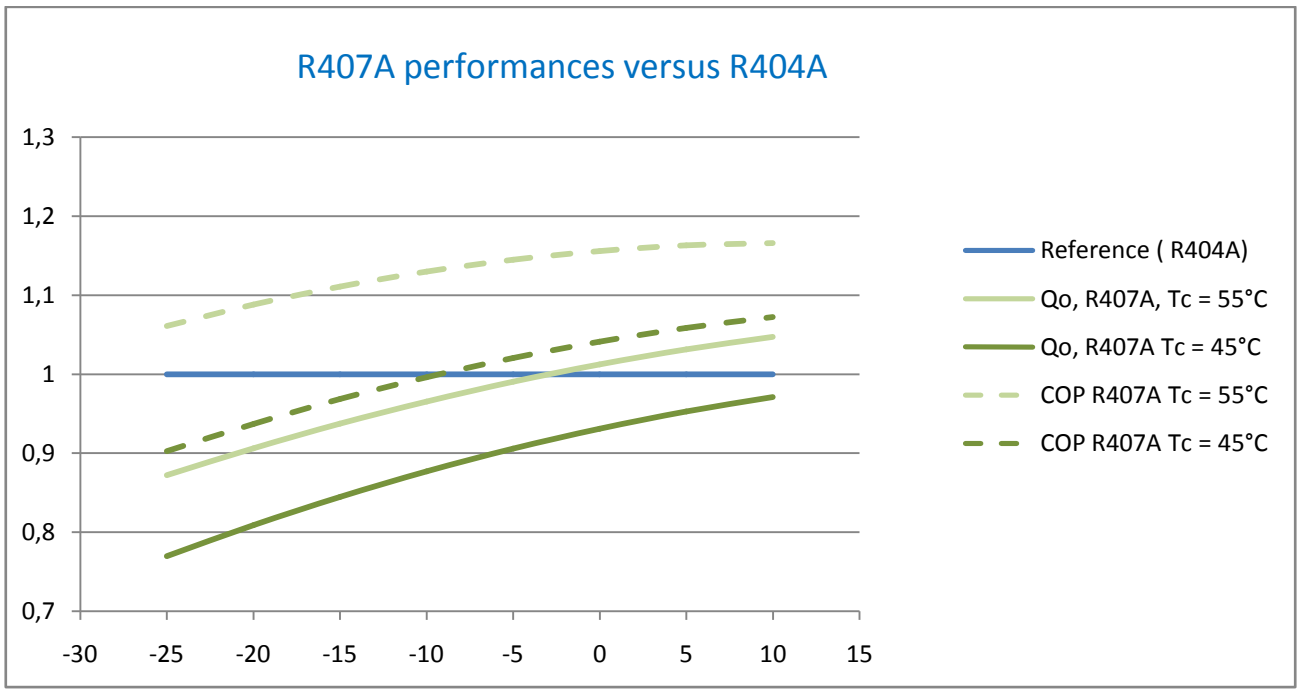
➔ Superheat will be mastered and reduced to a minimum necessary value to protect compressors against flood back and to maintain an efficient heat transfer.

5- MHP Compressors & condensing units' performances:

Measurements carried out by the Tecumseh Europe laboratory showed various fluid behaviors according to evaporating & condensing pressures:



Rating condition: SH = 10K, SC = 0



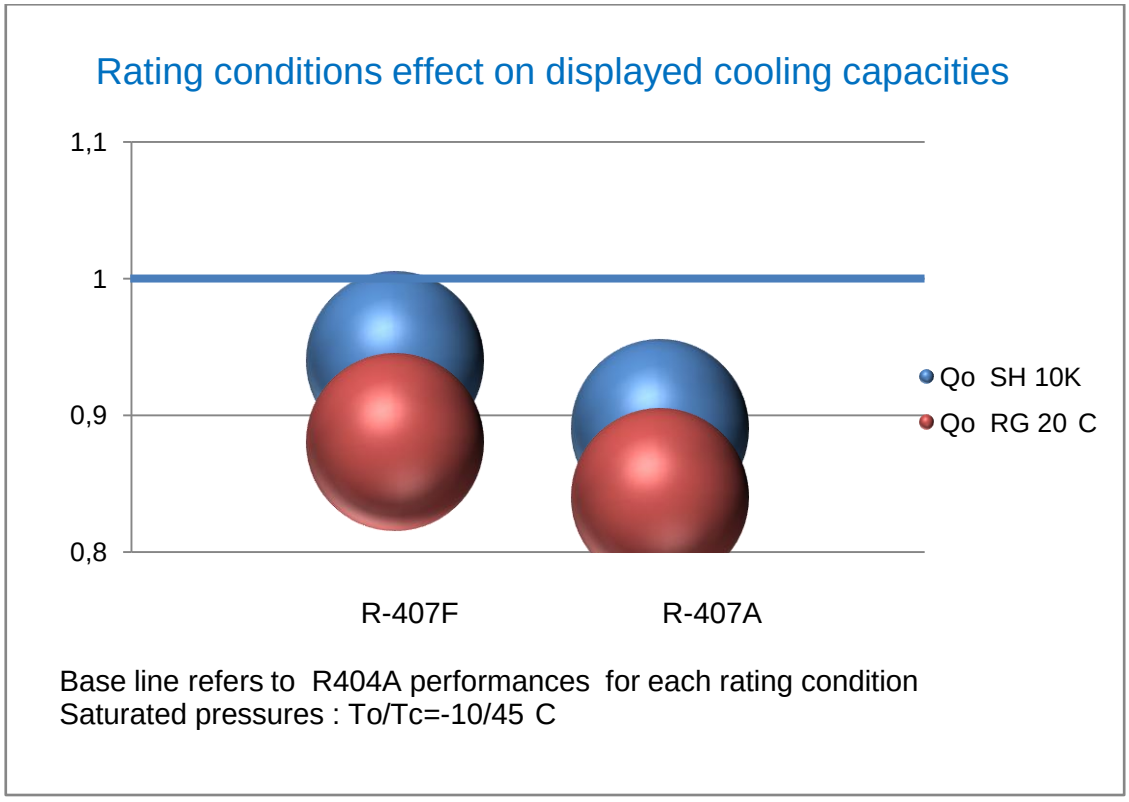
Rating condition: SH = 10K, SC = 0

Rating conditions & displayed performances according to ASERCOM reference standard

	Superheat / Return gas	Subcooling
EN12900	Fixed return gas: 20°C Or Fixed total superheat : 10K	No subcooling

According to the rating condition used, cooling capacity comparisons between fluids lead to various conclusions.

- EN12900 (RG 20°C) rating conditions are favorable to R404A versus R407A/R407F.
- During field running conditions, performances will be compared with 10K of superheat.



6- Compressor Reliability & Window Application:

Thanks to its low isentropic compression exponent, R404A can be used in medium and low back pressure applications.

R32 presence into R407A and R407F implies much higher discharge gas temperature.

- Compression ratio and return gas superheat will be limited as low as possible.
- Liquid/Vapor heat exchangers should not be applied when using R407A & R407F.

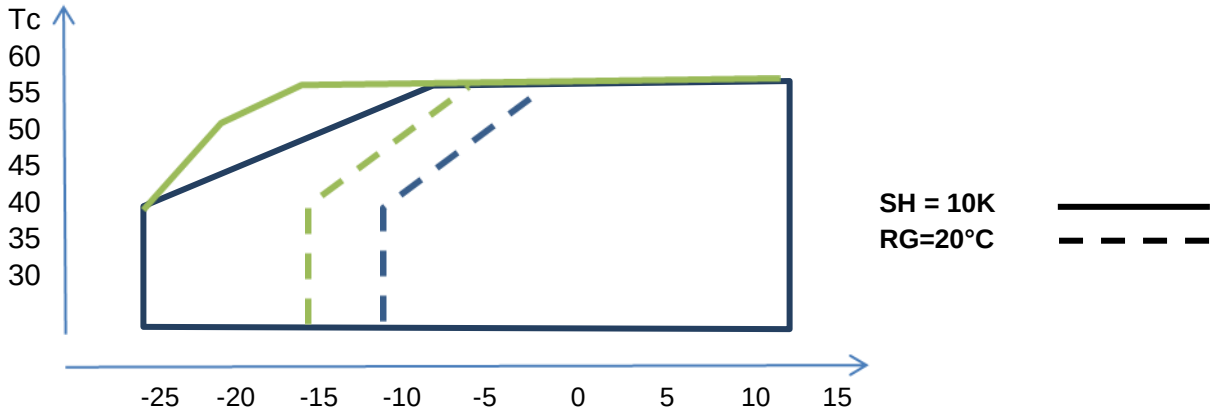
Special care will be taken with applications using a hot gas bypass valve or a constant evaporating pressure valve.

(eg: Air dryers, multi evaporators fed by a same condensing unit …)

- Discharge gas temperature will be measured prior to a retrofit sequence to manage the fluid change.

At the same running conditions, discharge gas & motor temperature will warm up by 15 to 25K. Tecumseh advises to maintain discharge gas temperature below 120°C.

HBP & MHBP applications with R407A, R407F



Discharge temperature measurement according to Discharge 2inches Insulated Tecumseh method:

Compressor cooling:

For any application we highly recommend appropriate fan cooling. Hermetic compressor cooling is also ensured by a mastered superheat. (i.e.: return gas temperature)

Tecumseh does not advise covering compressors running with R407A & R407F with any jacket.

Ability of oils to come back to compressor:

R407A & R407F are miscible with POE oil used by Tecumseh. No oil change is needed to ensure its return to compressor.
When a compressor will be replaced by another with a lower factory oil charge, some extra amount may be necessary.

7- Application Side

Refrigerant charge:

To not affect their composition into the refrigerating circuit and to get correct performances, (as with R404A) R407A & R407F will be charged in Liquid phase. Pre-charge installation recommended at 80% of initial amount into liquid receiver.

Final R407F & R407A refrigerant mass will be 5 to 10% higher than the one with R404A.

Liquid density for reference:

To/ Fluid	R-404A	R-407A	R-407F	Delta 407A/404A	Delta 407F/404A
	Kg/m3	Kg/m3	Kg/m3	%	%
-20	1223.1	1321.6	1289.5	8.1	5.4
-10	1188.1	1286.7	1255.0	8.3	5.6
40	966.1	1071.9	1045.0	10.9	8.2
60	815.8	942.8	921.9	15.6	13.0

To measure superheat & sub cooling refer respectively to Dew point and Bubble point saturated pressure.

Expansion device setting:

Due to lower mass flow driven by the compressor (-40% expected with R407F), and to a different cooling fluid capacity, the expansion device will need to be re-selected. Contact your supplier for more information.

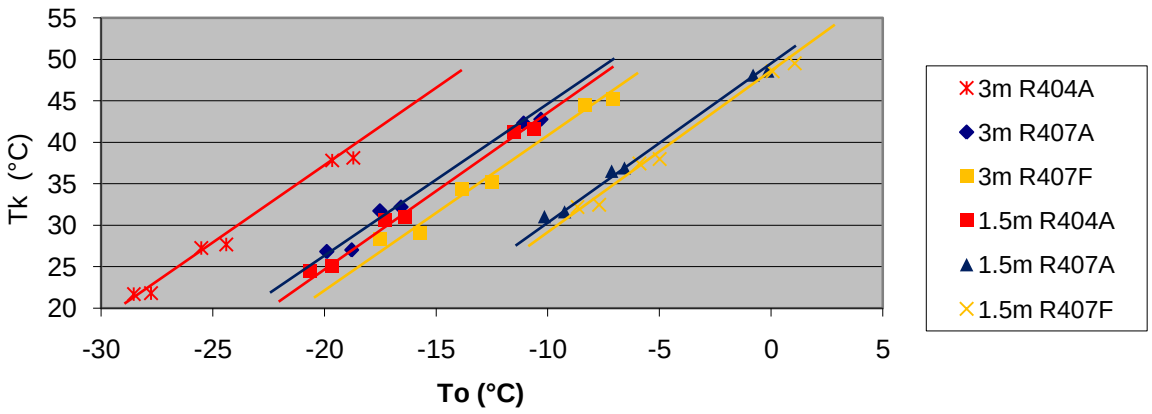
To retrofit applications performing some pull down with R407A or with R407F, expansion valves are preferable to capillary tubes in order to limit return gas superheat.

Average coefficients written hereunder will be used for positive and medium applications using High Back Pressure compressors.

- ➔ When passing from R404A to R407A, capillary tube length will be multiplied by 2.2
- ➔ When passing from R404A to R407F, capillary tube length will be multiplied by 2

We notice that with R407A or with R407F fluid, capillary tube lengths needed will be close to the ones used in the past with R22.

An example is given below, with a 15/10mm capillary tube and RGA4512Z compressor running with R404A then R407A & R407F. The graph provides Dew/Dew saturated pressures according to fluids passing through capillary tubes.



Condensing pressure deviation expected after a retrofit:

Expected saturated condensing temperatures will be equivalent or lower by 1 to 3K than with R404A @ same dew evaporating pressure.

Pressostat setting:

Saturated pressures with R407A & R407F are slightly lower than with R404A. Both LP and HP pressostat settings will be adjusted to not overpass compressors envelope limitation (maximum saturated discharge pressure equals 60°C). Refer to pressure chart.

Refrigerant mass flow:

Due to the lower specific volume of the R407A & R407F vapor at compressor inlet, mass flow could drop by 30 to 40%.

Compression ratio comparison @ dew rating conditions:

	R404A	R407A	R407F	R407C
-35/40	11.0	13.5	13.4	14.0
-25/45	8.2	9.8	9.7	10.1
-10/45	4.7	5.4	5.3	5.5
5/55	3.6	4.0	4.0	4.1
15/60	3.0	3.3	3.3	3.3

Sound level expected:

According to measurements carried out in the Tecumseh laboratory, acoustic power deviation of compressors running with R407A or R407F shall remain within +/- 2 dBA.

Material compatibility:

All row materials inside R404A Tecumseh Europe compressors, condensing units (& devices fitted on them) are compatible with molecules of R407A & R407F.

R22 compressors would require oil change.

8- Retrofit Procedure:

Retrofits can be classified in two categories:

- ✓ The compressor is defective and needs replacing.
- ✓ The system has developed a fault (leak, expansion device, drier, oil, etc…) that requires intervention and probably replacement of some components and charge.

Procedure N°1

This procedure is applicable to a conversion of a refrigerating system in a good condition that was using HFC (R404A or R507) refrigerant & a compressor which became defective and must be replaced.

When a same compressor is fitted, it should be noted that an application running in the lower side of the compressor evaporating range may not provide the same capacity as before.

1- Select a compressor for use with final refrigerant.
2- Ensure that the compressor or circuit is not open to atmosphere longer than a few minutes (15 minutes max).
3- Using an appropriate recovery unit, remove the original refrigerant from the unit. Record its amount.
4- Adapt expansion device to new refrigerant used. Note that capillary tube length could be twice the original one if system was running with R404A.
5- Fit a compatible, adequately-sized filter drier. Also ensure that the other components (sight glass etc...) are also compatible.

Always use the electrical components (relay, overload, capacitors,…) of the new compressor, as they may differ from the ones used with the old compressor.

6- Evacuate the system on both sides of the circuit to ensure that pressure is below 25mbar. An appropriate gauge is required.

Never energize a compressor under vacuum.

7- Ensure that the system is leak free.
8- Break the vacuum with the new refrigerant ensuring that any charge will be made in liquid state through the liquid line.
9- Charge the system using good refrigeration practices, keeping in mind that with the transitional refrigerants will require more refrigerant charge in weight (circa 5 to 10% versus R404A)
10- Run the system and measure pressures and temperatures to ensure compressor reliability criteria (discharge gas, motor temperature…) are respected.
11- Installation retrofit must be clearly identified with a label stating the type & mass of refrigerant.

Procedure N°2

Once you determine that a compressor needs to be replaced, you must then determine whether the system has been contaminated.

1- Using an appropriate recovery unit and correct procedure, recover old HFC from the system and record its amount.
2- Remove the compressor from the system, and drain the oil.
3- Fit the new compressor to the system and evacuate.
4- Recharge system with original refrigerant (R404A or R507) that was following standard refrigeration practices.
5- Run the system long enough to ensure that any original oil left in system mixes with the new POE oil.
6- Repeat this procedure (1 through 6) as many times as necessary to ensure that the original oil represents 1% or less in the new POE. Normally this is achieved after two to three flushes.

Remark: Normally the residual oil is trapped in the evaporator (in the lower section). Whenever possible, run the system for some minutes passing hot gas from the discharge line through the evaporator: high velocity of hot gas and temperature will help to return this oil to the compressor.

7- Using an appropriate recovery unit, recover the fluid from the system.
8- Replace oil of the compressor with the correct amount of Tecumseh recommended oil.
9- Fit appropriate capillary tube or expansion device according to manufacturer recommendations.
10- Fit a compatible, adequately sized filter drier with R407 series.

It is recommended that a suction filter is always fitted.

11- Vacuum system on both sides of the circuit to ensure that pressure is below 25mbar. An appropriate gauge is required.

Never energize a compressor under vacuum.

12- Ensure that system is leak free.
13- Break vacuum with new liquid state refrigerant ensuring that any charge will be made in liquid state and trough the liquid line.
14- Charge the systems referring to good refrigerating practices. R407 series will require more refrigerant charge in weight (circa 5% versus R404A).
15- Run the system, measure pressures and temperatures to ensure compressor reliability criteria (discharge gas, motor temperature...) are respected.
16- Installation retrofit must be clearly identified with a label stating the type & the mass of refrigerant.

Procedure N°3

Transitional refrigerants are not equivalent of the ones they replace. Reliability criteria may dictate some necessary system adaptations and ban a “drop-in” procedure.

Systems using hot valve injection, liquid/vapor heat exchanger may need redesign to run accordingly to the new compressor window.

1- Record operating data of current system running with old refrigerant before starting procedure.
2- Filter drier type will be selected accordingly to manufacturer recommendations.
3- Adapt expansion device to new refrigerant used. Note that capillary tube length could be twice the original one.
4- Charge the systems in liquid state, referring to good refrigerating practices. R407 series will require more refrigerant charge in weight (circa 5% versus R404A).
5- Run the system,. Measure pressures and temperatures to ensure compressor reliability criteria (discharge gas, motor temperature...) are respected.
6- Set LBP & HBP pressostats.
7- Installation retrofitted must be clearly identified with a label stating the type & mass of refrigerant.

Pressure chart:

Fluide	R404A		R407A		R407F		R407C	
T sat °C	P dew abs b	P buble abs b	P dew abs b	P buble abs b	P dew abs b	P buble abs b	P dew abs b	P buble abs b
-46	1,00	1,04	0,70	0,98	0,73	1,02	0,63	0,91
-44	1,10	1,14	0,77	1,07	0,81	1,12	0,70	1,00
-42	1,21	1,25	0,86	1,18	0,90	1,23	0,78	1,10
-40	1,33	1,37	0,95	1,29	1,00	1,35	0,86	1,21
-38	1,45	1,50	1,05	1,42	1,10	1,48	0,95	1,33
-36	1,59	1,64	1,16	1,55	1,21	1,62	1,05	1,45
-35	1,66	1,71	1,21	1,62	1,27	1,69	1,10	1,52
-34	1,73	1,78	1,27	1,69	1,33	1,77	1,16	1,59
-32	1,88	1,94	1,39	1,84	1,46	1,92	1,27	1,73
-30	2,04	2,10	1,53	2,00	1,60	2,09	1,39	1,88
-28	2,22	2,28	1,67	2,18	1,75	2,27	1,52	2,04
-26	2,40	2,47	1,82	2,36	1,91	2,47	1,67	2,22
-25	2,50	2,57	1,90	2,46	1,99	2,57	1,74	2,31
-24	2,60	2,67	1,99	2,56	2,08	2,67	1,82	2,40
-22	2,81	2,88	2,16	2,76	2,26	2,89	1,98	2,60
-20	3,03	3,10	2,35	2,99	2,46	3,12	2,15	2,81
-18	3,26	3,34	2,55	3,22	2,67	3,37	2,34	3,03
-16	3,51	3,59	2,76	3,47	2,89	3,63	2,53	3,26
-15	3,64	3,72	2,87	3,60	3,00	3,76	2,64	3,39
-14	3,77	3,86	2,99	3,73	3,12	3,90	2,74	3,51
-12	4,05	4,14	3,23	4,01	3,37	4,19	2,97	3,77
-10	**4,342**	**4,43**	**3,48**	**4,30**	**3,64**	**4,50**	**3,20**	**4,05**
-8	4,65	4,74	3,75	4,61	3,92	4,82	3,45	4,34
-6	4,97	5,07	4,03	4,93	4,21	5,16	3,72	4,65
-4	5,31	5,41	4,33	5,27	4,53	5,52	4,00	4,98
-2	5,67	5,77	4,65	5,63	4,86	5,90	4,30	5,32
0	6,04	6,15	4,99	6,01	5,21	6,30	4,61	5,68
2	6,44	6,54	5,34	6,41	5,58	6,71	4,94	6,06
4	6,85	6,96	5,71	6,82	5,97	7,15	5,29	6,45
5	7,06	7,17	5,90	7,04	6,17	7,38	5,47	6,66
6	7,28	7,39	6,10	7,26	6,37	7,61	5,66	6,87
8	7,73	7,85	6,51	7,71	6,80	8,09	6,04	7,30
10	8,20	8,32	6,94	8,19	7,25	8,59	6,45	7,76
12	8,69	8,82	7,40	8,69	7,73	9,11	6,87	8,23
14	9,21	9,33	7,87	9,21	8,23	9,66	7,32	8,73
15	9,47	9,60	8,12	9,48	8,48	9,94	7,55	8,99
16	9,74	9,87	8,37	9,75	8,75	10,23	7,79	9,25
18	10,30	10,43	8,89	10,32	9,29	10,83	8,28	9,79
20	10,89	11,02	9,44	10,91	9,86	11,45	8,80	10,36
22	11,49	11,63	10,01	11,52	10,46	12,10	9,33	10,95
24	12,13	12,27	10,60	12,17	11,09	12,77	9,90	11,56
26	12,78	12,93	11,23	12,83	11,74	13,48	10,49	12,20
28	13,47	13,61	11,88	13,53	12,43	14,21	11,10	12,87
30	14,18	14,33	12,55	14,25	13,14	14,97	11,74	13,56
32	14,92	15,07	13,26	15,00	13,89	15,76	12,41	14,28
34	15,69	15,84	14,00	15,77	14,66	16,57	13,11	15,03
36	16,49	16,64	14,77	16,58	15,47	17,42	13,84	15,80
38	17,31	17,47	15,57	17,42	16,32	18,31	14,60	16,61
40	**18,17**	**18,33**	**16,4**	**18,29**	**17,2**	**19,22**	**15,39**	**17,45**
42	19,07	19,22	17,27	19,19	18,11	20,17	16,21	18,31
44	19,99	20,15	18,17	20,13	19,07	21,15	17,07	19,21
45	**20,47**	**20,63**	**18,64**	**20,61**	**19,56**	**21,65**	**17,51**	**19,67**
46	20,95	21,11	19,11	21,10	20,06	22,16	17,96	20,14
48	21,95	22,11	20,09	22,11	21,09	23,21	18,89	21,11
50	22,98	23,14	21,11	23,15	22,17	24,30	19,85	22,11
52	24,05	24,20	22,16	24,23	23,28	25,42	20,85	23,14
54	25,16	25,31	23,26	25,35	24,44	26,58	21,89	24,21
55	25,73	25,88	23,83	25,92	25,04	27,17	22,42	24,76
56	26,31	26,46	24,40	26,50	25,65	27,78	22,97	25,31
	27,50	27,64	25,59	27,70	26,90	29,01	24,09	26,45
60	28,74	28,87	26,82	28,95	28,20	30,29	25,26	27,63