PURON® REFRIGERANT
R-410A

AN ENVIRONMENTALLY SOUND, HIGH-EFFICIENCY REFRIGERANT TO REPLACE R-22 IN NEW COMMERCIAL AIR CONDITIONING EQUIPMENT

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Syracuse, New York

October 2004

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Note:
All data, statements and recommendations included in this paper are based on the research of the indicated sources and are believed to be accurate. However, no guarantee of accuracy can be made and Carrier Corporation assumes no liability resulting from errors or inaccuracies in the quoted materials.

INTRODUCTION

To implement agreements made in the 1987 Montreal Protocol, the U.S. Congress enacted the Clean Air Act Amendments of 1990. The law mandated a phaseout schedule for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) refrigerants.

Production of CFCs for air-conditioning applications, primarily R-11 and R-12, stopped at the end of 1995. The air-conditioning industry responded with new products using different refrigerants that operated more efficiently and reliably than the refrigerants that were previously available.

HCFC's, due to their lower ozone depletion potential and because of their critical role in transitioning from CFCs, received an extended phaseout schedule. The plan now states: all manufacturers of air conditioning equipment must stop producing HCFC new equipment January 1, 2010.

Well before Congress enacted the Clean Air Act Amendments of 1990, research began on developing an environmentally sound replacement for R-22. In 1991, AlliedSignal (now Honeywell) announced development of a hydrofluorocarbon (HFC) refrigerant that they called Genetron® AZ-20®. The generic ASHRAE designation was later assigned as R-410A.

Carrier began a proactive, cooperative development program with Honeywell to develop the first residential air conditioners in the United States that would use R-410A. In 1995, Carrier launched a new product line using the registered trademark Puron® Refrigerant to distinguish it from earlier R-410A products.

In 1996, the U.S. Environmental Protection Agency (EPA) recognized Carrier's and Honeywell's foresight by presenting both collaborating companies with the Stratospheric Ozone Protection Award. Also in 1996, the EPA formally recognized R-410A as an acceptable substitute for R-22 (see EPA 1996).

Since that time, other manufacturers have followed Carrier's lead and developed their own line of R-410A products. There are now twelve different brands of air conditioners and heat pumps that use R-410A available in the United States and Canada. Every major air-conditioning equipment manufacturer, to a greater or lesser degree, has a line of R-410A equipment.

Until now, most R-410A equipment has been for residential service. Carrier is boldly breaking that barrier by introducing new lines of high-efficiency commercial air conditioning units specially designed for Puron refrigerant.

This white paper serves as a technical resource to discuss Puron refrigerant, to outline its unique advantages, and to provide comparison between Puron refrigerant and R-22.

For additional information, contact your local sales representative or visit the Carrier web site at http://www.commercial.carrier.com/.

PURON® REFRIGERANT

Puron refrigerant is Carrier's registered trademark for a refrigerant blend with the generic ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) designation R-410A.

The Puron refrigerant trademark does not make R-410A a proprietary refrigerant. It is available from several refrigerant and chemical suppliers, and may be used by any air conditioning manufacturer within the industry. Indeed, the chemical companies have made a strong effort to sell R-410A to air conditioning manufacturers as a long-term replacement for R-22.

Refrigerant suppliers who manufacture R-410A are:

Supplier	R-410A Product Name
Honeywell	Genetron AZ-20®
DuPont	Suva® 410A (9100)
Atofina	Forane® 410A

PHYSICAL PROPERTIES

Puron refrigerant (R-410A) is an azeotropic mixture of two hydrofluorocarbon (HFC) refrigerants blended in a 50-50 ratio (measured by mass):

R-32 (difluoromethane)
R-125 (pentafluoroethane)

Zeotropic and Azeotropic Blends

The individual component refrigerants in a blended refrigerant usually do not have identical physical characteristics. They may have different densities, different viscosities and different evaporation and condensation temperatures at a given pressure, etc. In some blends the individual components interact such that the vapor phase and liquid phase have the same composition at a given pressure. These blends are called azeotropic refrigerants. In some blends the individual components interact such that the vapor phase and liquid phase have the same composition at a given pressure. These blends are called azeotropic refrigerants. In other blends the components maintain their original properties and the mixture changes composition as the blend boils or condenses

A *zeotropic* blend combines component refrigerants of different volatilities that when used in a refrigerant cycle, change volumetric composition and saturation temperatures as they evaporate or condense at constant pressure. When heat is added to a zeotropic blend at a constant pressure, the more volatile components boil off first, changing the composition (mole fraction) of the remaining liquid. The composition of the gas will also differ since it is initially composed of only the most volatile refrigerant(s). As the process temperature rises, the less volatile components eventually boil off as well. Obviously, when heat is removed from the zeotropic blend, the less volatile refrigerant(s) condense first.

An *azeotropic* blend behaves as a pure fluid or close enough to be considered near-azeotropic. When heat is added to or removed from an azeotropic refrigerant blend, the composition (mole fraction) of the gas and the liquid remain essentially unchanged throughout the complete process. **Puron refrigerant is an azeotropic blend** and performs essentially as a pure fluid.

As a point of comparison, the combination of refrigerant and lubricating oil is a zeotropic blend. For instance, when the refrigerant goes

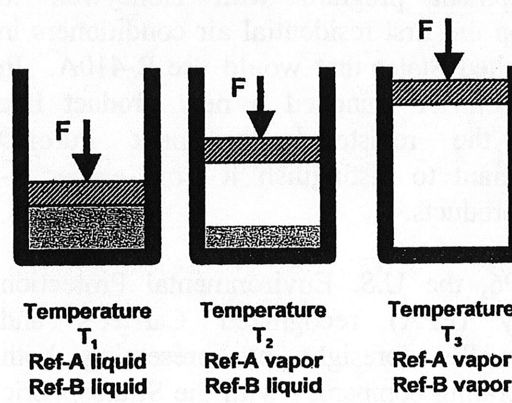

Fig. 1. Action of a zeotropic mixture of refrigerant components A and B in a constant pressure container as the temperature increases from T_1 to T_3.

through a phase change from liquid to gas in the evaporator of the air conditioning system, lubricating oil remains a liquid state, because the process temperature is not nearly high enough to cause the lubricant to boil.

Temperature Glide

The characteristic called *temperature glide*, refers to the range of temperatures at which components in a blended refrigerant boil or condense at a given pressure. A pure substance (like water) at a constant pressure, will go through a complete phase change at a constant temperature. Conversely, a zeotropic blended refrigerant must proceed through a range of temperatures in order to complete the phase change process.

The name *temperature glide* refers to this range of temperature. For Puron refrigerant (R-410A) temperature glide is <0.3°F.

Table A – Comparison of Refrigerant Physical Properties

ASHRAE Number	R-410A	R-22
Type of refrigerant	HFC azeotropic mixture of HFC-32 and HFC-125	HCFC
Chemical name	Difluoromethane (R-32) Pentafluoroethane (R-125)	Chlorodifluoromethane
Chemical formula	CH_2F_2 (R-32) CHF_2CF_3 (R-125)	$CHClF_2$
Composition (by mass)	R-32 50% R-125 50%	N/A
Molecular weight	72.6	86.5
Boiling point (at 1.0 atm.), °F	-62.9	-41.4
Freezing point (at 1.0 atm.), °F	-247	-256
Critical temperature, °F	163	205
Critical pressure, psia	720	722
Saturated liquid density (at 86°F), lb/ft^3	64.64	73.09
Specific heat of liquid (at 86°F), Btu/lb-°F	0.42	0.31
Specific heat of vapor at constant pressure C_p (at 86°F and 1.0 atm.), Btu/lb-°F	0.21	0.16
Flammable range (% volume in air) (Note 1)	None	None
ANSI/ASHRAE Standard 34-1992 Safety Group Classification	A1	A1
Ozone depletion potential (ODP) (Notes 2 and 4)	0.00	0.05

Global warming potential (GWP), 100 yr. (Notes 3 and 4)	1,997	1,780
Montreal Protocol phase out date	None	2030

Notes:
1. Based on ASHRAE Standard 34 - 2001 Designation and Safety Classification of Refrigerants.
2. ODP: a normalized indicator of the ability of a refrigerant to destroy stratospheric ozone molecules referenced to a value of 1.000 for CFC-11.
3. GWP: a mass-weighted average indicator of the ability to trap radiant energy as a greenhouse gas relative to carbon dioxide (CO2) for a 100-year integration period.
4. Information sources: Honeywell (2003), ANSI/ASHRAE Standard 34-2001, and ODP and GWP data WMO (2002).

Temperature Glide Effects

In systems using zeotropic refrigerant blends with a relatively high temperature glide, the more volatile components will escape first if there is a leak while the system is shutdown. This process is called *fractionation.* However, while the unit is operating, the action of the compressor and expansion device tend to keep the refrigerant blended and a leak is less likely to result in fractionation. Furthermore, fractionation complicates the refrigerant charging process.

In systems utilizing azeotropic refrigerant blends, there will be no fractionation, since all components will tend to escape at similar rates, if there is a leak in the system.

Density

Density differences cause zeotropic blended refrigerant components to segregate while the system is inactive. This has a greater effect on flooded refrigerant systems than non-flooded systems.

An azeotropic blend with similar density of the constituents will act as a single component substance, eliminating any concerns regarding stratification.

ENVIRONMENTAL CONSIDERATIONS

The two measures of environmental effect are Ozone Depletion Potential (ODP) and Global Warming Potential (GWP).

Ozone Depletion Potential

As an HFC, Puron refrigerant (R-410A) has an ODP rating of 0.00 versus 0.05 for R-22. Since Puron refrigerant has such a low ODP rating, it is not covered under the Montreal Protocol and has no phaseout date.

ODP is a normalized indicator based on an assigned value of 1.000 for CFC-11. It represents the relative ability of a refrigerant to destroy stratospheric ozone molecules when released to the atmosphere.

Global Warming Potential

GWP is a normalized indicator representing the relative ability of a refrigerant to trap radiant energy. GWP values are calculated relative to carbon dioxide (CO_2) over an integration period of 100 years. The GWP values have changed over the years as the atmospheric models have improved, but generally remain consistent.

Although the GWP ratings are slightly higher for Puron refrigerant, in comparison to R-22, they do not provide an accurate representation for air-conditioning systems that have both direct and indirect effects on global warming. The direct effect, which GWP measures, comes from refrigerant release to the atmosphere through leaks. The indirect effect is a function of energy consumption necessary to produce cooling. Air-conditioning systems using electricity indirectly influence global warming through the release of carbon dioxide and other greenhouse gases from combustion of fossil fuels at the electric generating station.

Researchers have developed an index called the Total Equivalent Warming Impact (TEWI) that considers both the direct and indirect global warming effects of a refrigerant.

Gopalnarayanan (1999) examined eight different refrigerants as possible substitutes for R-22. He found that for all eight refrigerants, the direct GWP effect of a refrigerant represented less than 7.5% of the TEWI at performance rating conditions[1]. This means that the indirect effect of a system's energy efficiency is more than 13 times more important than GWP. Therefore, TEWI, which considers both the direct and indirect global warming effects of a refrigeration system is a much more accurate indicator.

In addition, Gopalnarayanan (1999) also found that of all eight refrigerants examined, Puron refrigerant (R-410A) had the best performance from the point of view of energy efficiency and TEWI.[2] Many other studies supporting aforementioned conclusions have been also conducted and can be found in numerous ASRAE publications.

EFFICIENCY

In new commercial air-conditioning systems designed to use Puron refrigerant with scroll or reciprocating compressors, tests have shown the Puron refrigerant air conditioner to be 5 to 6 percent more efficient than a comparable R-22 system, while operating in a typical application range. This is attributable to several characteristics.

First, Puron refrigerant has a much higher specific heat in both liquid and vapor form than R-22. For instance, in the vapor phase, Puron refrigerant has more than 31% greater heat carrying capacity per pound than R-22. This phenomenon leads to a lower temperature rise during heat transfer interaction that usually results in reduced losses for the air conditioning cycle. From Table A on page 5:

	R-410A	R-22
Specific heat of liquid (at 86°F), Btu/lb-°F	0.42	0.31
Specific heat of vapor at constant pressure C_p (at 86°F and 1.0 atm.), Btu/lb-°F	0.21	0.16

Second, because Puron refrigerant operates at a higher pressure, the refrigerant gas density is higher, enabling a unit to operate at lower volumetric flow rates than a comparable R-22 unit. Since total heat transfer is a function of mass flow rate (mass flow rates are similar for Puron refrigerant and R-22), and not volumetric flow rate,smaller, slower and somewhat quieter compressors can be utilized.

Furthermore, Honeywell, the original developer of Puron refrigerant, has documented a number of research studies by universities, and manufacturers of tubing, air-conditioning systems and refrigerants (Honeywell 2000). The results indicate that the evaporation heat transfer coefficient for Puron refrigerant consistently averages about 30% higher than R-22. In addition, the system pressure drop for both evaporation and condensation average about 40% less than R-22. Hence, reduced size refrigerant lines, smaller evaporator coils and longer heat transfer circuits can be employed, giving flexibility to a system designer and benefiting end customers.

Recent trends in the industry to reduce life-cycle cost of equipment along with environmental regulations and newly introduced legislation promote air conditioning systems of premium efficiency and

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[1] The calculated GWP effect assumed that 4% of the refrigerant charge was lost as leakage each year. For a system that has no leaks, the TEWI is fully attributable to energy consumption and the GWP effect is zero.

[2] Two flammable refrigerants were found to have somewhat better energy efficiency and lower TEWI than Puron refrigerant. However, considering the practical problems and liability issues associated with flammable refrigerants, Puron refrigerant stands out as the best performing substitute for R-22.

consequently their operation at a reduced discharge pressure.

RELIABILITY

The service pressure of Puron refrigerant (R-410A) is 235 psig. Operating pressures in a Puron refrigerant system average about 60% higher than in a comparable R-22 system. At first, this may seem to be a negative characteristic. In fact, just oppositely, the higher pressures have led air conditioning system designers to more robust designs and superior control and protection techniques. As a result, system reliability was not compromised and actually improved.

Because Puron refrigerant is not a direct, functional replacement for R-22, air conditioners must be specifically designed to operate with R-410A. Puron refrigerant units are designed for heavy-duty operation with a thicker compressor shell and heavy-wall tubing. Thicker materials in turn enabled the manufacturer to create heavier, better welds at joints, which improve their resistance to abuse.

Since 1995, over 1,000,000 R-410A air-conditioning units have been manufactured, sold and operated worldwide. The field-testing and product history to date for residential systems and some commercial equipment suggest that the R-410A refrigerant units are any more reliable than R-22 units.

Carrier has noted an exceptional record of reliability in its Puron refrigerant products. Carrier's Puron refrigerant lines of air conditioners and heat pumps have the lowest recorded rate of warranty claims.

Lubricants

All air conditioners and heat pumps using scroll and reciprocating compressors circulate oil with the refrigerant to keep the compressor lubricated. R-22 units use mineral oil. Most air conditioning and heat pump units operating with HFC refrigerants such as, R-32, R-125, R-134a, R-143a and their mixtures, including Puron refrigerant, are recommended to use polyolester (synthetic) lubricants. Synthetic lubricants are not uncommon and are commercially available.

Synthetic lubricants are more soluble with Puron refrigerant than traditional mineral oils are with R-22. Improved solubility allows the oil to mix easier with Puron refrigerant and circulate more efficiently. Overall, this improves oil return, reduces compressor wear and generally improves reliability. Also, just like synthetic motor oils used in automobiles, synthetic oils circulating with Puron refrigerant are less likely to breakdown under extreme service conditions. This serves as another benefit to achieving greater system reliability.

The one challenge with synthetic lubricants is that they are prone to absorb moisture from the atmosphere due to polarity of the molecules and ability to attract water molecules. This requires service technicians to take simple precautions to prevent exposing the oil to air. It is as simple as keeping the oil container sealed and transferring oil with a pump rather than pouring it. But, if the oil, as well as Puron refrigerant, does absorb a small amount of moisture, each refrigerant system contains a filter-dryer with the express purpose of cleaning and drying refrigerant and oil circulating through the system.

SAFETY

The following safety-related information is taken from Honeywell's published data for Genetron® AZ-20®. For complete details and safety information, see Honeywell (2000) and (2003) listed in the References section of this paper.

Toxicity

The components of Puron refrigerant have intrinsically low toxicity. As such, Puron refrigerant can be safely used when handled in accordance with the manufacturer's Material Safety Data Sheet (MSDS).

Flammability

ASHRAE Standard 34-2001 classifies Puron refrigerant (R-410A) in safety group A1 meaning that it is non-flammable at one atmosphere of pressure and 70°F.

Puron refrigerant does not have a flash point and requirements regarding the flash point do not apply to it, as per U.S. Department of Transportation (DOT) regulations. Puron refrigerant has no flame limits and DOT considers it to be non-flammable. Underwriters' Laboratory has recognized Puron refrigerant as being practically non-flammable.

Inhalation Exposure

Ingredient Name	ACGIH TLV TWA[2]	OSHA PEL[3]	Other Limits (Note 1)
Difluoromethane (R-32)	None	None	1,000 ppm
Pentafluoroethane (R-125)	None	None	1,000 ppm

Notes:
1. 8-hour time weighted average (8-hr TWA) limit established by Honeywell.
2. ACGIH TLV-TWA: American Conference of Governmental Industrial Hygienists Threshold Limit Value – Time Weighted Average
3. OSHA PEL: Occupational Health and Safety Administration Permissible Exposure Limit
4. Source: Honeywell (2003).

Leaks

The vapor density of Puron refrigerant is approximately three times that of air. If released into an enclosed space, refrigerant gas may accumulate in low areas and near the floor, displacing available oxygen. Asphyxiation is the primary risk associated with a major leak.

As with any refrigerant, when Puron refrigerant is released to the atmosphere in an enclosed space, the area should be immediately evacuated and ventilated. Unprotected personnel should not return to the area until it has been determined to be safe.

Installation and application of air-conditioning equipment operating with Puron refrigerant should follow the applicable requirements of ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems*.

Thermal Stability

Puron refrigerant is stable under normal operating conditions. Exposure to extremely high temperatures can lead to the formation of toxic and/or corrosive decomposition products, as is does in all refrigerants.

SUMMARY

Puron refrigerant (R-410A) is the leading replacement for refrigerant R-22 in the coming years.

Between now and 2010, all air-conditioning manufacturers must develop new products that operate with refrigerants other than R-22. Carrier has taken a proactive and leading role in development of residential, and now commercial equipment, to use Puron refrigerant.

The new Carrier Puron refrigerant products are more efficient and more reliable than ever before. The Puron refrigerant product line has the lowest incidence of warranty claims of all Carrier air conditioning units.

Equipment operating with Puron refrigerant must be designed specifically to handle the higher operating pressure and to take advantage of its high-efficiency characteristics.

Puron refrigerant is safe, non-toxic, non-flammable and environmentally responsible. It does not deplete stratospheric ozone, and has been shown to be one of the lowest overall impacts on global warming of all viable R-22 replacement refrigerants.

Pressure-Temperature Chart for R-410A and R-22

°F	R-410A	R-22	°F	R-410A	R-22	°F	R-410A	R-22	°F	R-410A	R-22
-40	10.8	0.6	10	62.2	32.8	60	169.6	101.6	110	364.1	226.4
-39	11.5	1.0	11	63.7	33.8	61	172.5	103.5	111	369.1	229.6
-38	12.1	1.4	12	65.2	34.8	62	175.4	105.4	112	374.2	232.8
-37	12.8	1.8	13	66.8	35.8	63	178.4	107.3	113	379.4	236.1
-36	13.5	2.2	14	68.3	36.8	64	181.5	109.3	114	384.6	239.4
-35	14.2	2.6	15	69.9	37.8	65	184.5	111.2	115	389.9	242.8
-34	14.9	3.1	16	71.5	38.8	66	187.6	113.2	116	395.2	246.1
-33	15.6	3.5	17	73.2	39.9	67	190.7	115.3	117	400.5	249.5
-32	16.3	4.0	18	74.9	40.9	68	193.9	117.3	118	405.9	253.0
-31	17.1	4.5	19	76.6	42.0	69	197.1	119.4	119	411.4	256.5
-30	17.8	4.9	20	78.3	43.1	70	200.4	121.4	120	416.9	260.0
-29	18.6	5.4	21	80.0	44.2	71	203.6	123.5	121	422.5	263.5
-28	19.4	5.9	22	81.8	45.3	72	207.0	125.7	122	428.2	267.1
-27	20.2	6.4	23	83.6	46.5	73	210.3	127.8	123	433.9	270.7
-26	21.1	6.9	24	85.4	47.6	74	213.7	130.0	124	439.6	274.3
-25	21.9	7.4	25	87.2	48.8	75	217.1	132.2	125	445.4	278.0
-24	22.7	8.0	26	89.1	50.0	76	220.6	134.5	126	451.3	281.7
-23	23.6	8.5	27	91.0	51.2	77	224.1	136.7	127	457.3	285.4
-22	24.5	9.1	28	92.9	52.4	78	227.7	139.0	128	463.2	289.2
-21	25.4	9.6	29	94.9	53.7	79	231.3	141.3	129	469.3	293.0
-20	26.3	10.2	30	96.8	55.0	80	234.9	143.6	130	475.4	296.9
-19	27.2	10.8	31	98.8	56.2	81	238.6	146.0	131	481.6	300.8
-18	28.2	11.4	32	100.9	57.5	82	242.3	148.4	132	487.8	304.7
-17	29.2	12.0	33	102.9	58.8	83	246.0	150.8	133	494.1	308.7
-16	30.1	12.6	34	105.0	60.2	84	249.8	153.2	134	500.5	312.6
-15	31.1	13.2	35	107.1	61.5	85	253.7	155.7	135	506.9	316.7
-14	32.2	13.9	36	109.2	62.9	86	257.5	158.2	136	513.4	320.7
-13	33.2	14.5	37	111.4	64.3	87	261.4	160.7	137	520.0	324.8

-12	34.2	15.2	**38**	113.6	65.7	**88**	265.4	163.2	**138**	526.6	329.0
-11	35.3	15.9	**39**	115.8	67.1	**89**	269.4	165.8	**139**	533.3	333.2
-10	36.4	16.5	**40**	118.1	68.6	**90**	273.5	168.4	**140**	540.1	337.4
-9	37.5	17.2	**41**	120.3	70.0	**91**	277.6	171.0	**141**	547.0	341.6
-8	38.6	17.9	**42**	122.7	71.5	**92**	281.7	173.7	**142**	553.9	345.9
-7	39.8	18.7	**43**	125.0	73.0	**93**	285.9	176.4	**143**	560.9	350.3
-6	40.9	19.4	**44**	127.4	74.5	**94**	290.1	179.1	**144**	567.9	354.6
-5	42.1	20.1	**45**	129.8	76.1	**95**	294.4	181.8	**145**	575.1	359.0
-4	43.3	20.9	**46**	132.2	77.6	**96**	298.7	184.6	**146**	582.3	363.5
-3	44.5	21.7	**47**	134.7	79.2	**97**	303.0	187.4	**147**	589.6	368.0
-2	45.7	22.4	**48**	137.2	80.8	**98**	307.5	190.2	**148**	596.9	372.5
-1	47.0	23.2	**49**	139.7	82.4	**99**	311.9	193.0	**149**	604.4	377.1
0	48.3	24.0	**50**	142.2	84.1	**100**	316.4	195.9	**150**	611.9	381.7
1	49.6	24.9	**51**	144.8	85.7	**101**	321.0	198.8			
2	50.9	25.7	**52**	147.4	87.4	**102**	325.6	201.8			
3	52.2	26.5	**53**	150.1	89.1	**103**	330.2	204.7			
4	53.6	27.4	**54**	152.8	90.8	**104**	334.9	207.7			
5	55.0	28.3	**55**	155.5	92.6	**105**	339.6	210.8			
6	56.3	29.2	**56**	158.2	94.4	**106**	344.4	213.8			
7	57.8	30.1	**57**	161.0	96.1	**107**	349.3	216.9			
8	59.2	31.0	**58**	163.8	98.0	**108**	354.2	220.0			
9	60.7	31.9	**59**	166.7	99.8	**109**	359.1	223.2			

Source: Honeywell. The above data, including recommendations for application and use of R-410A (Genetron® AZ-20®) are available at http://www.genetron.com.

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