Introduction to the Refrigeration Cycle

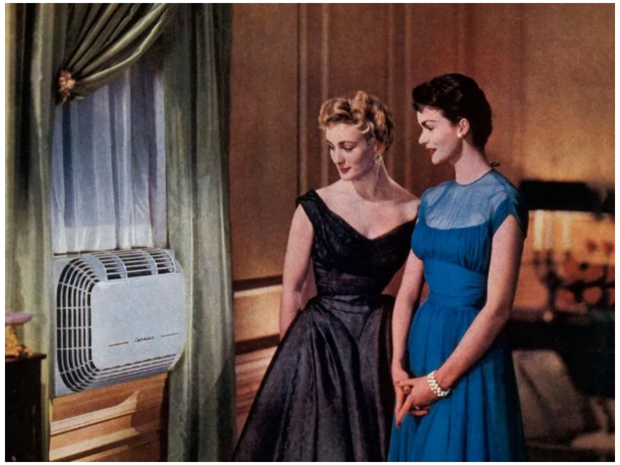
The Circular Life of a Refrigerant

. . . **More Than Just Heat**

EST. 1978

The Wonder of Air Conditioning

- Today, a U.S. household is more likely to have central air conditioning or a window unit than it is to have a dining room, garage or even a dishwasher.
- In 1914, the first domestic air conditioning unit (7 ft × 6 ft × 20 ft) was installed in the Minneapolis home of Charles Gilbert Gates.



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Temperature Difference (TD)

- The purpose of an AIR CONDITIONER is to create a temperature difference between an enclosed space and the outside
- The purpose of a REFRIGERATOR is to create a temperature difference between a room and the beer inside a sealed box.

Types of Temperature

Sensible Heat: Heat level or heat intensity of a substance that can be readily measured or felt. A CHANGE IN TEMPERATURE without a change in state/phase. This is the temperature/heat level that you feel when you walk into a hot room, easily measured on a thermometer.

Latent (Hidden) Heat: Heat that is added to a substance, without a change in temperature, but with a CHANGE IN STATE/PHASE. Once water is boiling, adding more heat makes it boil faster BUT THE TEMPERATURE DOES NOT RISE. Latent heat is the AMOUNT OF ENERGY that is needed for a substance to change state (through either vaporization, condensation, freezing, or melting).

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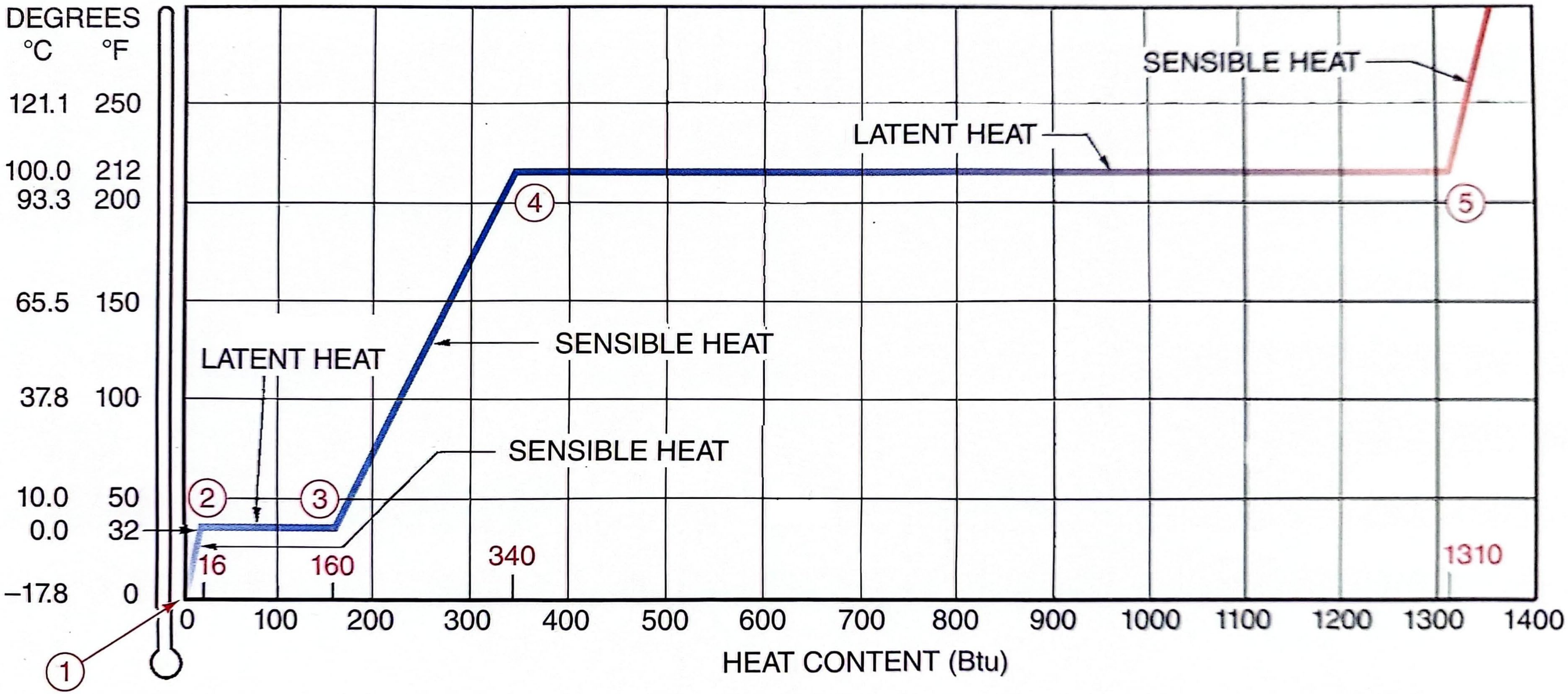
Sensible Heat VS Latent Heat



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Temperature and Pressure Relationship

Water (and other substances) have many boiling points. **The boiling point of water can be changed (and controlled) by adjusting the vapor pressure above the water.**

- Water boils at 212°F at pressure of 29.92 in. Hg (Mercury) (14.7 PSI), the absolute atmospheric pressure at sea level
- In Denver CO (5,000 ft; 25 in. Hg), water boils at 203.4°F (thinner atmosphere, reduction in pressure)
- In a pressure cooker (+15 PSI to 30 PSIA), water boils at 250°F
- In a vacuum chamber (0.739 in. Hg) water boils at 70°F

REFRIGERANTS boil at a MUCH LOWER temperature (40°F — 50°F) than water

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Temperature and Pressure Alignment

Conditions necessary for corresponding Temperature/Pressure alignment:

- Both vapor and liquid must be present
- A change of state (either boiling or condensation) must be occurring
- The refrigerant must be at equilibrium (no heat is being added or removed)

Opteon™

Refrigerants by The Chemours Company

Pressure-Temperature Guide for A/C

Key: Green (in of Hg) = Vacuum
Black (psig) = Saturated Vapor (calculate superheat)
Bold (psig) = Saturated Liquid (calculate subcooling)

	Freon™ **410A** (R-410A)	Opteon™ **XL41** (R-454B)	Freon™ **407C** (R-407C)	Freon™ **NU-22B™** (R-422B)	Freon™ **MO99™** (R-438A)	Freon™ **22** (R-22)	**R-32**
SAFETY GROUP	A1	A2L	A1	A1	A1	A1	A2L
°F	psig	psig	psig	psig	psig	psig	psig
-50	4.9	3.1	11.0	11.6	11.4	6.1	5.2
-45	7.6	5.6	8.0	8.7	8.5	2.7	8.0
-40	10.7	8.4	4.6	5.5	5.2	0.6	11.0
-35	14.0	11.4	0.9	1.9	1.5	2.6	14.4
-30	17.7	14.8	1.6	1.1	1.2	4.9	18.2
-25	21.8	18.5	3.9	3.2	3.5	7.4	22.3
-20	26.2	22.6	6.5	5.7	5.9	10.2	26.8
-18	28.1	24.3	7.6	6.7	7.0	11.4	28.7
-16	30.0	26.1	8.7	7.8	8.1	12.6	30.7
-14	32.0	27.9	9.9	8.9	9.2	13.9	32.8
-12	34.1	29.8	11.1	10.1	10.4	15.2	34.9

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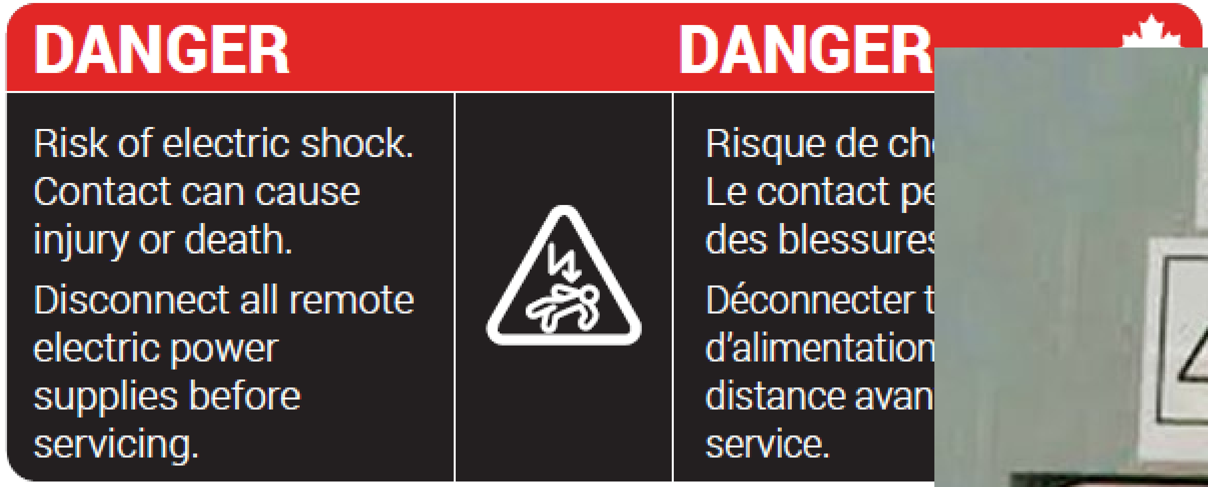
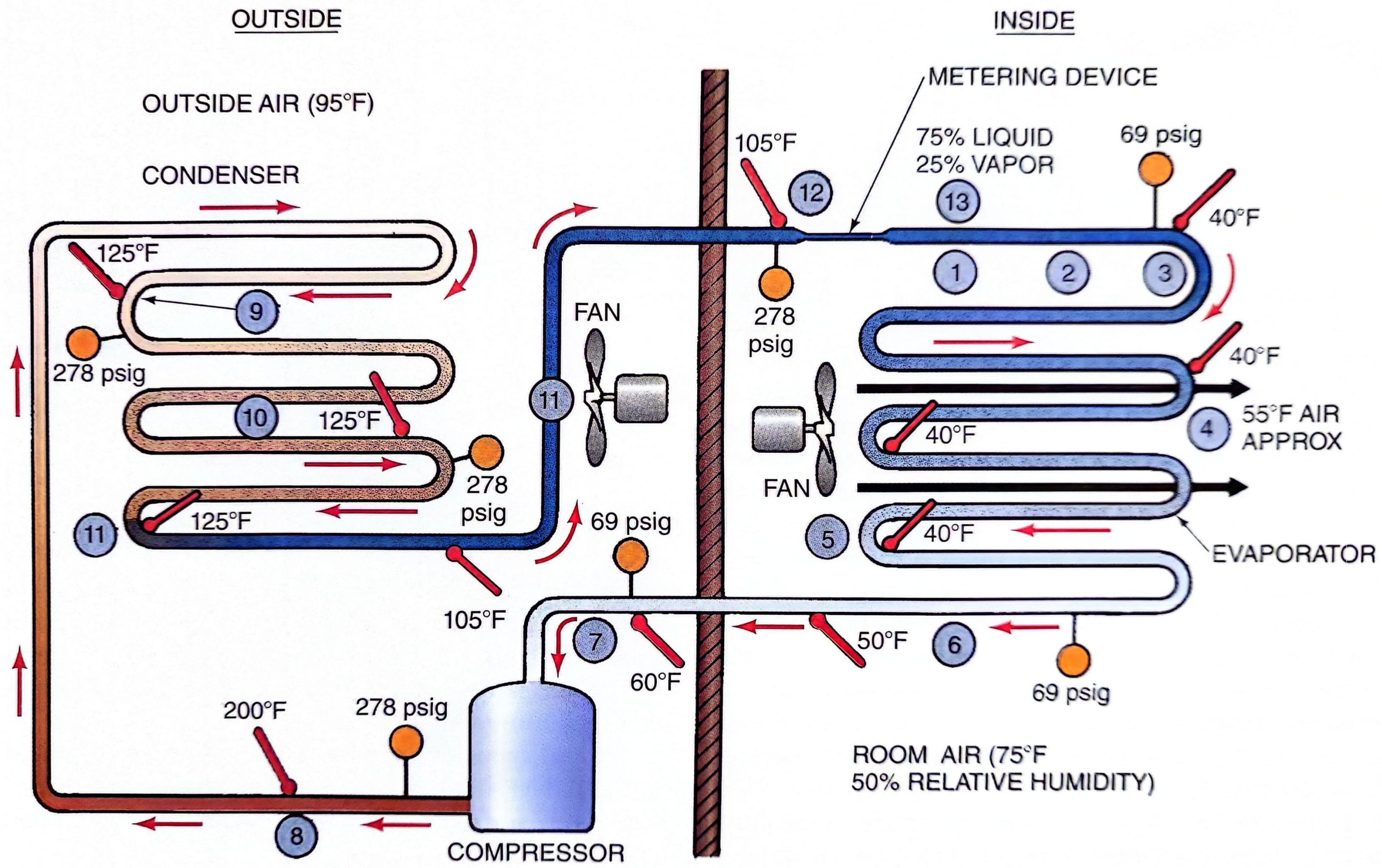
REFRIGERANT & ELECTRICAL WARNINGS



Typical Residential R-22 Air Conditioning System



The LATENT HEAT occurs in both coils as change in state happens

NOTE: Temperatures will be different depending on the refrigerant.

Real Life Condensation

Think of a seeing your breath on a cold winter day…

Your breath of warm, moist air exits your mouth and hits the cold winter air where it turns to tiny water droplets that form a little cloud.

The drop in temperature that happens when your breath meets the cold air causes the moisture in your breath to **change state** from a **vapor to a liquid**.

In a refrigeration condenser coil, hot, pressurized gas (breath) is cooled by colder ambient air which turns the vapor to liquid.

Condense: concentrate, reduce the volume of, make compact

Condenser (High) Side Circuit

Refrigerant vapor from the evaporator is put under higher pressure (meaning a higher temperature, as well) by the compressor and enters the condenser coil at almost 200°F. Cooler ambient air (even hot 95°F air) passes over the condenser coil and will cool the 200°F vapor enough (below 125°F) so that it will condense to a liquid inside the coil before it returns to the evaporator (low pressure) side of the system.

In a refrigerant system, the condensation occurs INSIDE THE COIL where the HOT ambient outside air cools the MUCH HOTTER refrigerant and changes its state from vapor to liquid.

Sub-Cooling Effect

- Although hot summer air will not drop the temperature of the refrigerant liquid much below the 125°F condensation point, the liquid will continue to cool to become a completely saturated liquid.
- Since there is no more vapor to turn to liquid, the liquid temperature continues to fall below the ambient temperature passing over the outside of the condensation coils.
- This is SUBCOOLING, which can reduce the temperature of the saturated liquid 10°F to 20°F below the condensation point of 125°F, which ensures that ONLY LIQUID arrives and will FLASH at the metering device.

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Real Life Evaporation

Picture an open can of beer under a beating summer sun…

As the radiant heat of the sun beats down on your beer, its cold contents will **evaporate** (turn to vapor) right out of the can. In addition, the warmer ambient air on the aluminum can will cause the moisture in the air around the can to **condense** on the can.

The rise in temperature that happens to your beer in the sun causes its contents to **change state** from a **liquid to a vapor**, as well as the moisture in the air around the can to **change state** from a **vapor to a liquid**.

In a refrigeration evaporator coil, cool liquid refrigerant absorbs heat from the conditioned space to boil the liquid and cool the room, while also producing condensation on the surface of the coil.

Evaporate: pass off in vapor, give off moist

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Evaporator (Low) Side Circuit

After the refrigerant liquid/vapor mixture has been cooled by the condenser coil and changed to a mostly liquid, this mixture passes into the metering device and is aerosolized (pressure and temperature both drop) into the evaporator coil, cooling the mixture even further to 40-50°F.

Once the cold liquid/vapor mixture hits the evaporator coil, the mixture absorbs ambient heat, which boils the liquid into vapor and in turn cools the space. This change in state inside the coil also causes liquid condensation to form on the outside of the coil, which must be drained away from the unit.

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Super-Heat Effect

- At the end of the latent heat cycle, when the liquid has boiled completely into a vapor, sensible heat can continue. SUPERHEAT occurs when you heat vapor above its boiling point.
- If a refrigerant boils at 40°F in the evaporator, once it is all vapor you can continue to heat the vaporized refrigerant, elevating it to become a 50° vapor.
- This temperature increase above the boiling point is SUPERHEAT, which ensures that all liquid is turned to vapor before it reaches the compressor.

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Changing State is the KEY

Seeing your breath on a winter day, lamenting as your beer evaporates, and a sweaty beer can all illustrate what happens when water changes state. These state changes occur continuously in a refrigerant system.

- In the condenser circuit, hot outside air cools the super hot liquid/vapor mixture within the condenser coil, which condenses the mixture and turns it into a liquid (condensation) which is passed through the metering device to the evaporator circuit.
- In the evaporator circuit, the cold liquid/vapor in the coil absorbs the heat from the room (cooling the room) to heat/boil the refrigerant into a pure vapor (evaporation) which is passed through the compressor to the condenser circuit. **This cycle repeats continuously…**

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Characteristics of a Refrigerant

A refrigerant is a liquid substance that can be changed readily to a vapor by boiling it and then changed to a liquid by condensing it. The refrigerant must be able to make this change repeatedly without altering its characteristics. But every refrigerant changes state at different temperatures and requires different amounts of energy to change state.

The ideal refrigerant would be: non-corrosive, non-toxic, non-flammable, with no ozone depletion and no global warming potential. It should preferably be natural with well-studied and low environmental impact. It also needs to have: a **boiling point that is somewhat below the target temperature** (although boiling point can be adjusted by adjusting the pressure appropriately).

Wikipedia: Refrigerant

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A Pretty Good Refrigerant: R-410A

R-410A is an eco-friendly refrigerant (does not contribute to ozone depletion), and has the following characteristics:

- Absorbs and releases more heat than R-22
- Compressor runs cooler
- Functions at a higher pressure than R-22
- Uses synthetic oil which operates more efficiently than the R-22 lubricant, reducing wear and tear on the compressor

Units using R-410A will no longer be built after January 2025

The New Refrigerant: R-454B (Opteon XL41)

R-454B is a more eco-friendly refrigerant and has the following characteristics:

- Demonstrated increased energy efficiency of up to 5% compared to R-410A systems (lower pressure level and enhanced thermodynamic properties)
- Superior cooling capacity allows for smaller equipment sizes and lower refrigerant charge
- Lower Global Warming Potential (GWP) and Zero Ozone Depletion Potential (ODP)
- Slightly higher flammability rating than predecessors like R-410A, classified as an A2L

Thermophysical Properties of Refrigerants

Refrigerant	Boiling Point (°F)	Common Use
Water	212	Ambient above 100°F
R-454B	-58.9	HVAC, refrigerators, commercial
R-410A	-55.3	To be phased out in January 2025
R-12 (Freon)	-21.6	Banned in 1996
R-22	-41.3	Phased out
R-134a	-15.3	HVAC, refrigerators, cars
R-32	-62	Air conditioners
Propane (R-290)	-42	Refrigerators
Ammonia (R-717)	-28	Hockey rinks
CO_2 (R-744)	-108.4	Hockey rinks

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