

## Cryogenic Turbine Expanders

**CRYODYNAMICS<sup>®</sup>**  
CRYOGENIC EXPANDERS FOR LIQUEFIED GAS

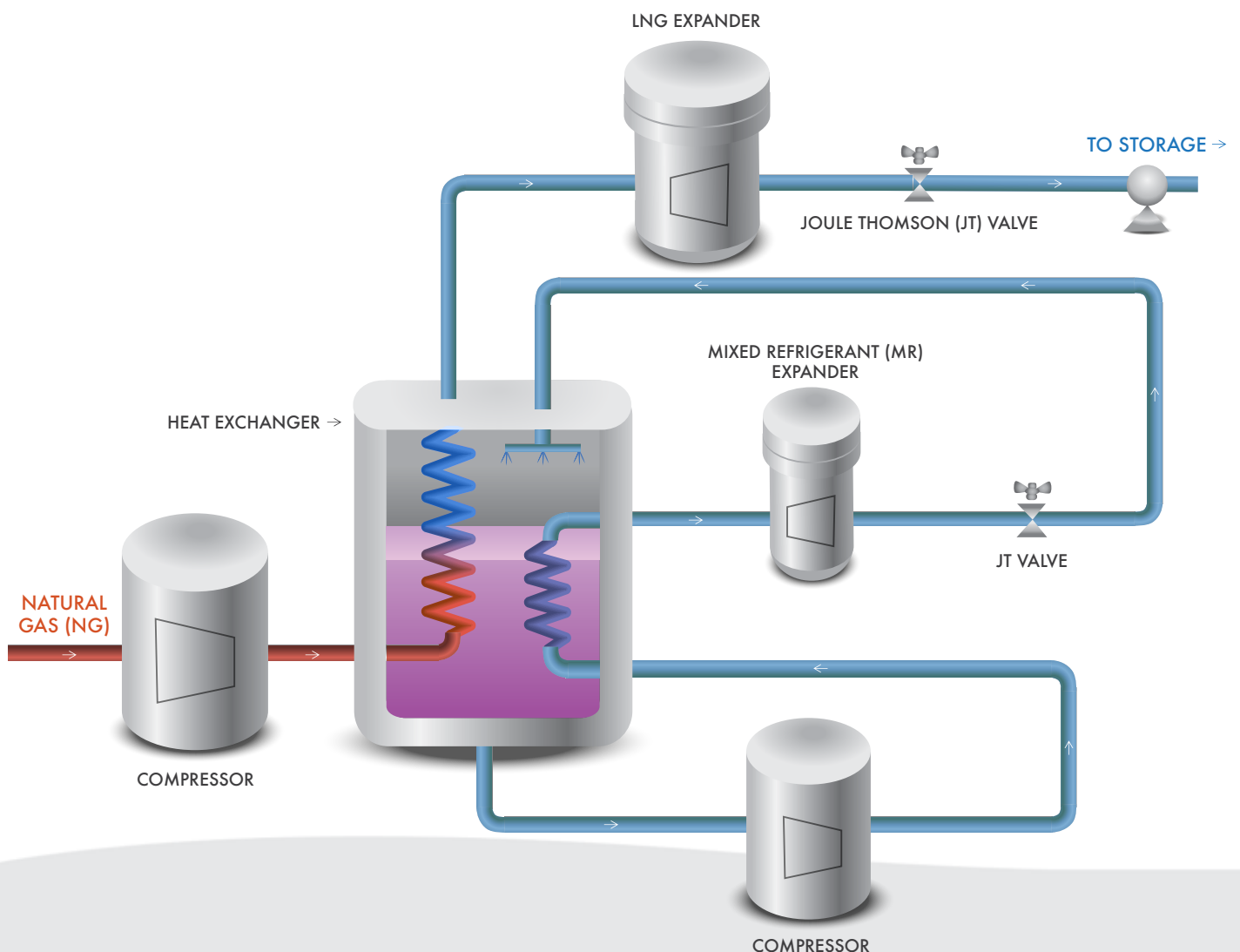
# WHO WE ARE

## Elliott Group, Cryodynamic Products

Elliott Group, Cryodynamic Products is the premier manufacturer of cryogenic pumps and expanders for the many segments and applications of the worldwide liquefied gas industry. With over 40 years of continuous engineering advancement and the largest cryogenic test stand in the world, Cryodynamic Products is the only manufacturer of its kind with the knowledge and expertise to provide the most complete catalog of both standard and custom cryogenic pump equipment in the world. Cryodynamics® products incorporate the highest caliber of quality, engineering and technological advancement, delivering the most dependable and efficient equipment you can buy.



## Expanders in the Liquefaction Process



# LIQUEFACTION

The liquefaction process takes gas and cyclically compresses and cools it until liquefied, resulting in very high pressure that is not suitable for storage or transport. Typically, the fluid is expanded through a Joule-Thomson (JT) valve to lower the pressure. While using a JT valve, there is no enthalpy change (no energy change) but there is always some degree of subsequent vaporization that is either lost or returned to the liquefaction process.

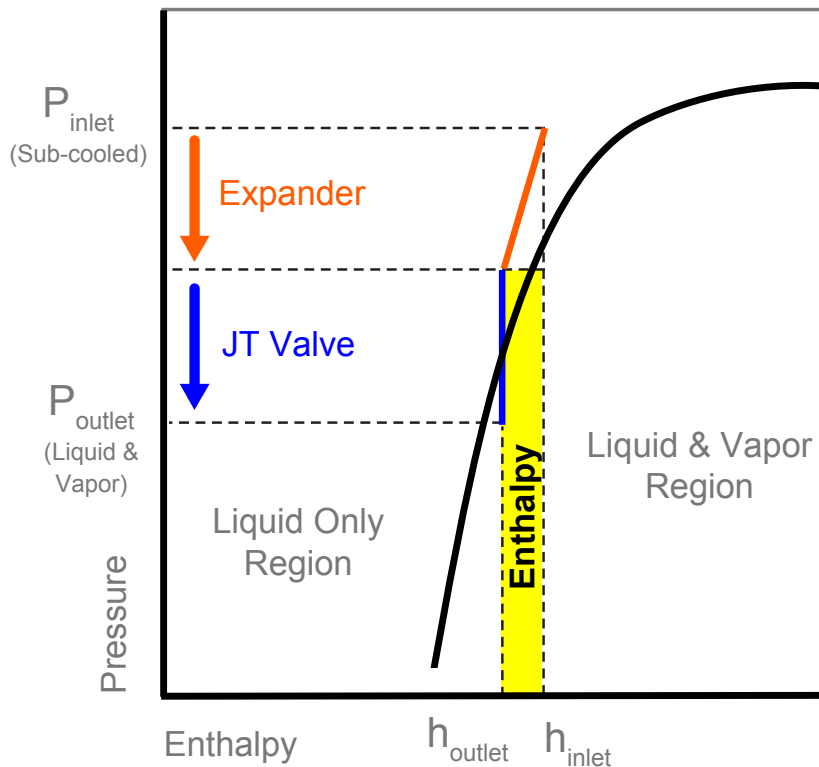
- By including a liquid cryogenic turbine expander in the liquefaction process, we can also achieve:
- The same pressure drop as a JT valve.
- Power recovery as a benefit from the enthalpy change.
- Reduced boil-off gas from the let-down process, resulting in higher liquefaction production and overall efficiency.
- Incredible investment return. For every metric tonne per annum (MTPA) in the process, an expander can provide an estimated return of up to \$17M per year. Investment payback may be achieved in months, sometimes weeks.
- Other additional benefits such as reduced carbon emissions.



*Typical JT Valve*

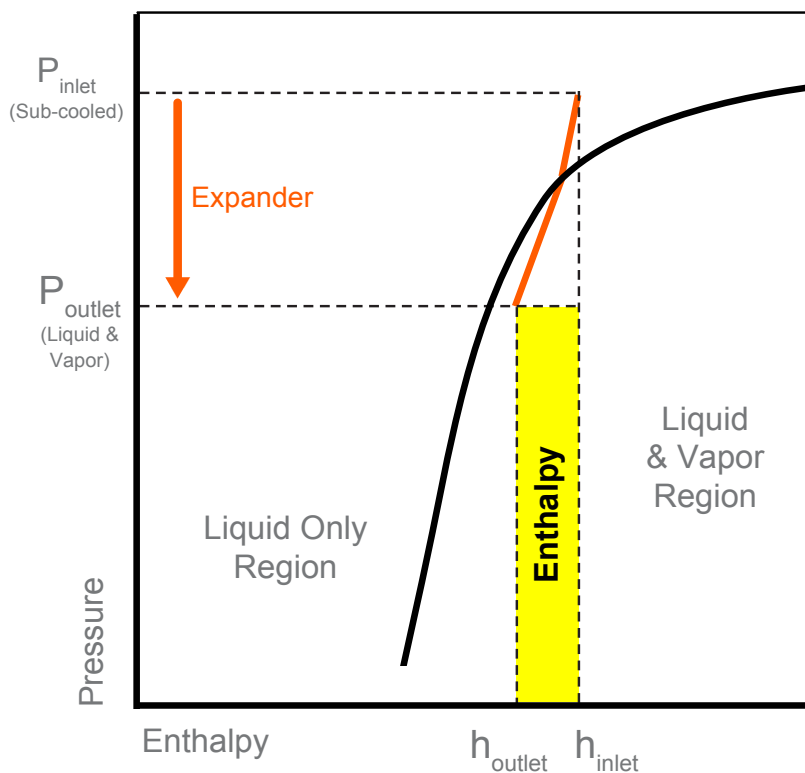
# EXPANSION

## SINGLE-PHASE EXPANDER WITH JT VALVE



- Lowers enthalpy (liquid energy extracted as electrical power).
- Operates in the liquid only region to avoid vapor.
- Bulk of expansion by expander.
- Remaining expansion and phase change by JT valve.

## TWO-PHASE EXPANDER, NO JT VALVE



- Lowers enthalpy (liquid and vapor energy extracted as electrical power).
- Operates in liquid & vapor region by controlling phase change with special hydraulic components.
- Performs all expansion, without a JT valve, to improve overall plant efficiency.
- Greater benefit than single-phase due to greater expansion range.

# EXPANSION EVOLUTION

## Highlights

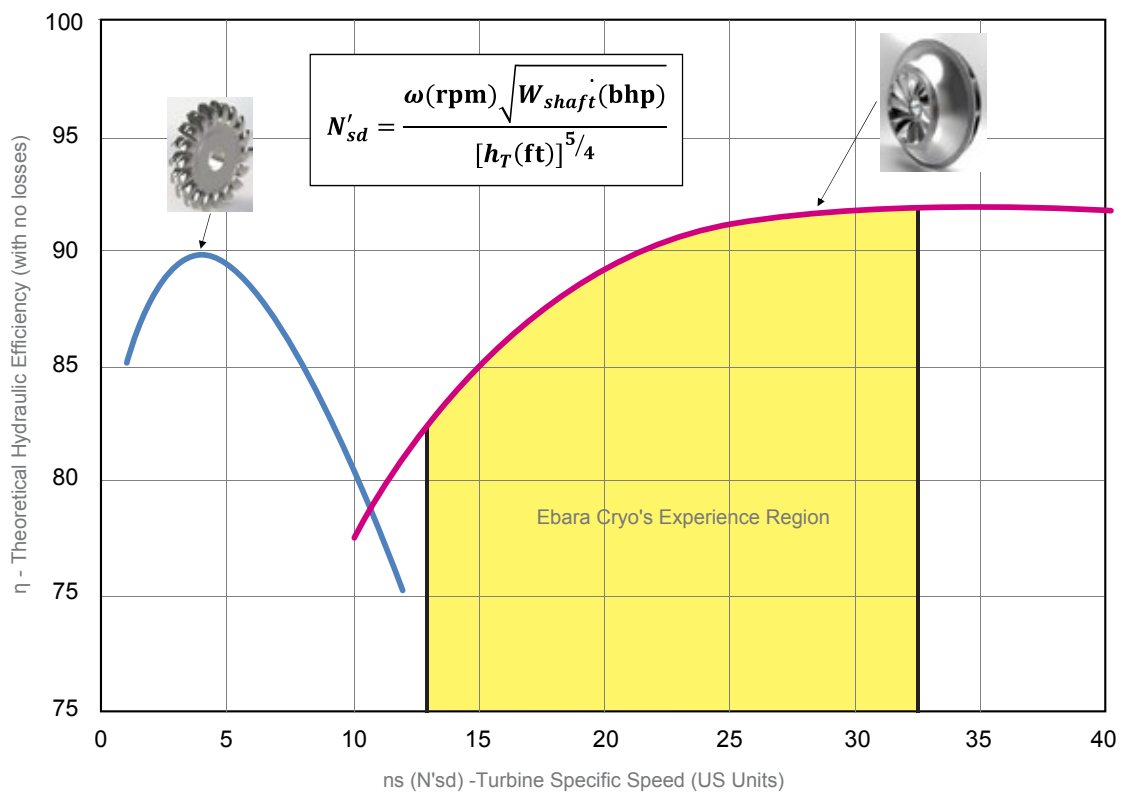
- 1997: Original, First Expander
- 2001: First Two-Phase Installation
- 2008: First Two-Phase Tandem Installation
- 2011: First Floating Application:  
Shell Prelude
- Cryodynamics expanders are available as large as 3.3 megawatt.
- Over 150 expanders are installed around the world.



Courtesy of Photographic Services/Shell International Limited

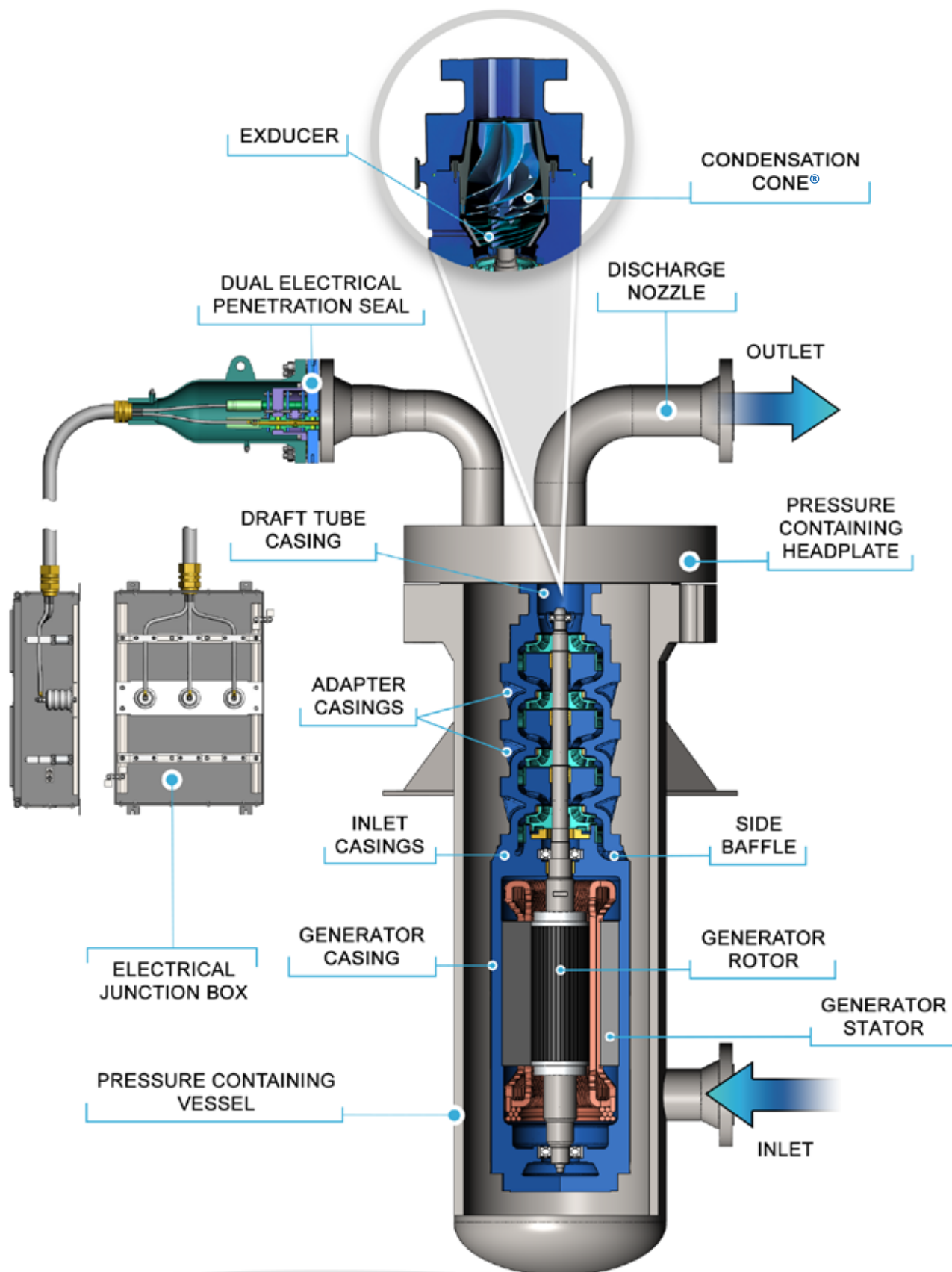
## TURBINE (POWER) SPECIFIC SPEED MAP (SPECIFIC GRAVITY = 1)

— Impluse  
— Francis



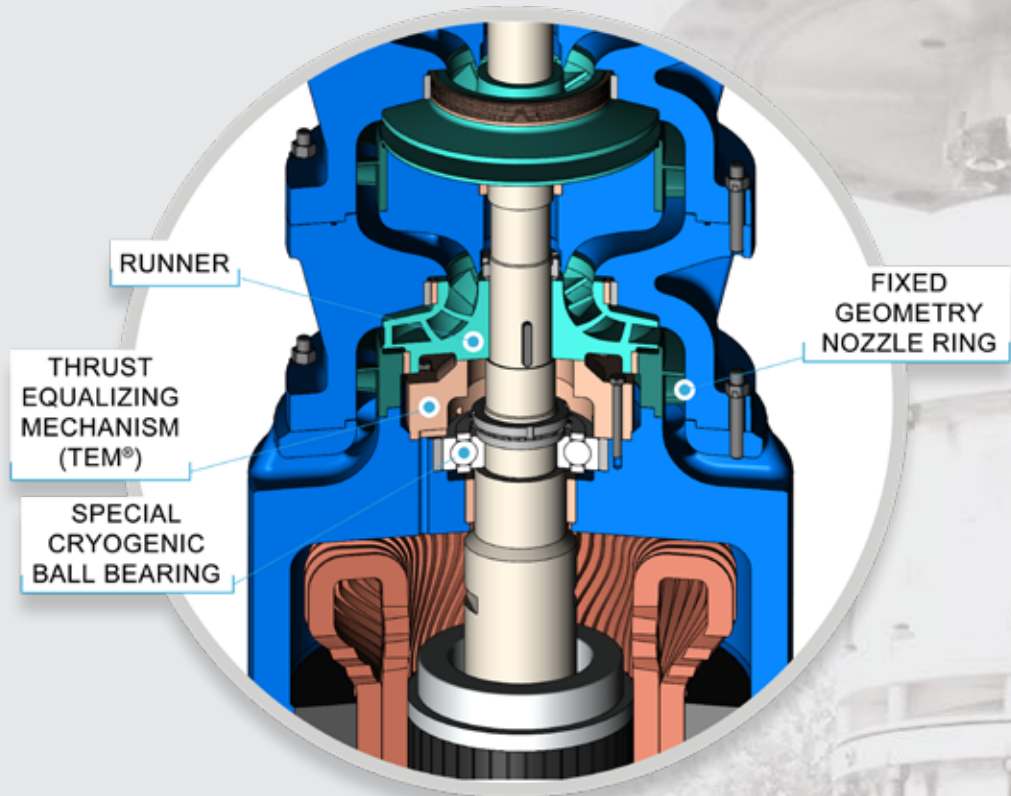
# DESIGN

## TWO-PHASE DISCHARGE COMPONENTS



SINGLE PHASE

# MAIN BEARING REGION



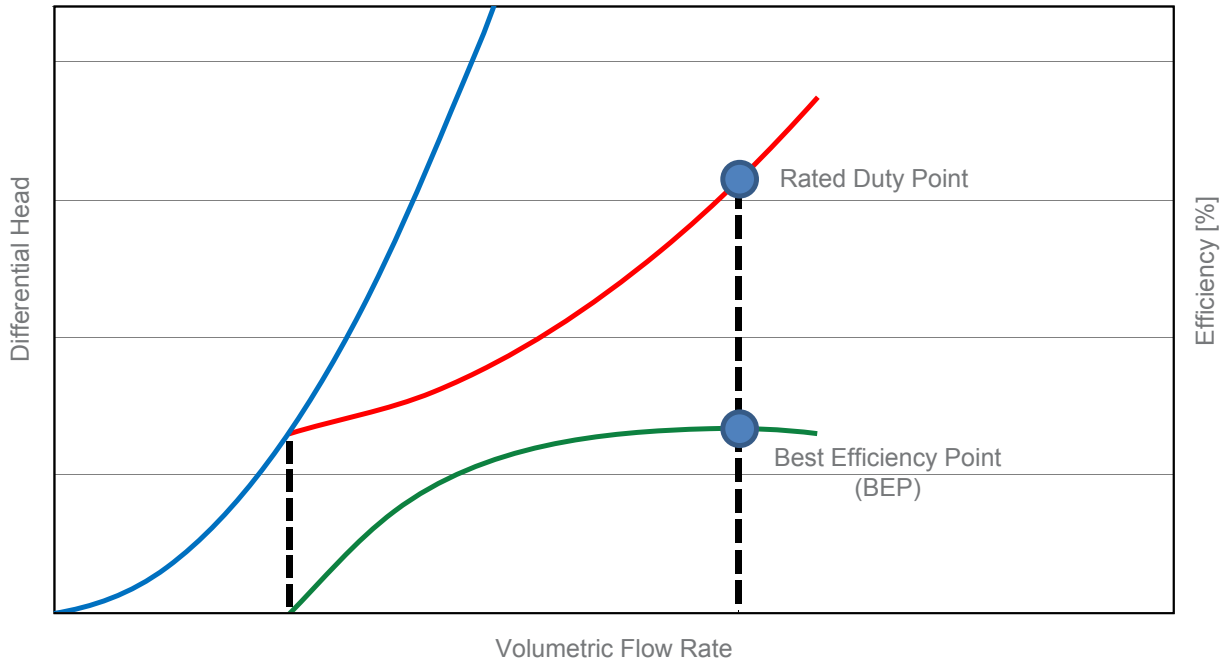
## Design Features

- Within an upward flow design, high-pressure fluid enters the vessel through a side inlet nozzle, then feeds the expander through side-baffles, and finally discharges upward through the hydraulic stages and the headplate discharge nozzle.
- In an upward flow configuration, debris collects at the bottom of the pressure vessel prior to entering the machine for improved reliability. This area can be cleaned during periodic maintenance.
- For two-phase expanders, the upward configuration follows the natural buoyancy of gas formation, so the flow and buoyancy move in the same direction. Any bubbles caused by vaporization travel with the process flow of the liquid through the expander, completely eliminating any concerns about bearing lubrication and axial balancing.
- Upward flow expanders are under external pressure, eliminating the need for double-shell designs and redundant casings. The pressure vessel, already designed at maximum working pressure for safety, functions as the primary containment housing. This allows for reduced casing size and thickness, providing lower overall weight, a reduced vessel diameter, and a more compact design.
- The smaller, lighter design gives the customer more flexibility and convenience with installation and periodic maintenance, particularly in marine or retrofit applications where weight and space are important considerations.

# SINGLE SPEED & EFFICIENCY

## SINGLE SPEED & EFFICIENCY

- Zero Torque Head
- Fixed Speed Curve
- Efficiency



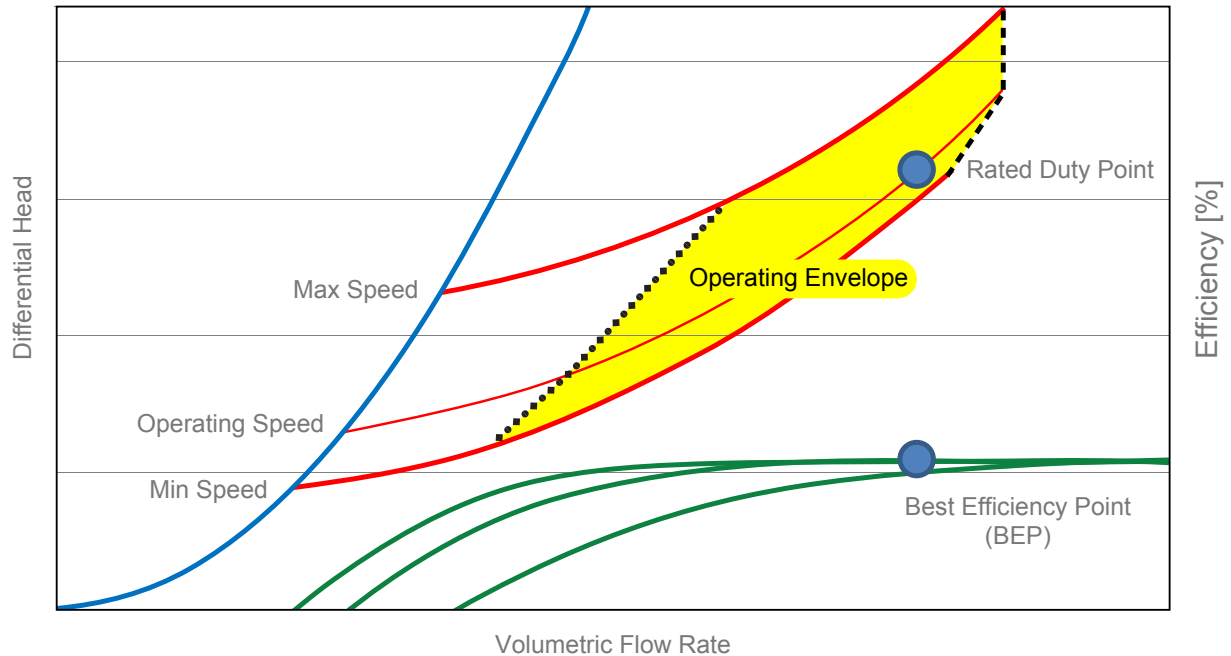
## Min & Max Speed Limits

- The critical speed of any rotating equipment occurs when rotational speed coincides with the natural frequency, causing destructive vibration and catastrophic failure.
- Expander maximum operational speed always remains below the first critical speed.
- Using rotordynamic analysis, all critical speeds are established and calculated during the design process to ensure safe operation and long-term machine reliability.

# MULTIPLE SPEED

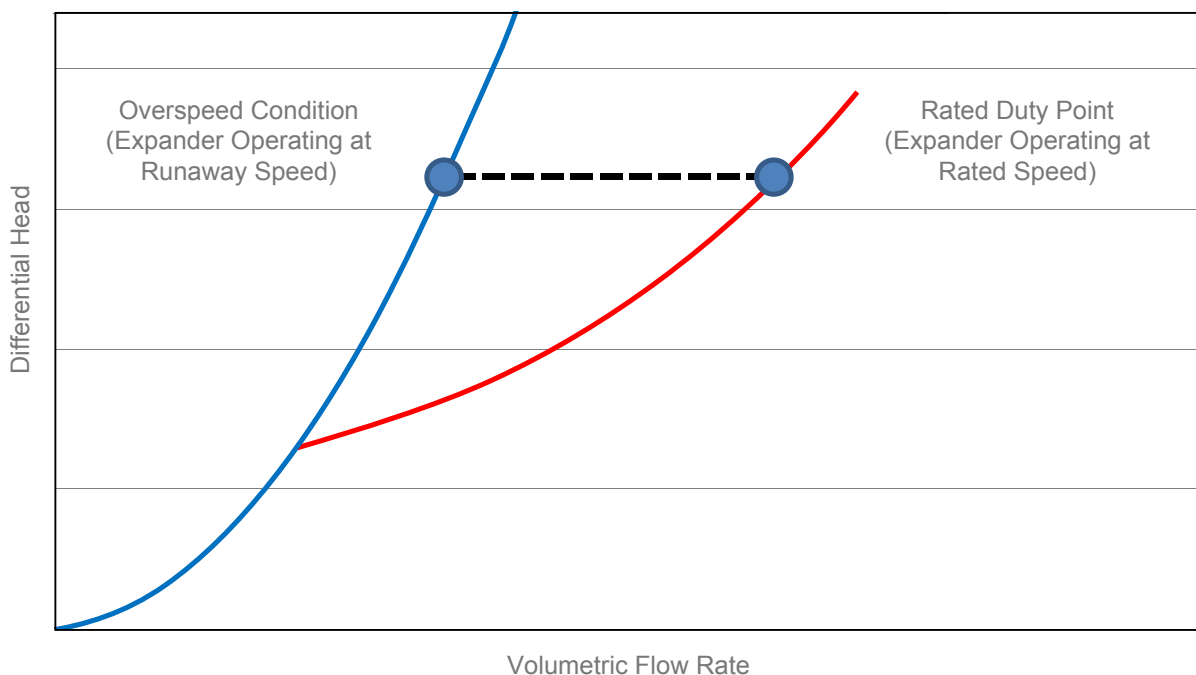
## MULTIPLE SPEED PERFORMANCE

- Min Flow (65% BEP)
- ..... Max Flow (Generator Limit)



## OVERSPEED CONDITION

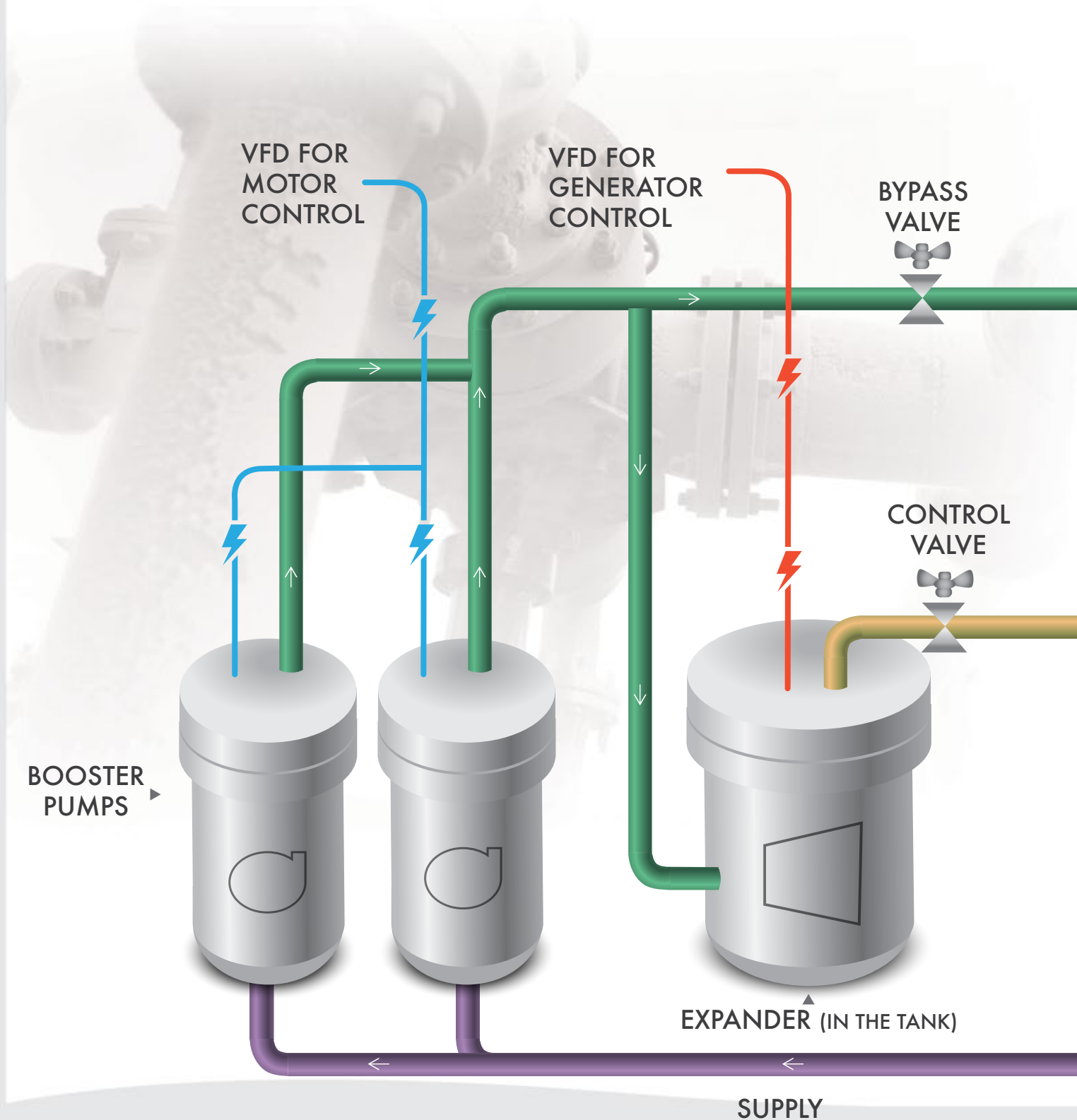
- Zero Torque Head
- Fixed Speed Curve



# EXPANDER TEST LOOP

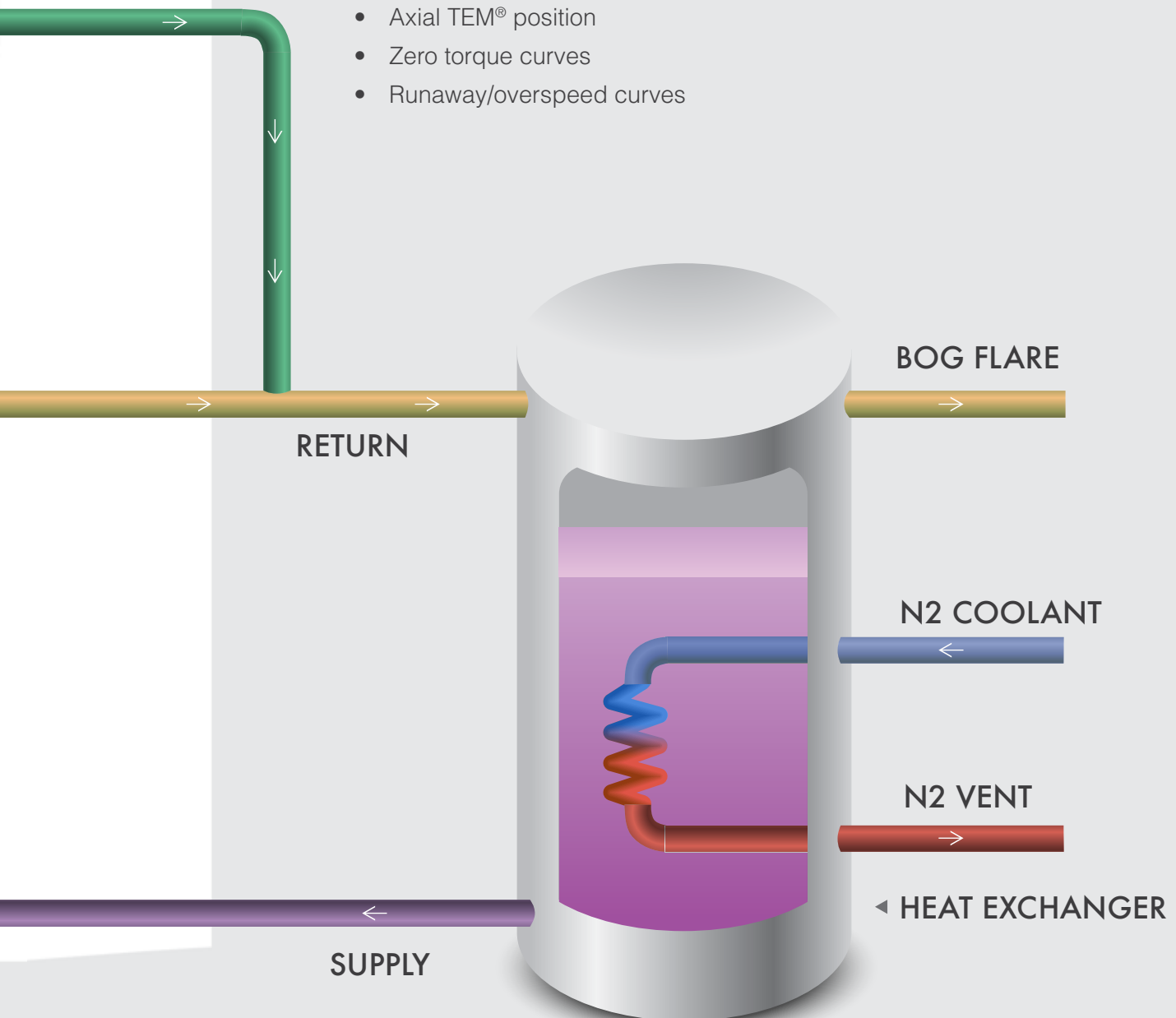
## Test Facility

The Cryodynamic Products test facility includes several test vessels and heat exchangers that can be configured to test a full range of cryogenic equipment. With five pump test tanks and one dedicated liquid expander vessel, the test stand can evaluate up to six different pieces of equipment each day, greatly increasing throughput and decreasing the total time spent to complete a project.



## Testing Scope

- Each expander receives full-scale testing at customer duty points.
- Testing includes a string test of the customer's variable frequency drive (VFD) power control system.
- The following items are recorded and monitored during testing using Electronic Data Acquisition (DAQ):
  - Power/voltage/current/frequency at the output of the generator
  - Inlet liquid temperature
  - Outlet liquid temperature
  - Differential pressure
  - Flow rate (derived from delta P across an orifice plate)
  - Speed
  - Vibration (overall and spectral)
  - Noise (recorded manually during endurance test)
  - Axial TEM® position
  - Zero torque curves
  - Runaway/overspeed curves



# FINANCIAL BENEFITS

## Estimated Return on Investment

### Single-Phase

mmtpa	4	\$33,786,000	\$49,917,000	\$66,049,000	\$82,181,000
	3	\$25,339,000	\$37,437,000	\$49,537,000	\$61,635,000
	2	\$16,893,000	\$24,959,000	\$33,024,000	\$41,090,000
	1	\$8,446,000	\$12,479,000	\$16,512,000	\$20,545,000
Electricity (4) kW Hours		\$0.08	\$0.09	\$0.10	\$0.11
mmbtu		\$4.00	\$6.00	\$8.00	\$10.00

### Two-Phase

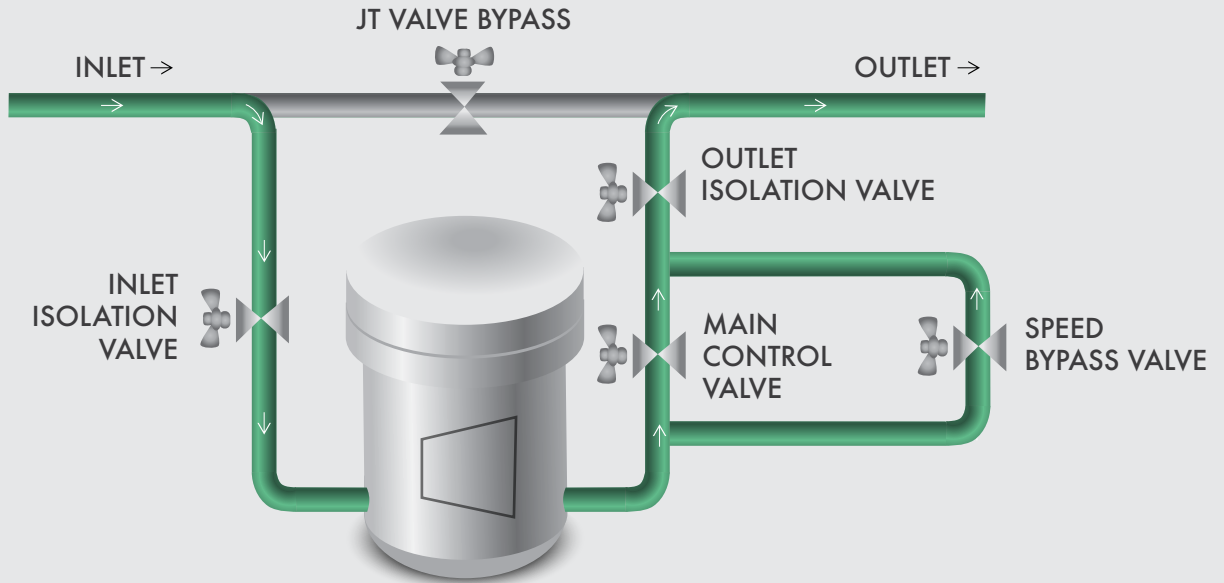
mmtpa	4	\$36,352,000	\$53,710,000	\$71,067,000	\$88,424,000
	3	\$27,264,000	\$40,281,000	\$53,300,000	\$66,318,000
	2	\$18,176,000	\$26,854,000	\$35,533,000	\$44,211,000
	1	\$9,088,000	\$13,427,000	\$17,766,000	\$22,106,000
Electricity (4) kW Hours		\$0.08	\$0.09	\$0.10	\$0.11
mmbtu		\$4.00	\$6.00	\$8.00	\$10.00



- Expanders increase production of liquefied gas by ~20 tonnes per day.
- Each megawatt of generated power increases the LNG production by ~60,000 tonnes per year.
- Expanders remove otherwise wasted energy from the LNG stream, decreasing the total power consumption and further cooling the cryogenic fluid.

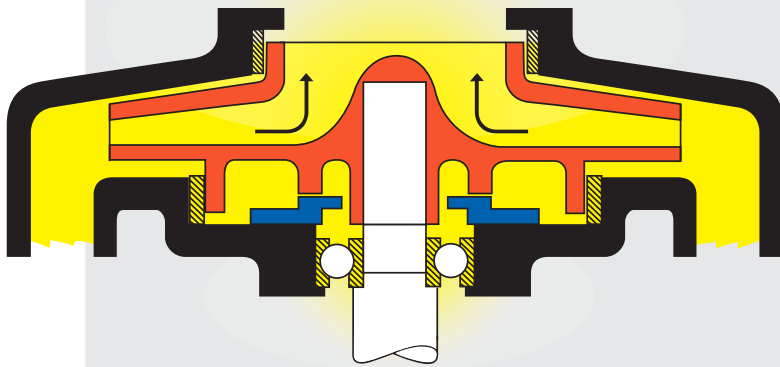


# EXPANDER OPERATION

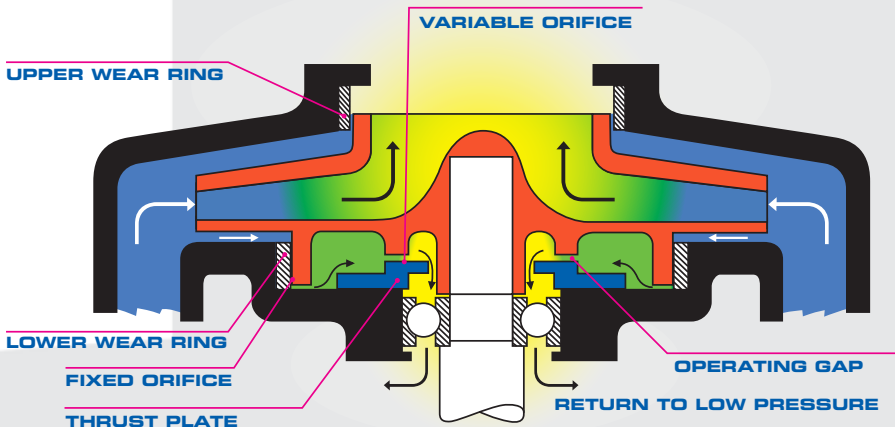


- The main control valve is used during startup and shutdown.
- The speed bypass valve is used for finite adjustments during operation.
- Isolation valves are used for maintenance or shutdown purposes.

## EXPANDER TEM® IN NON-OPERATING CONDITION



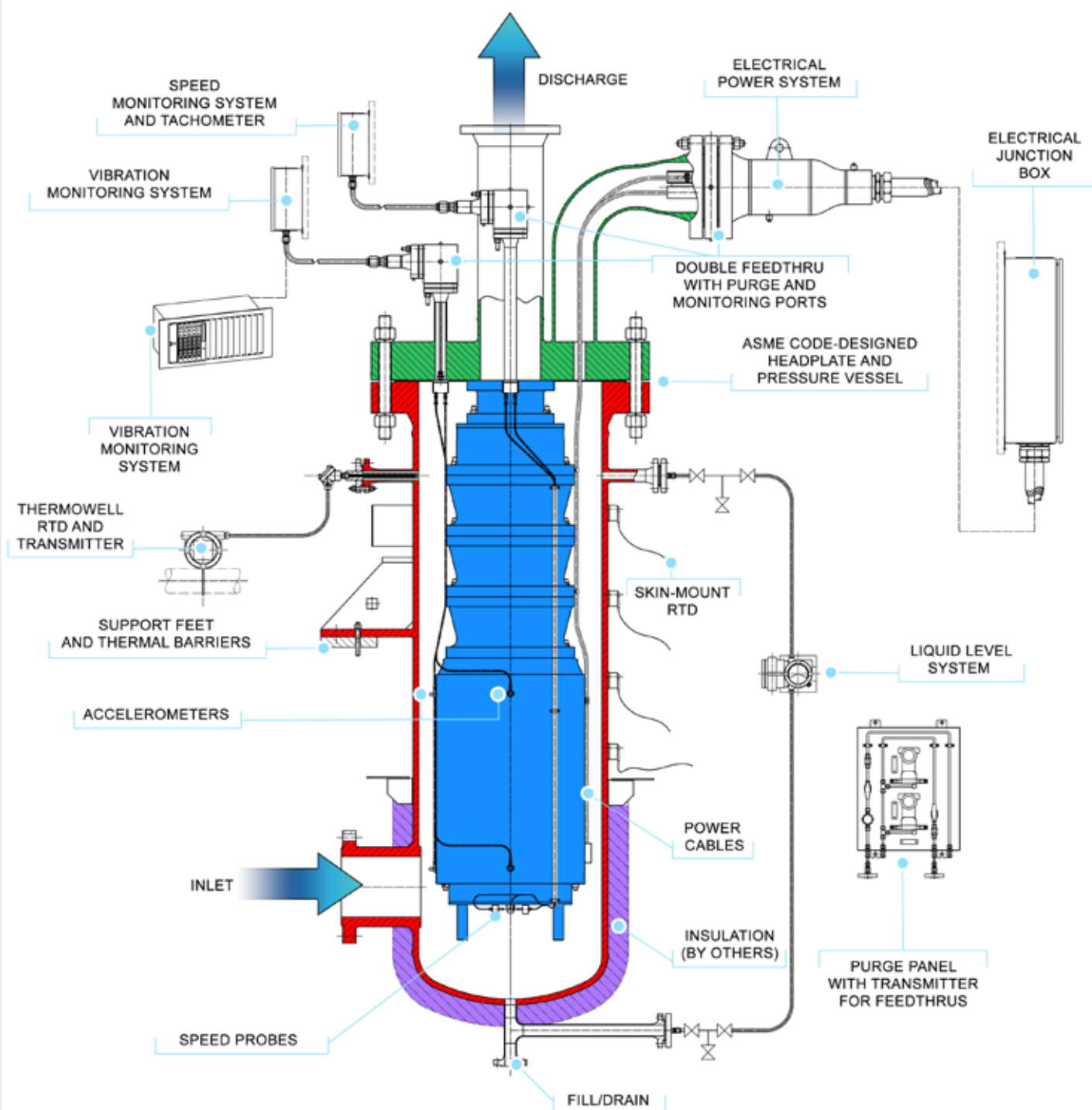
## EXPANDER TEM® IN OPERATING CONDITION



## Thrust Equalizing Mechanism (TEM®)

In all Cryodynamics pumps and expanders, a small portion of pumped fluid will pass through our patented Thrust Equalizing Mechanism (TEM®). The TEM creates an equilibrium between the upper and lower impeller surfaces to provide an extremely stable system with zero thrust loads on the bearings. This feature substantially increases the reliability and life span of the bearings and reduces equipment maintenance requirements.

# SCOPE OF SUPPLY



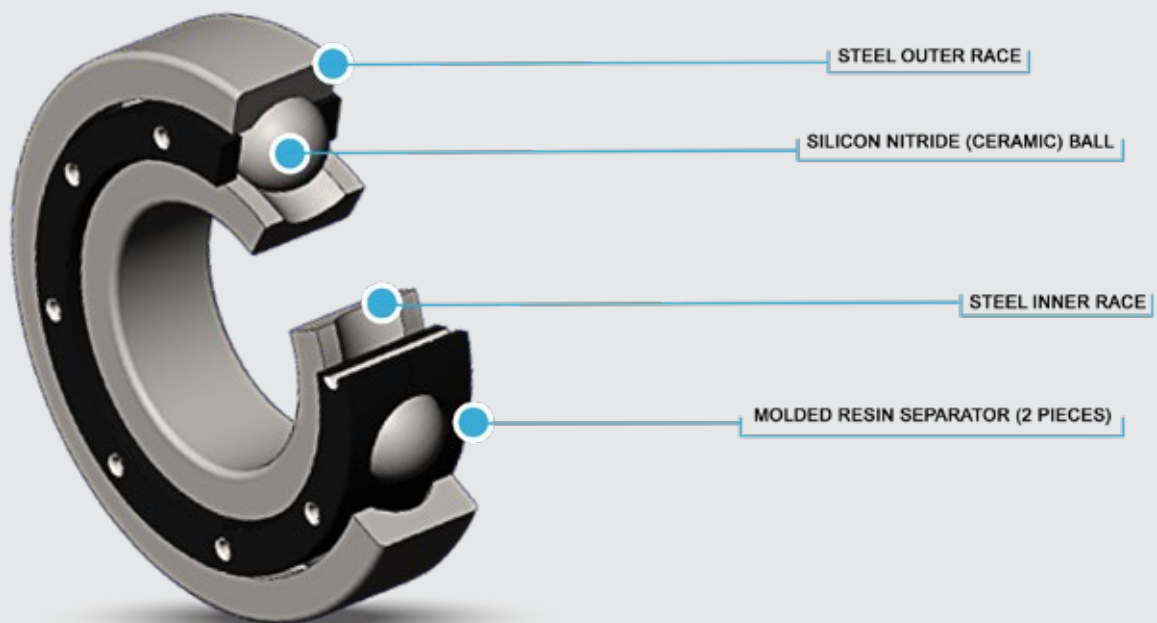
## Expander with Integral Electric Generator

- Electrical system with dual electrical penetration seal and junction box suitable for hazardous areas
- Stainless steel pressure containing vessel and headplate assembly
- Vibration monitoring system (VMS)
- Speed monitoring system
- Liquid level system
- Instrumentation junction box for VMS, suitable for hazardous areas

### Optional Accessories:

- BN 3500 vibration monitoring control room equipment
- Resistance temperature detector (RTD) temperature monitoring system located on pressure vessel
- Nitrogen purge system (electrical, VMS, and speed)
- Variable frequency drive (VFD)

## Cryo-specialty Hybrid Ceramic Bearings



- Steel inner and outer races with silicon nitride balls and molded resin separator.
- Insulated bearings prevent electrical arcing damage
- Longer life than standard steel bearings
- More resistant to debris damage
- Less wear in low lubrication conditions



Elliott Group is a global leader in the design, manufacture, and service of technically advanced centrifugal compressors, steam turbines, power recovery expanders, cryogenic pumps and expanders, and axial compressors used in the petrochemical, refining, oil & gas, liquefied gas, and process industries, as well as in power applications.

Elliott Group is a wholly owned subsidiary of Ebara Corporation, a major industrial conglomerate headquartered in Tokyo, Japan.



901 North Fourth Street  
Jeannette, PA 15644-1473  
Telephone: 724-527-2811  
Fax: 724-600-8442  
Email: [info@elliott-turbo.com](mailto:info@elliott-turbo.com)

350 Salomon Circle  
Sparks, NV 89434 USA  
Telephone: 775-356-2796

Email: [info@elliott-turbo.com](mailto:info@elliott-turbo.com)  
[www.elliott-turbo.com](http://www.elliott-turbo.com)

T H E W O R L D T U R N S T O E L L I O T T



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