Heat Pump Closed Loop Spray Dryer
Engineering Considerations

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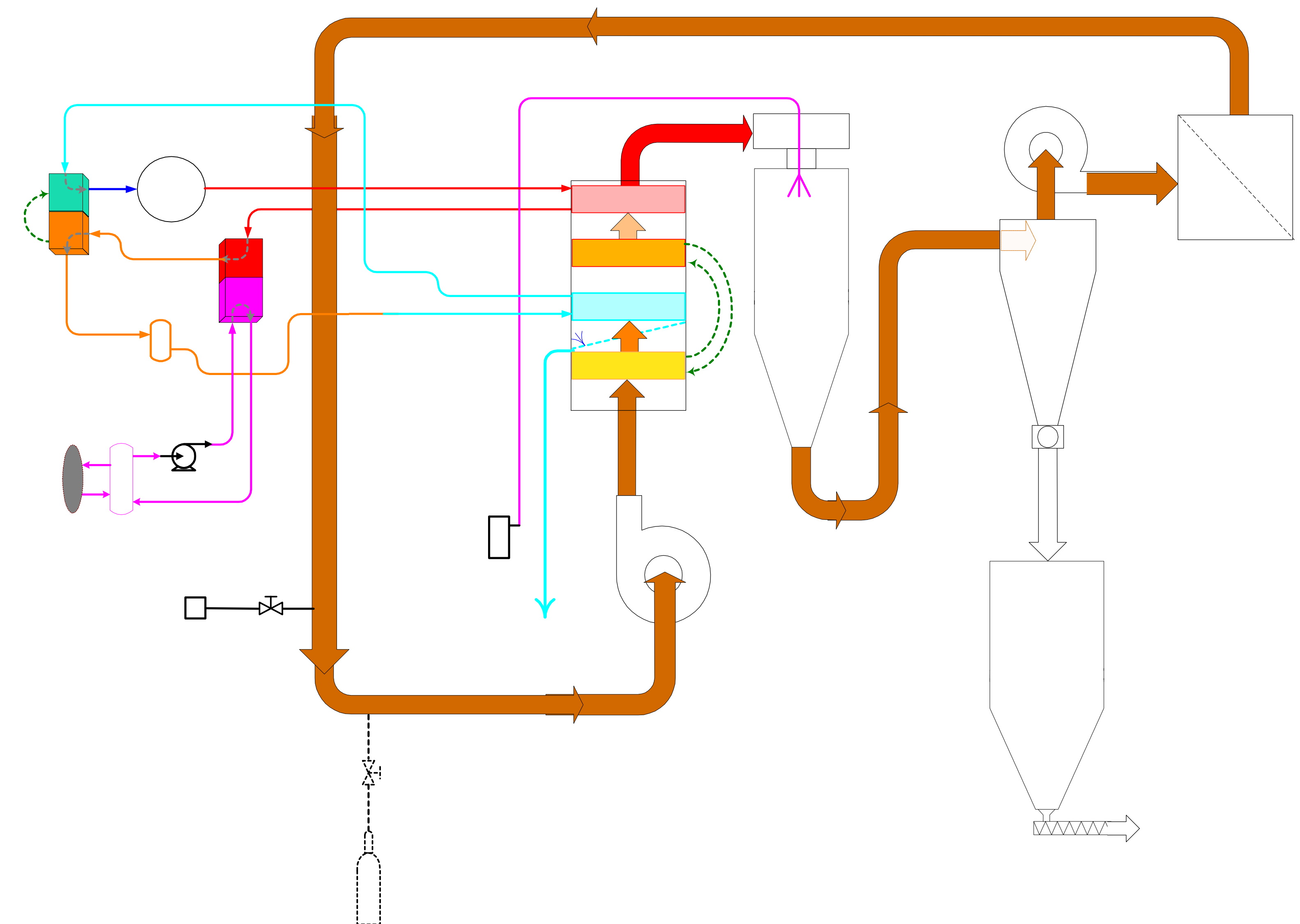
Base Heat Pump Overview

External Process Heat

Air Economizer

Refrigerant Economizer

Inert Drying Gas



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Base Heat Pump Overview

Inside the drying chamber, the heat pump dryer functions in the same way as a conventional dryer. Heated dry air enters the drying chamber, extracts moisture from the product, and then leaves the drying chamber, cooler and wetter.

Instead of continually heating ambient air and then venting it, the heat pump dryer dries and warms the air from the drying chamber exhaust, and returns it to the drying chamber. Useful heat is recovered and reused instead of being vented out of the building.

This is accomplished by connecting the drying chamber exhaust back to the drying chamber inlet, in a closed loop.

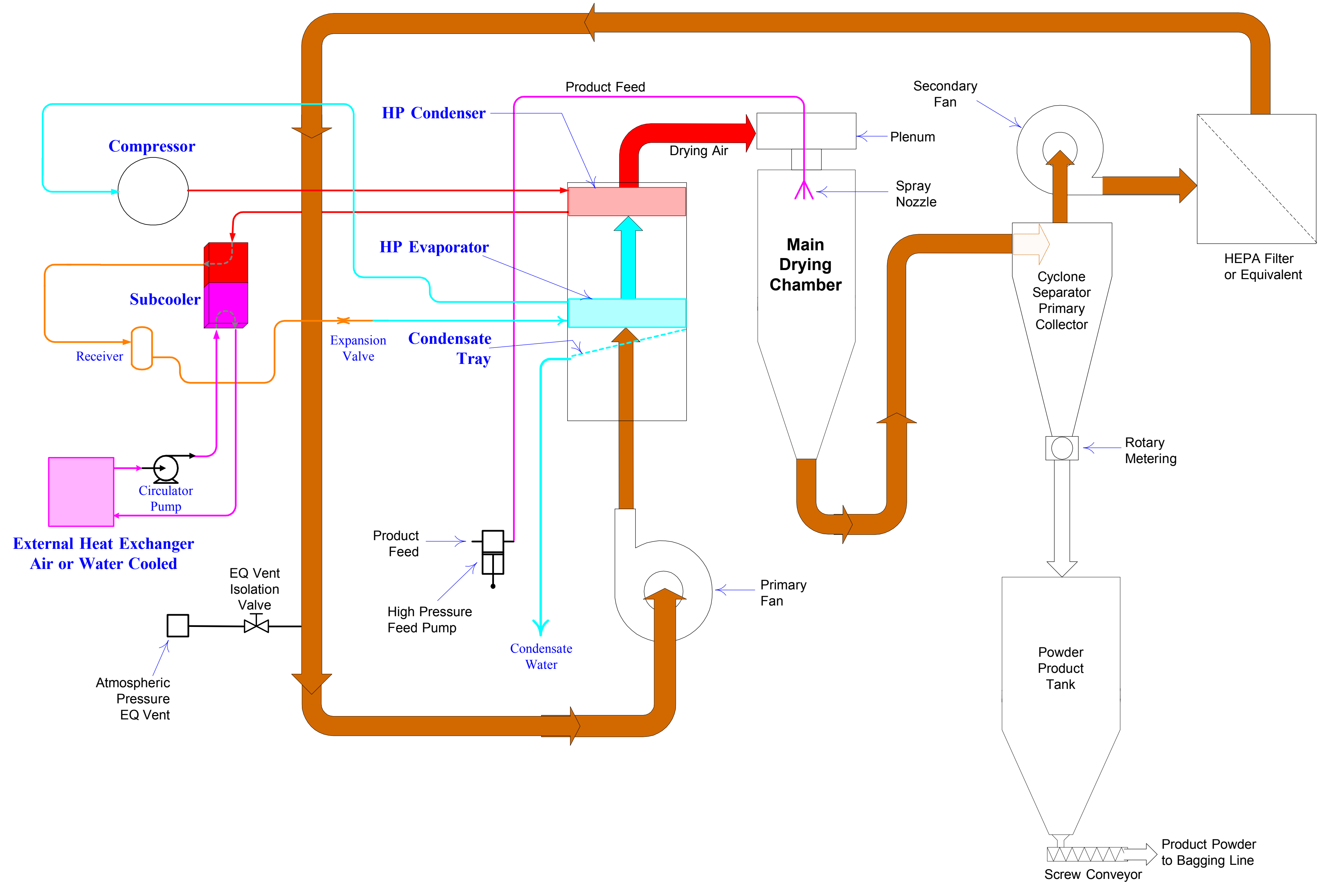
The heat pump is configured as a dehumidifier, and removes entrained moisture from wet air exiting the drying chamber, reheats the air, and returns it to the drying chamber.

Air entering the evaporator is chilled to its dew point. Most of the entrained moisture condenses out onto the condensate tray.

The air then passes through the condenser, which heats the air to a moderate drying temperature of 160^{o} ~ 180^{o} F, at ~2% rH.

The subcooler extracts heat equal to the compressor power consumption. This is necessary because unlike an air conditioner, which releases excess heat through its outdoor condenser, the dryer is a closed loop.

The subcooler may be cooled by an external heat exchanger, which in turn may be air or water cooled, as desired.



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External Process Heat

The heat pump compressor energy consumption, for a typical industrial dairy spray dryer, is on the order of 4,100,000 BTU/Hr, or 1,200 KW.

All heat pumps reject heat equal to the compressor energy consumption.

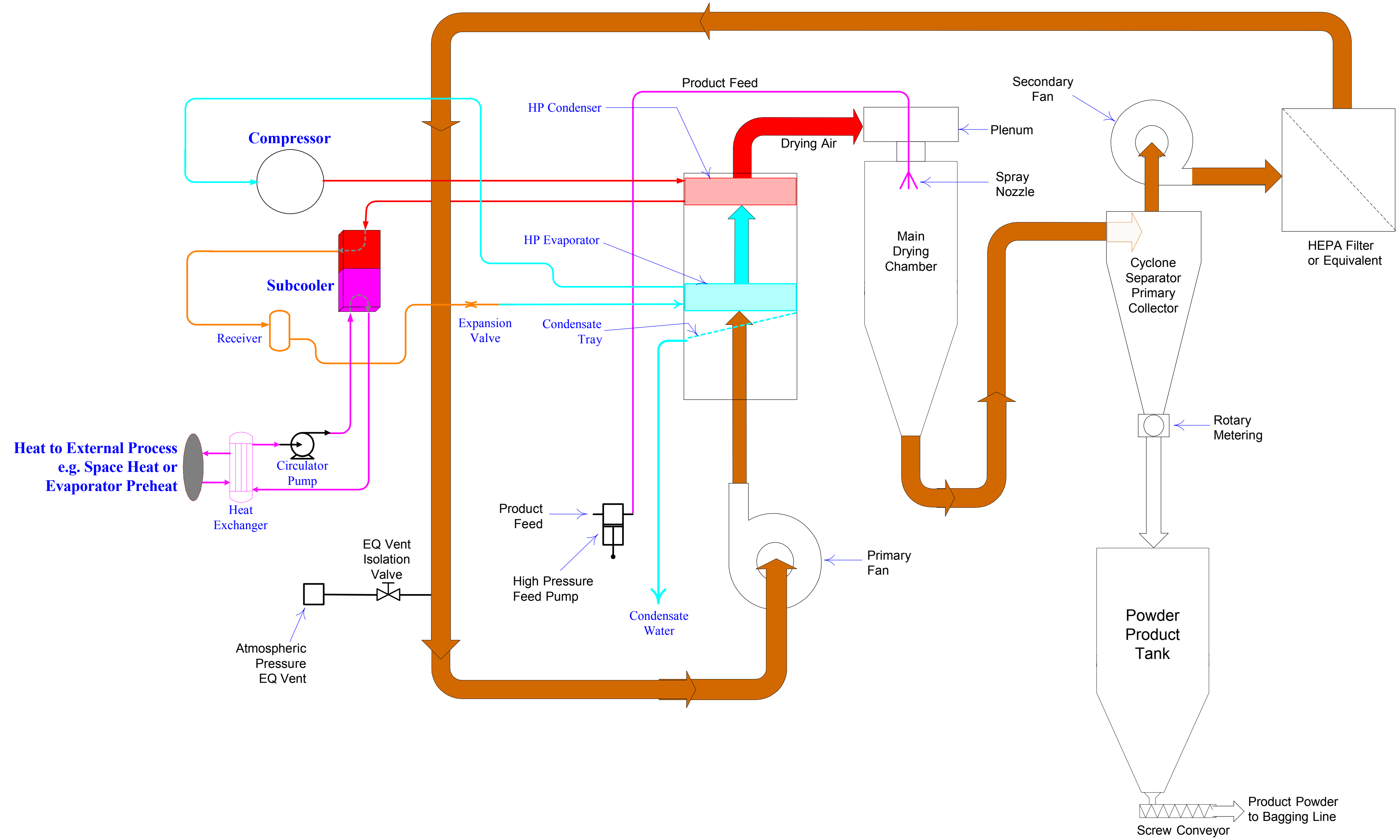
It is entirely practical to reject this heat to the atmosphere, via an evaporative chiller or the like.

It is however, significantly more efficient to use this heat for another creamery process, such as space heat, or preheating an evaporator stage.

This approach will effectively eliminate energy consumption and cost equal to the heat pump energy consumption.

An external proccess heat exchanger can be used to supply a creamery process, even if it is a significant distance from the heat pump, e.g., in an adjacent building.

If this heat is used for an external process, the heat pump net energy consumption is zero.



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Air Economizer

In a pure dehumidification application, in which cooling is not required, the drying air must nevertheless be cooled to its dewpoint before mosture condensation commences.

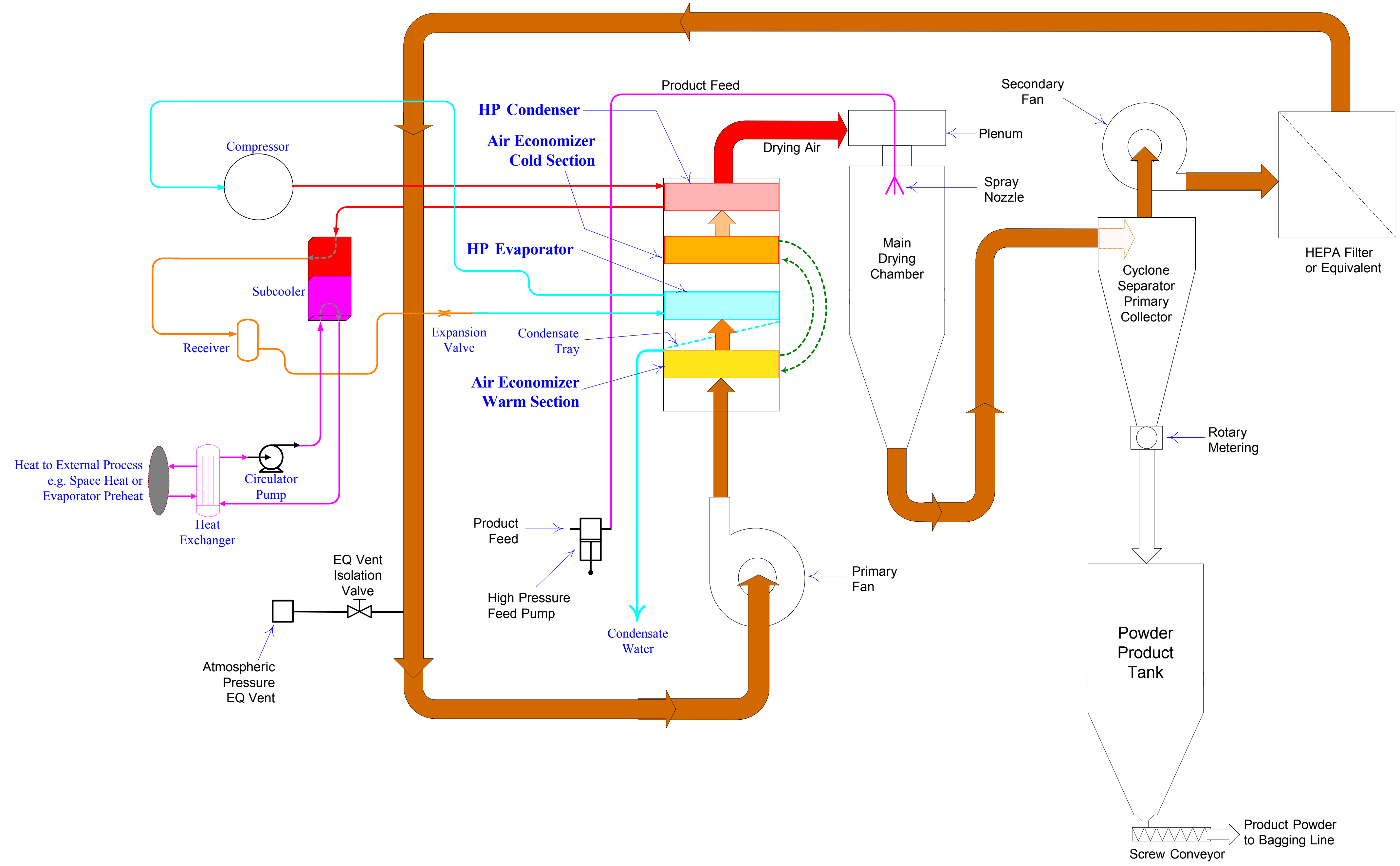
As a result, the evaporator has two cooling loads. The first is sensible heat, which must be removed to cool the air. The second is the true target, the heat of condensation of the entrained water.

As a result, both the evaporator coil and the compresor must be large enough to remove the sum of the sensible heat *and* the heat of condensation.

The air economizer eliminates this issue, by passively transporting heat, from air entering the evaporator, to air exiting the evaporator.

The air economizer effectively lowers the incoming air temperature to the dew point, with no energy consumption, and raises the air temperature entering the condenser.

This permits using a smaller evaporator, condenser, and compressor, for the same drying capacity; reducing capital cost, and substantially improving efficiency.



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Refrigerant Economizer

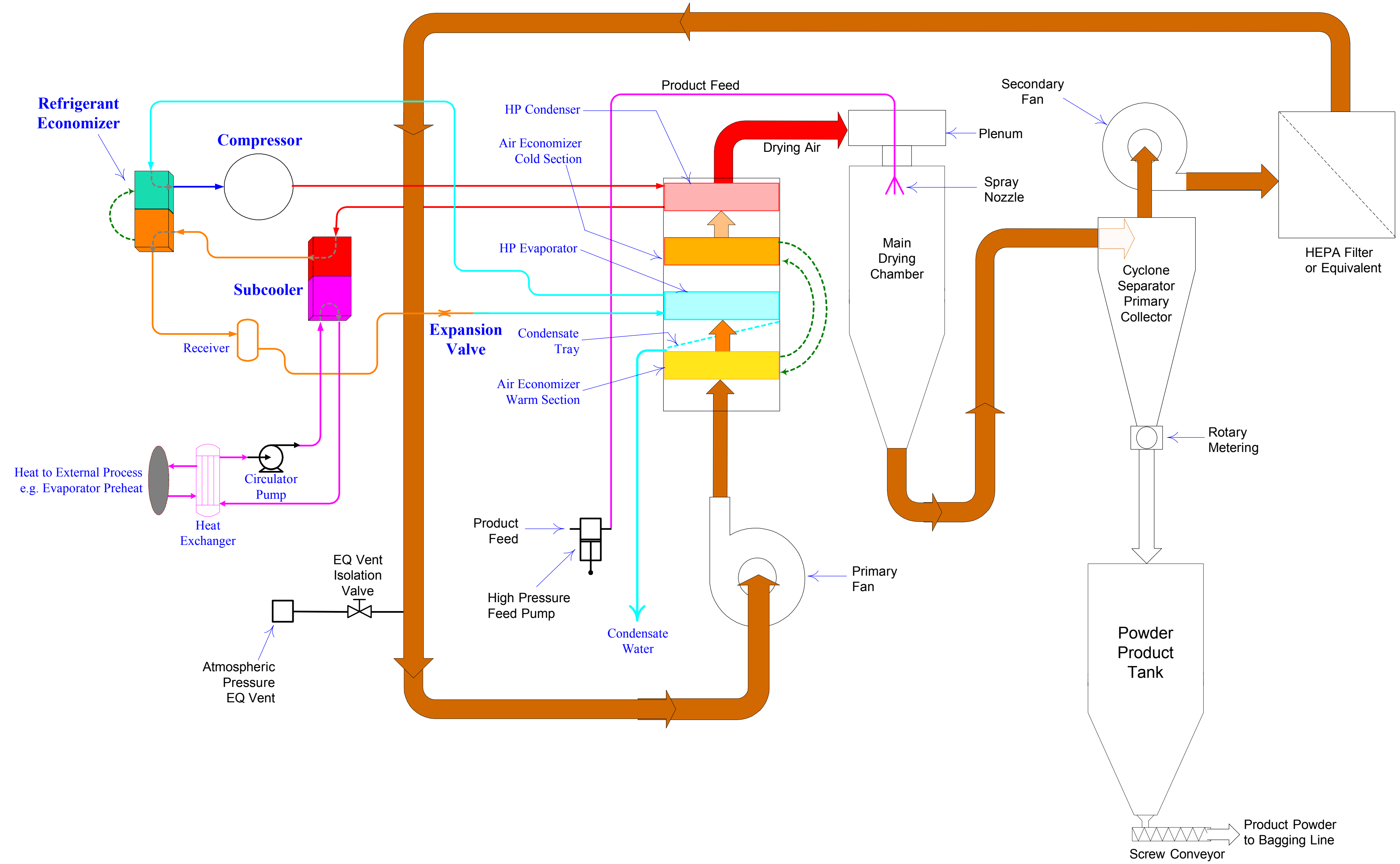
Refrigerant economizers are commonly used in conventional heat pump applications, such as air conditioning. It behaves similarly in the spray dryer.

Subcooler discharge refrigerant gives up some heat to the compressor suction refrigerant, via the refrigerant economizer.

This modestly cools the refrigerant entering the expansion valve, slightly reducing its vapor quality. This slightly increases the evaporator capacity.

It also modestly heats the suction gas, slightly raising the compressor suction pressure.

The aggregate effect typically improves overall heat pump efficiency by about 10%.



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Inert Drying Gas

As the heat pump dryer comprises a closed drying air loop, a simple equalizer vent is provided. This keeps the static pressure in the air circuit nominally equal to the ambient atmospheric pressure.

An equalizer vent isolation valve is provided to allow closing the EQ vent as needed, for maintenance or the like.

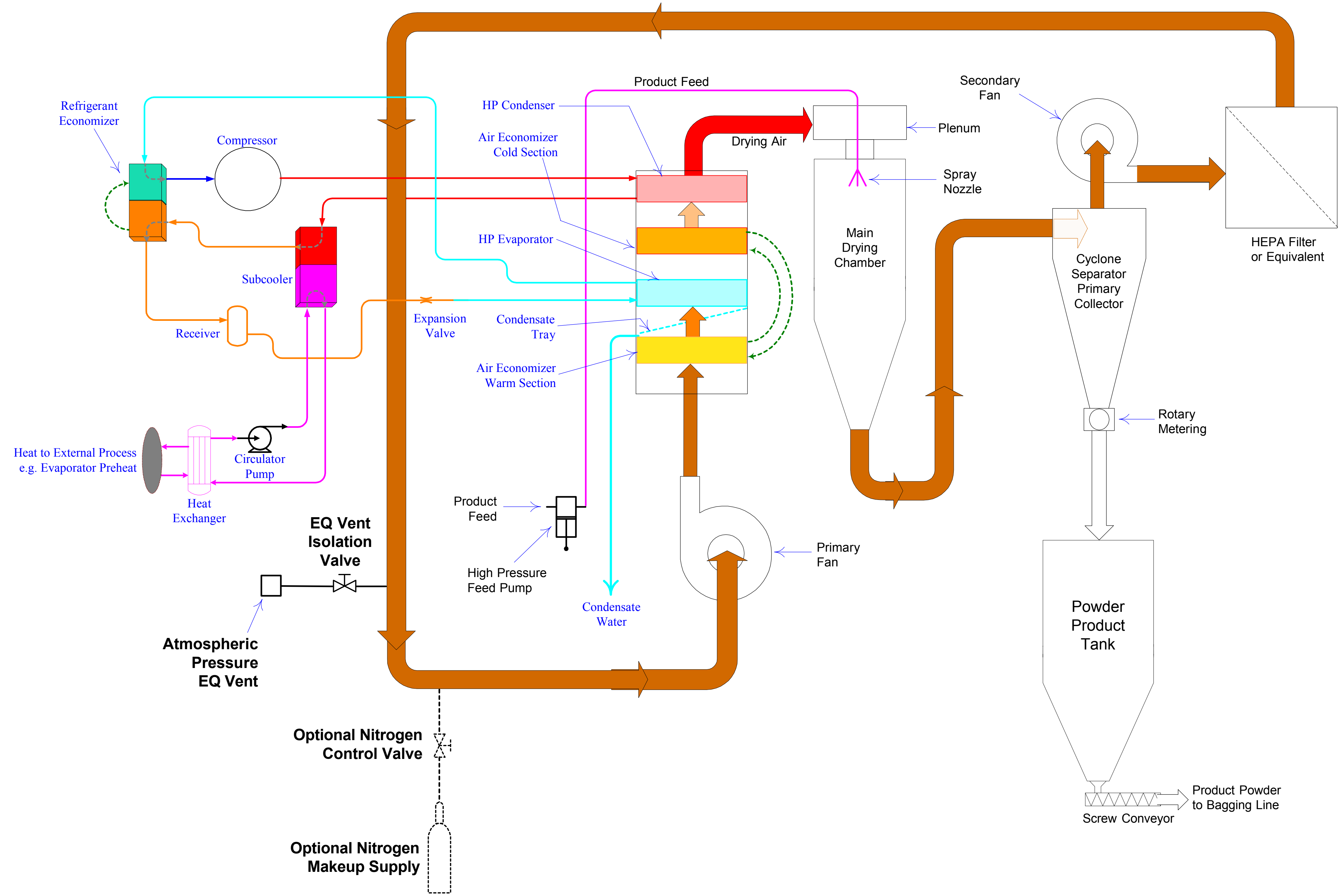
While the standard configuration for drying dairy products uses air as the drying gas, the heat pump closed loop dryer is entirely compatible with inert or zero oxygen drying gas, such as nitrogen.

For an inert gas application, a suitable makeup gas supply may be connected.

The oxygen level of the drying gas can be monitored, and automatically controlled, by venting drying gas as needed via the EQ vent isolation valve, and adding makeup gas as needed.

Inert drying gas is a staple of the pharmaceutical sector.

It also presents an opportunity to investigate potential benefits for dairy product drying.



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