Development of Two-Phase Dense Fluid Expander for Advanced Cryogenic Air Separation and Low-Grade Heat Recovery

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Presentation Outline

- Project Objectives
- Background
- Prototypes machines
- Test results
- Next phase of testing.

Project Objectives

- The first objective is to better understand the limitations associated with two-phase dense fluid expansion from aerodynamic, thermodynamic, and mechanical perspectives

- The second objective is to apply this knowledge to construct <u>two prototype devices</u> to further explore the basic properties of two-phase dense fluid expansion

Background

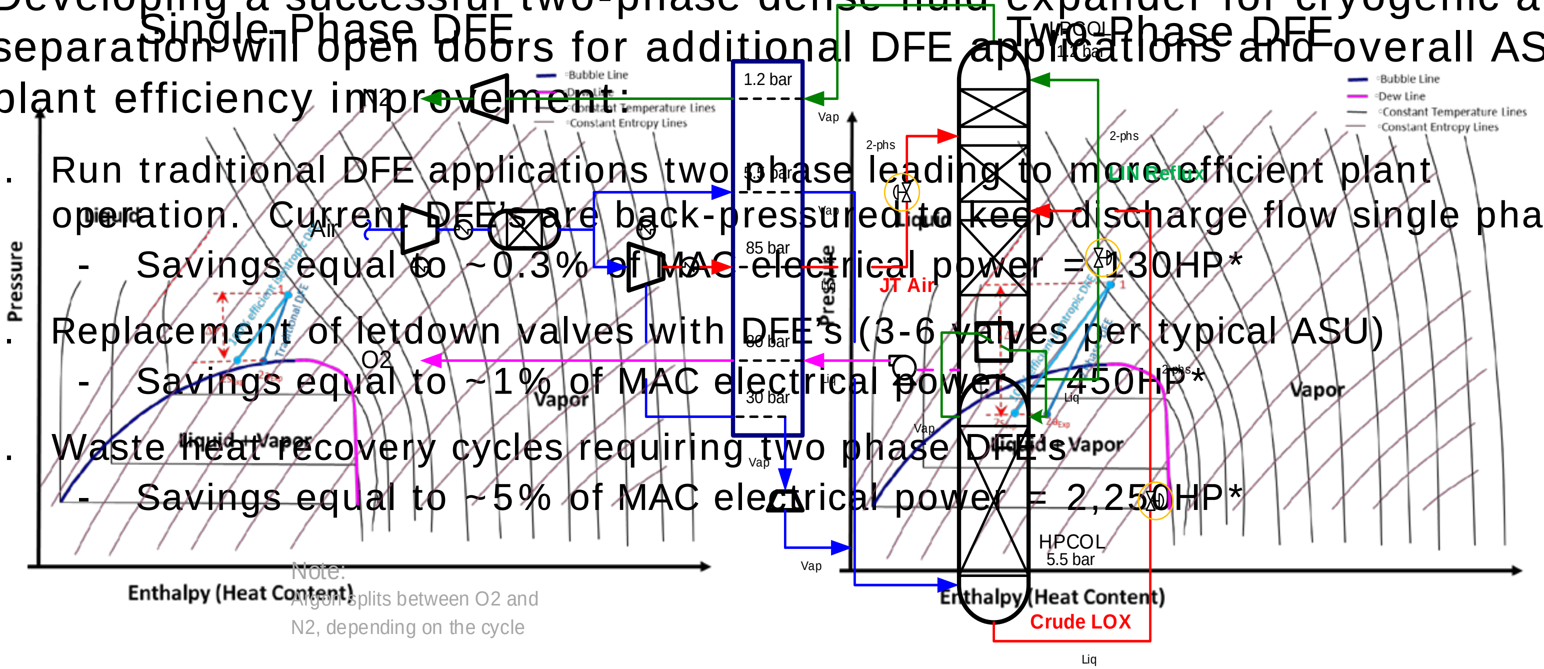
Background

- Cryogenic air separation is the state of the art technology used to supply the vast amounts of oxygen required for coal gasification
- Power needed to drive the main air compressor (MAC) in a typical air separation unit (ASU) represents approximately 70-90% of ongoing operating cost for the entire ASU
- Usage of a dense fluid expander (DFE) within an ASU allows for more efficient plant operation, and therefore less power is required to produce an equivalent amount of oxygen product
- Typically 1HP refrigeration power created by the DFE equates to 5-6HP of electrical power savings

Background

- Developing a successful two-phase dense fluid expander for cryogenic air separation will open doors for additional DFE applications and overall ASU plant efficiency improvement:

1. Run traditional DFE applications two phase leading to more efficient plant operation. Current DFE's are back-pressured to keep discharge flow single phase.
   - Savings equal to ~0.3% of MAC electrical power = 130HP*
2. Replacement of letdown valves with DFE's (3-6 valves per typical ASU)
   - Savings equal to ~1% of MAC electrical power = 450HP*
3. Waste heat recovery cycles requiring two phase DFE's
   - Savings equal to ~5% of MAC electrical power = 2,250HP*



Note: Argon splits between O2 and N2, depending on the cycle

Background

- State of the art cryogenic dense fluid expanders used in air separation are typically limited to single-phase flow (liquid in, liquid out)
- A single-phase DFE design with only liquid in the discharge typically experiences very little volume change upon expansion
- A two-phase DFE may experience volume increases of up to 10 times upon expansion
- The large volume difference between vapor and liquid poses challenges to designing equipment as it relates to machine efficiency, durability, erosion, stable operation, and other performance criteria

Background

Two different types of expander prototypes identified.

1. Centrifugal machine with two phase operation.
   - Two part testing
   - Part 1 : Identification of two phase operation and issues in the plant.
   - Part 2 : Modifications for improvement of plant performance in two phase operation

2. Axial Impulse type machine for higher vapor phases.

Centrifugal DFE

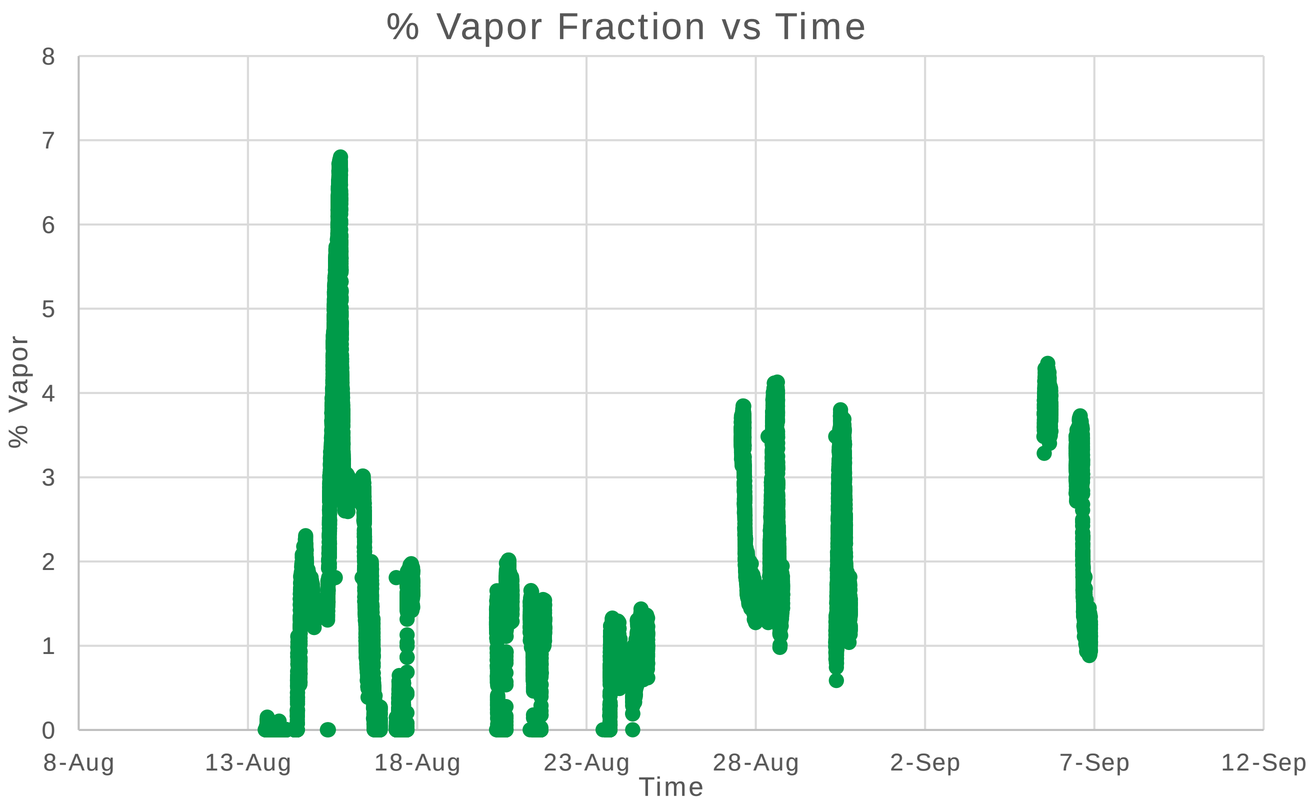
Part 1 - Testing

- Lube Oil Supply (TI-1022) & Lube Oil Drain (TI-1011): Replace existing elements (unused and both in thermowells) with a 4-wire RTD.

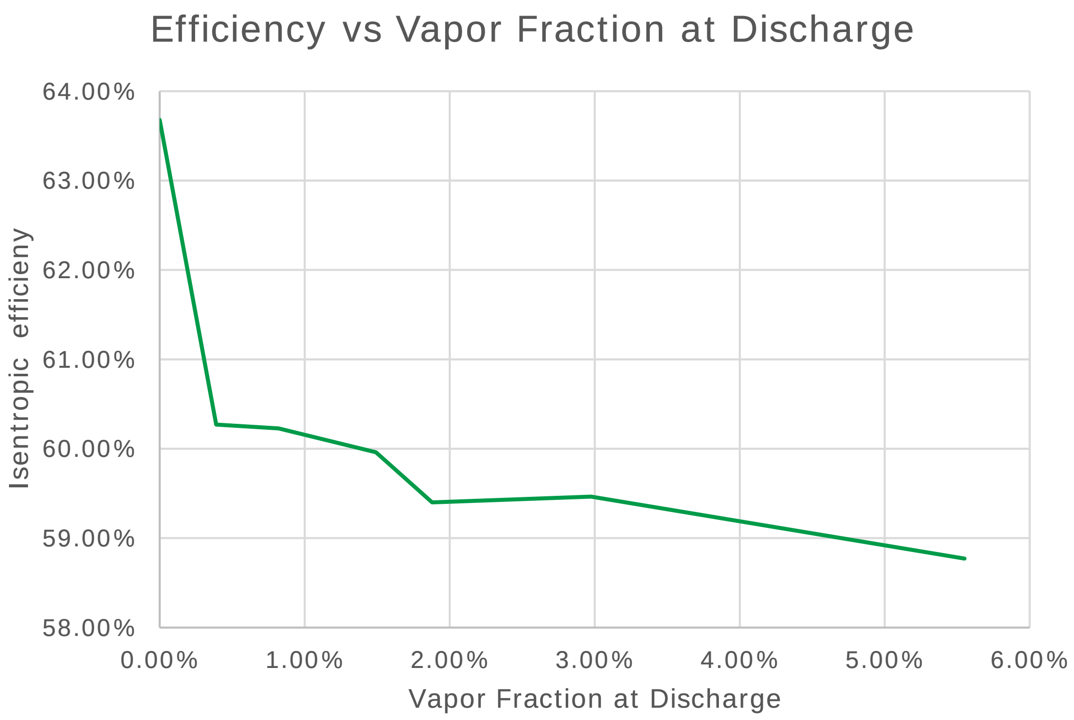
- Lube Oil Flow Meter (FE-1021)

- Replace existing variable area meter with a new turbine-type meter. New meter to be plumbed external to existing panel and connected via hoses in order to achieve the required straight upstream and downstream lengths.

Part 1 - Testing



Part 1- Testing



Part 2 - Testing

- New prototype device based on the data from part -1 testing was designed.

- In process of manufacturing and assembling the machine.

- Part-2 testing Mid June 2019.

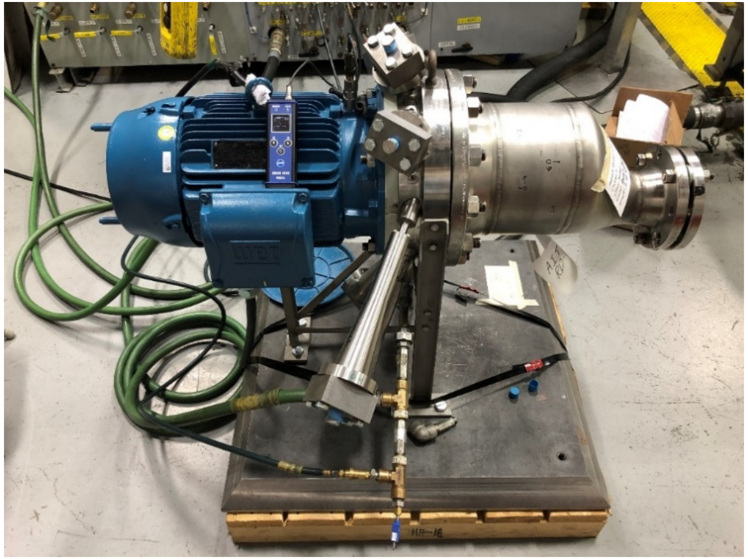
Axial Impulse DFE

Axial Impulse DFE

Axial Impulse design is attractive from various aspects

- High tolerance to 2 phase mixtures both at inlet and discharge
- Slower rotor speeds – improved reliability, lower cost (manufactured and installed)
- Simple and inexpensive to manufacture relative to radial inflow designs
- Low cost installation
  (no lubrication system, limited monitoring/controls)
- Ability to use off the shelf induction motor as basis for the unit for our application

AIT – Mechanical testing



- Motor/generator wired to a 480V variable frequency drive (VFD)
- Plugged inlet nozzles
- Seal gas supply connected to an instrument air system and a flow meter
- Seal gas vent connected to a flow meter
- Discharge connection covered with a blind flange (for personnel protection)
- Accelerometer with portable vibration monitor attached to motor housing

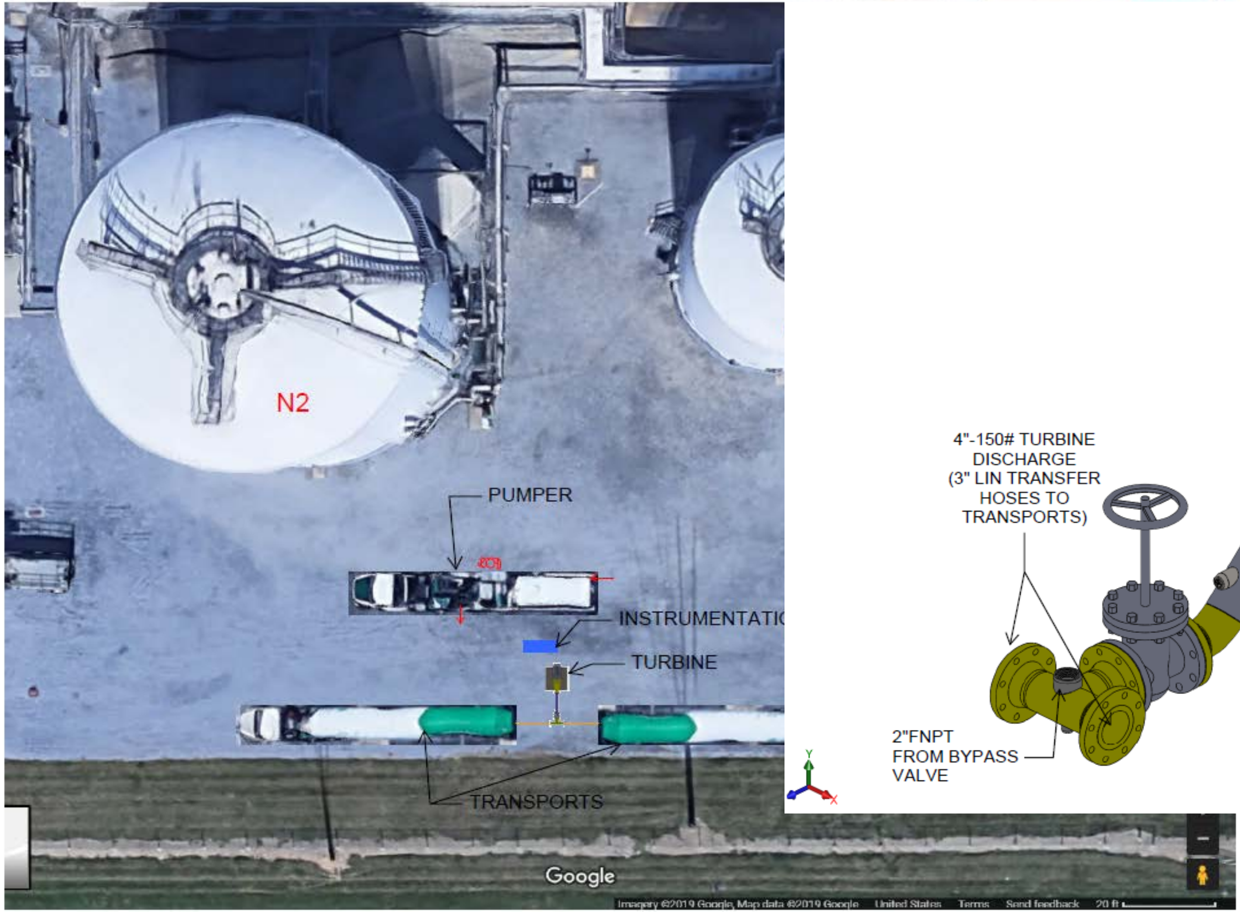
AIT – Mechanical testing

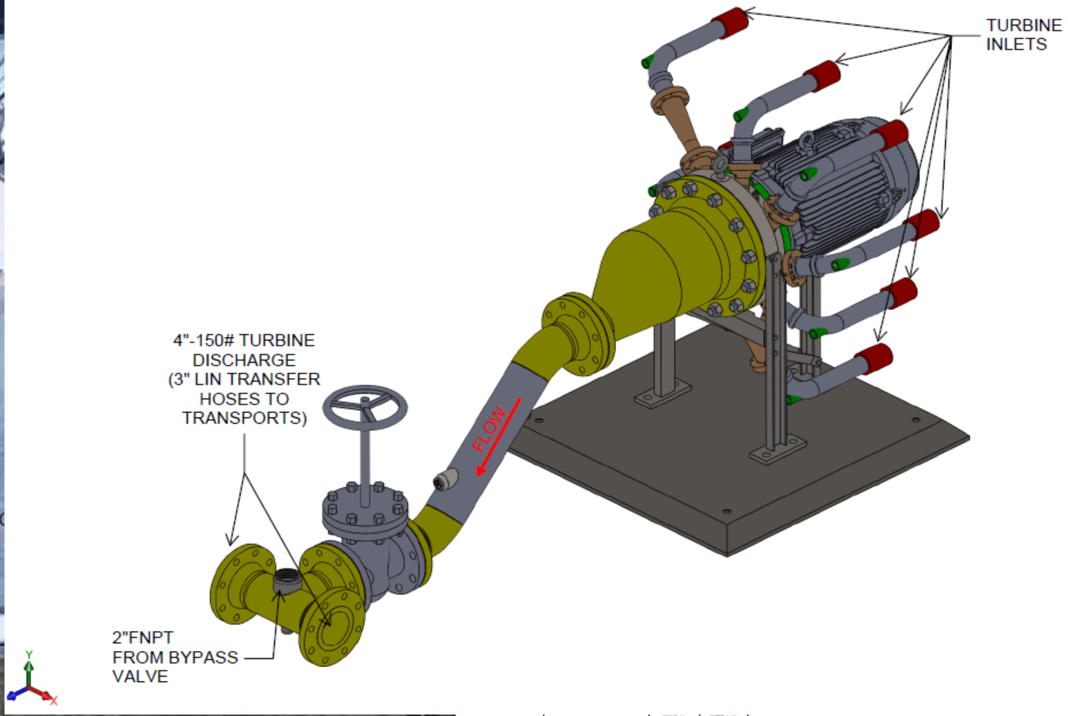
- The machine was operated at various speeds from 10 to 100% (3,520 rpm) for approximately one hour while observing the housing vibration.
- After the test, the discharge housing was removed, and a visual inspection of the turbine impeller was performed. It was concluded that the turbine passed all mechanical test acceptance criteria and is ready for the next step: two-phase cryogenic nitrogen testing.

AIT – Performance test plan

- Planned performance testing.
- Identified location for testing.
    - Lancaster, PA.
- Finished P&ID and test plan.

AIT – Performance test plan





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AIT – Next steps

- Complete testing week of 4/22/19 at Lancaster, PA facility.
- Finalize and create reports of the test data by June 2nd week and conclude AIT prototype program.

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Acknowledgement

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