

- Provides lower operating temperatures for new products
- Improves temperature control
- Increases yield and product selectivity
- Prevents runaway reactions
- Improves process reliability
- Shortens batch time
- Lowers capital and maintenance costs
- Prevents freezing and other process disruptions

Cryogenic liquid nitrogen has gained popularity as the refrigeration of choice for cooling low temperature reactions of chiral chemicals and other low-temperature chemical synthesis applications. The advantages of using liquid nitrogen include:

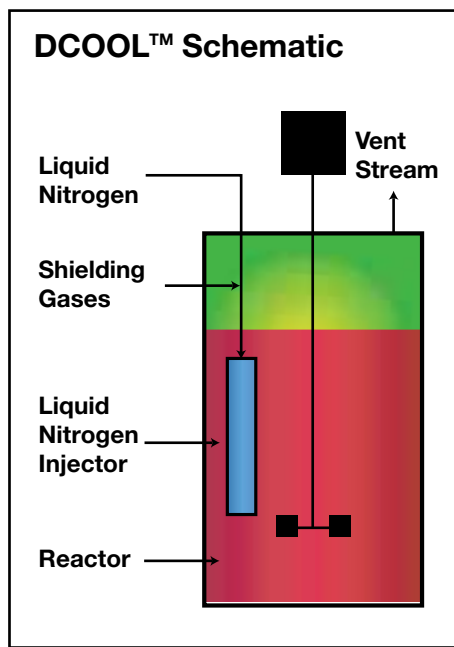
- flexibility in refrigeration loading
- low-capital requirement
- low-maintenance cost
- fast-quenching cooling rate
- coldest operating temperatures
- improved reliability
- environmentally-friendly (alternative to freon-based systems)

Because of the extreme low temperature of liquid nitrogen, freezing is the biggest roadblock to its wider adaptation. Praxair has developed non-freezing direct and indirect contact techniques for transferring refrigeration from liquid nitrogen to

the reactants. Praxair's patented shielding gas and buffering technologies are used to prevent icing during heat exchange with cryogenic nitrogen. Without icing, product purity and process reliability can be greatly improved.

The three main cryogenic reactor cooling methods include:

- **Direct Contact Cooling System** — a direct injection cooling technique utilizing a proprietary non-freezing liquid nitrogen injector.
- **Non-Freezing Heat Exchanger System** — an indirect contact cooling technique utilizing a proprietary non-freezing heat exchanger.
- **Semi-Indirect Cooling System** — A semi-indirect cooling technique in which liquid nitrogen flows through a reactor coil and is controlled through a programmable controller.

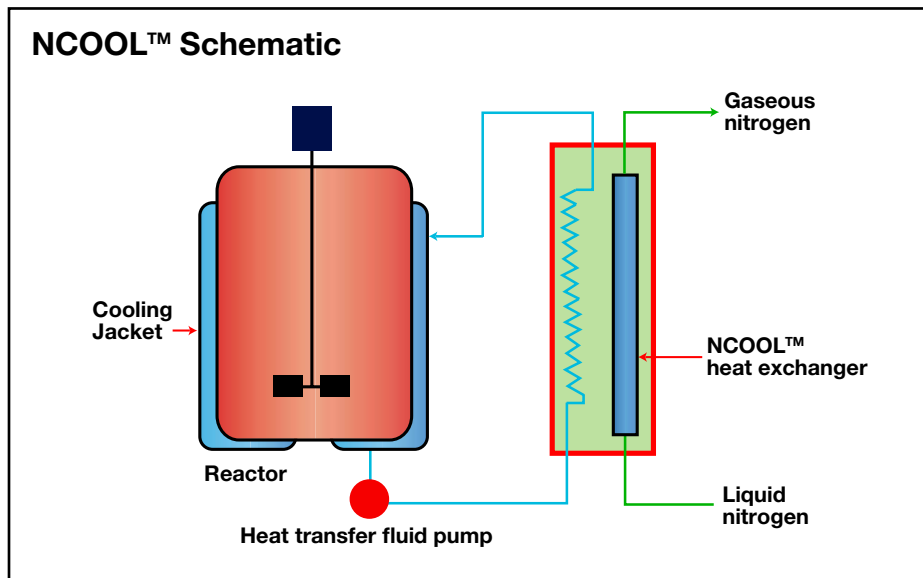


Direct Contact Cooling System (DCOOL™)

Praxair's Direct Contact Cooling System is primarily used to inject liquid nitrogen directly into process fluids or reactants. Direct contact cooling has the advantage of fast response and precise temperature control. It can also be used for direct contact cooling of heat transfer fluids. In this case, the cryogenic nitrogen is injected directly into a tank of heat transfer fluid, which will subsequently be re-circulated through a reactor or other process equipment.

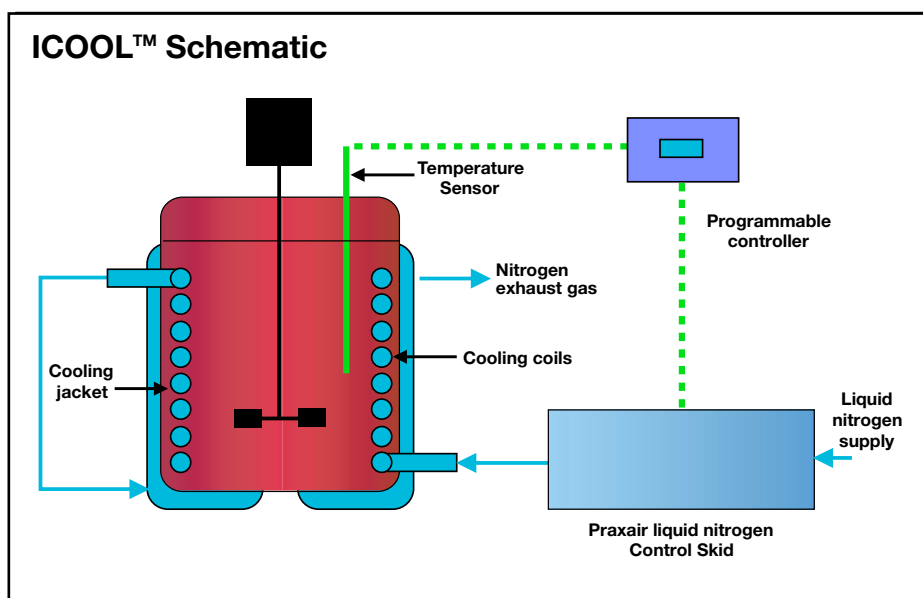
Non-Freezing Heat Exchanger System (NCOOL™)

Praxair's Non-Freezing Heat Exchanger System is used to facilitate the heat transfer between liquid nitrogen and process or heat transfer fluids without freezing. Since the liquid nitrogen is used indirectly, nitrogen gas may be available for other uses in the plant. Specially selected heat transfer fluids are used so that reactors or process equipment can operate at a temperature as low as -190 F (-125 C).



Semi-Indirect Contact Cooling System (ICOOL™)

Praxair's Semi-Indirect Contact Cooling System (ICOOL™) is used to facilitate heat transfer by a controlled flow of liquid nitrogen through reactor cooling coils. A programmable controller that monitors the temperature of the reactor will operate a nitrogen flow control skid. The liquid nitrogen will absorb heat and be vaporized in the reactor's jacketing and internal cooling coils. Gaseous nitrogen will be discharged from the reactor cooling system and may be available for other uses in the plant.



Please call **1-800-PRAXAIR** or contact your local account representative to learn more about the advantages of our cryogenic reactor cooling technologies.



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