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Beyond Initial Costs: Exploring the Full Lifecycle of Biogas

Feed Compressors

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MAYEKAWA MYCOM

Presenter

Carlos Falsiroli

Sales Manager, Oil & Gas Chemical
MAYEKAWA USA

- 28 years of experience in the field of compression and refrigeration.
- MBA from University of Toronto
- Certificate in Strategy and Global Business from Harvard Business School
- Joined Mayekawa USA in May, 2021

About Mayekawa

As a leading manufacturer of industrial compressors, Mayekawa supplies high-quality, durable, and manageable compressors to industrial refrigeration and freezing, heat pump, and oil and gas markets around the globe.

100+
Years of Experience

100,000+
Screw Compressors Installed Worldwide

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Mayekawa’s global network

43 countries

Locations
103 offices

Production Sites
7 plants

SOUTH KOREA
CHANGWON PLANT
MYCOM KOREA CO., LTD.

SERBIA
SERBIA PLANT
D.O.O. "MAYEKAWA SRB" - SMEDEREVO

INDIA
CHENNAI PLANT
MAYEKAWA INDIA PVT. LTD.

BELGIUM
BRUSSELS PLANT
N.V. MAYEKAWA EUROPE S.A.

U.S.A.
KATY PLANT
MAYEKAWA U.S.A. INC.

MEXICO
CUERNAVACA PLANT
MAYEKAWA DE MEXICO, S.A. DE C.V.

BRAZIL
ARUJA PLANT
MAYEKAWA DO BRASIL EQUIPAMENTOS INDUSTRIAIS LTDA

*As of Dec 31, 2024

Agenda

2

Biogas Treatment Process

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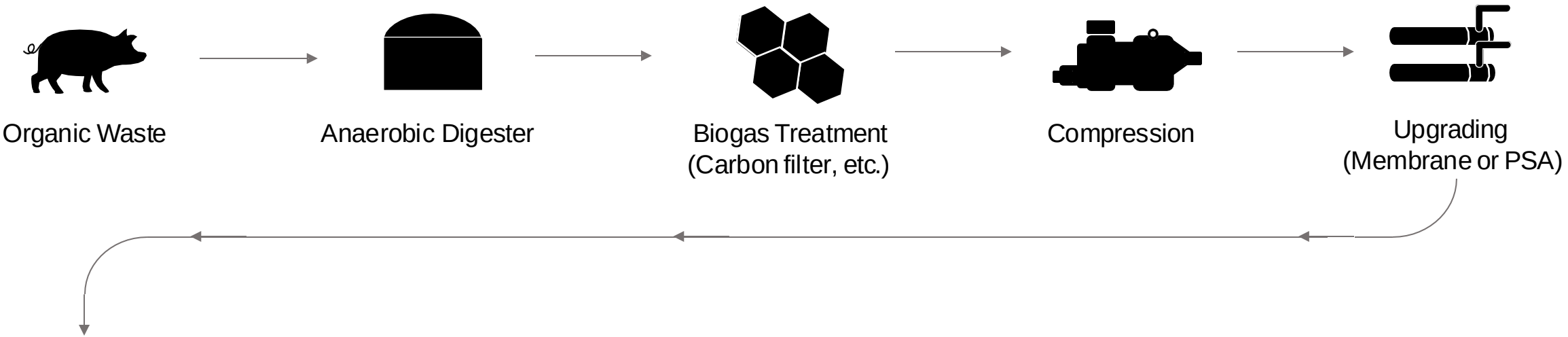
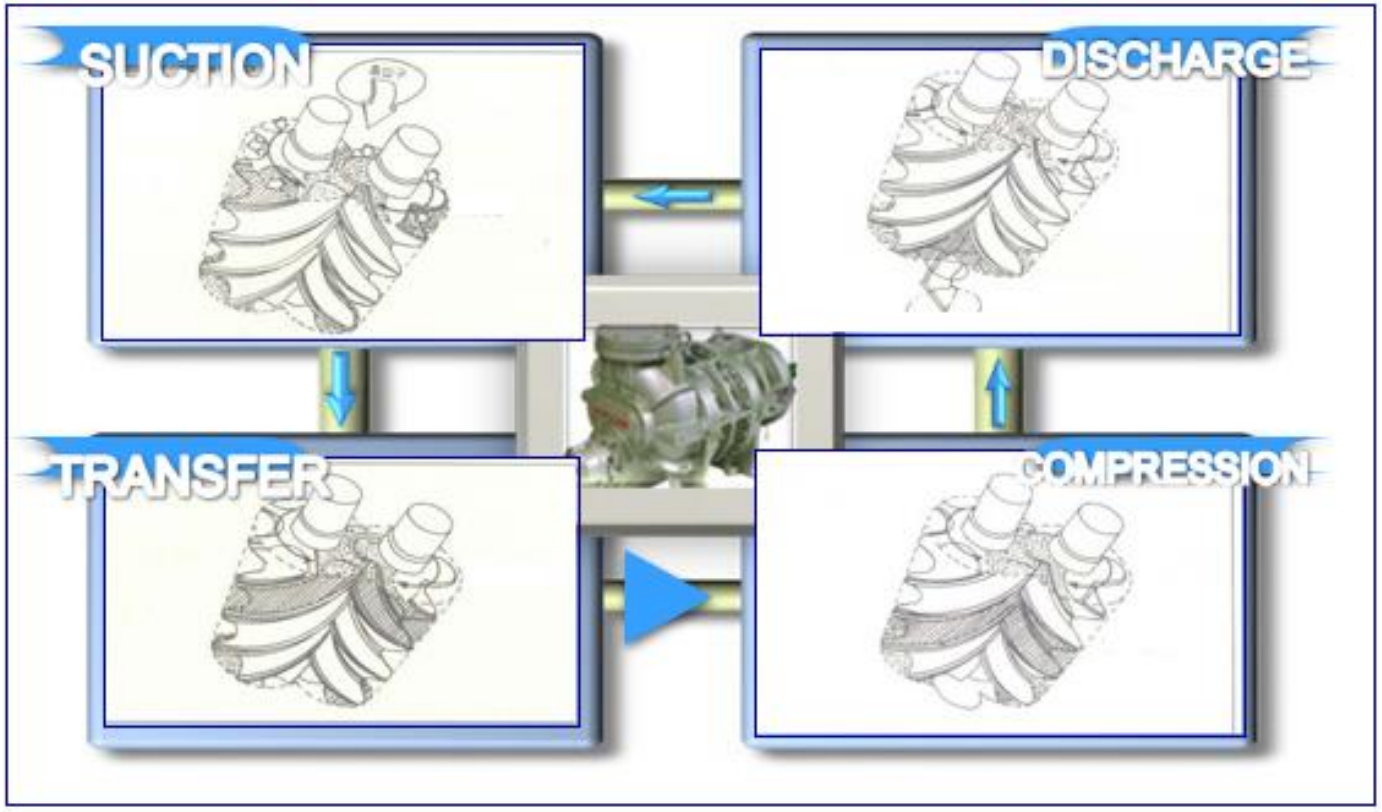
Biogas Treatment Process



3

How Do Screw Compressors Work?

- Gas enters the rotors from the suction port.
- Gas then fills both the male and female rotors.
- Gas begins to be sealed between the rotor and the compressor casing.
- As the rotors turn further, the lobes mesh from the suction side. The inter-lobe space also decreases progressively, and as a result, the gas pressure increases as the rotation continues
- The amount of internal compression which occurs before release, is therefore a characteristic which can be designed by the positioning of the discharge port to suit a particular duty. This feature is known as the **"Built in Volume Ratio“ - Vi.**



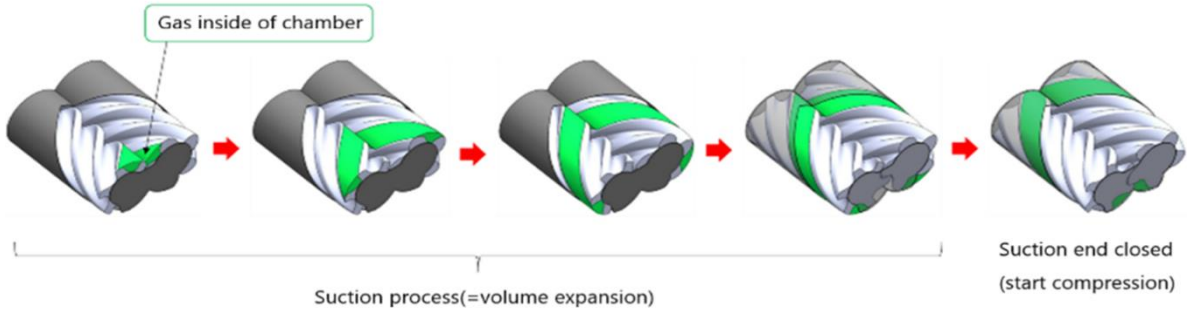
How do Screw Compressors work?

1. Screw compressors compress gas by volume reduction within the compressor casing before the gas reaches the discharge port;

2. $(\frac{V_1}{V_o})^k = \frac{P_d}{P_s} = r$ where,

   1. $K = \frac{c_p}{c_v} = adiabatic\ coefficient$
   2. $V_1 = inlet\ volume$
   3. $V_o = outlet\ volume$
   4. $P_d = discharge\ pressure$
   5. $P_s = suction\ pressure$
   6. $r = compressio\ ratio$
   7. $v_i = built\ in\ volume\ ratio$

$$Vi = \frac{\text{Volume of suctioned refrigerant gas immediately before the start of compression}}{\text{Volume of refrigerant gas just before pushed out to discharge port}}$$



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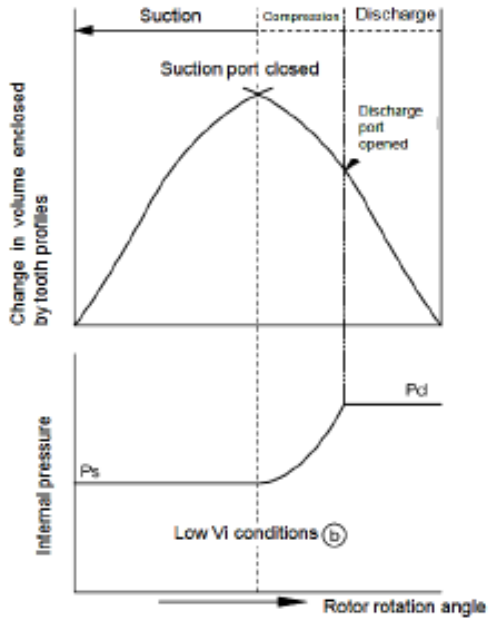
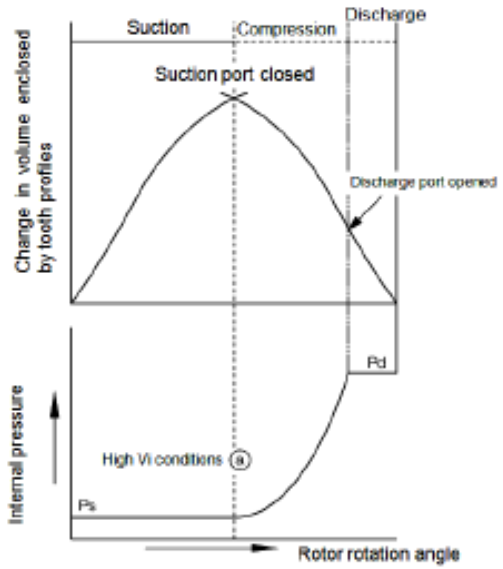
Mismatching Vi or Compression Ratio

Both the required compression ratio and Vi are low.

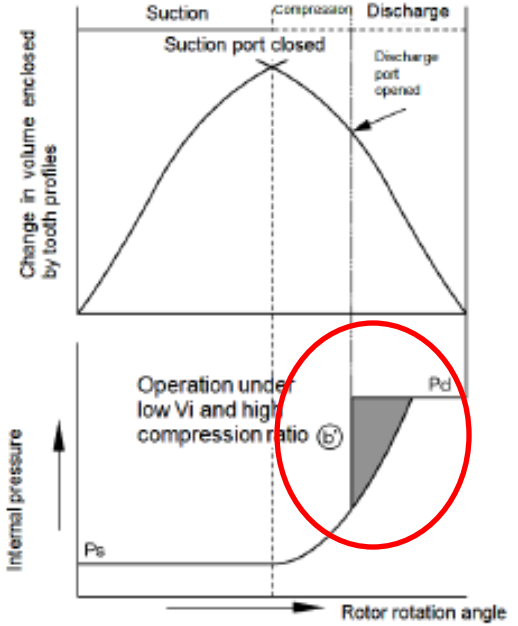


Both the required compression ratio and Vi are high.

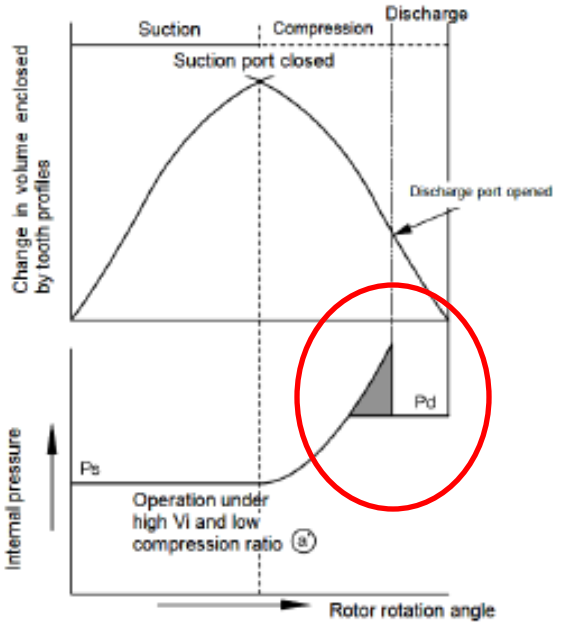


(B) Improperly adapted Vi to load condition

Vi is too low compared to the required compression ratio.



Vi is too high compared to the required compression ratio.



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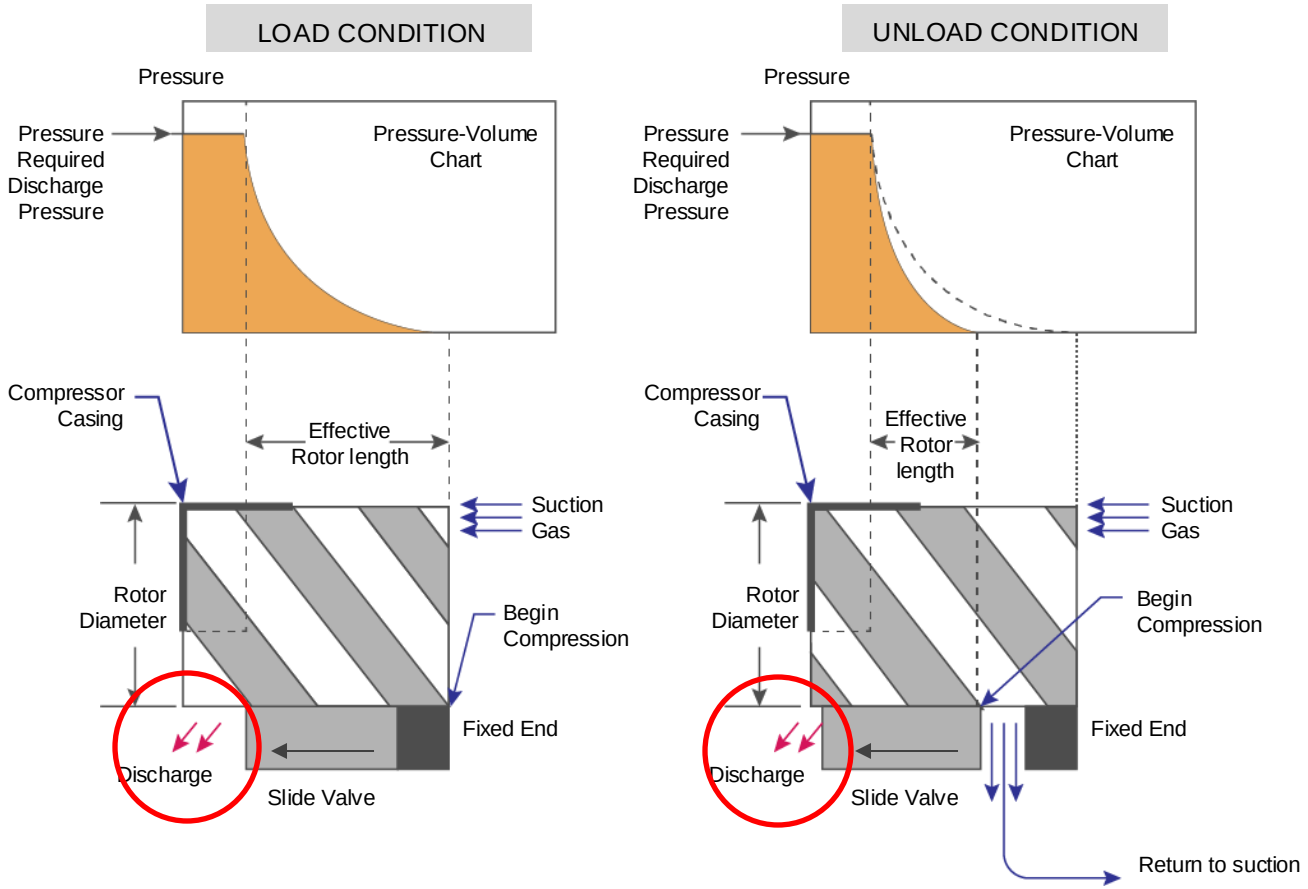
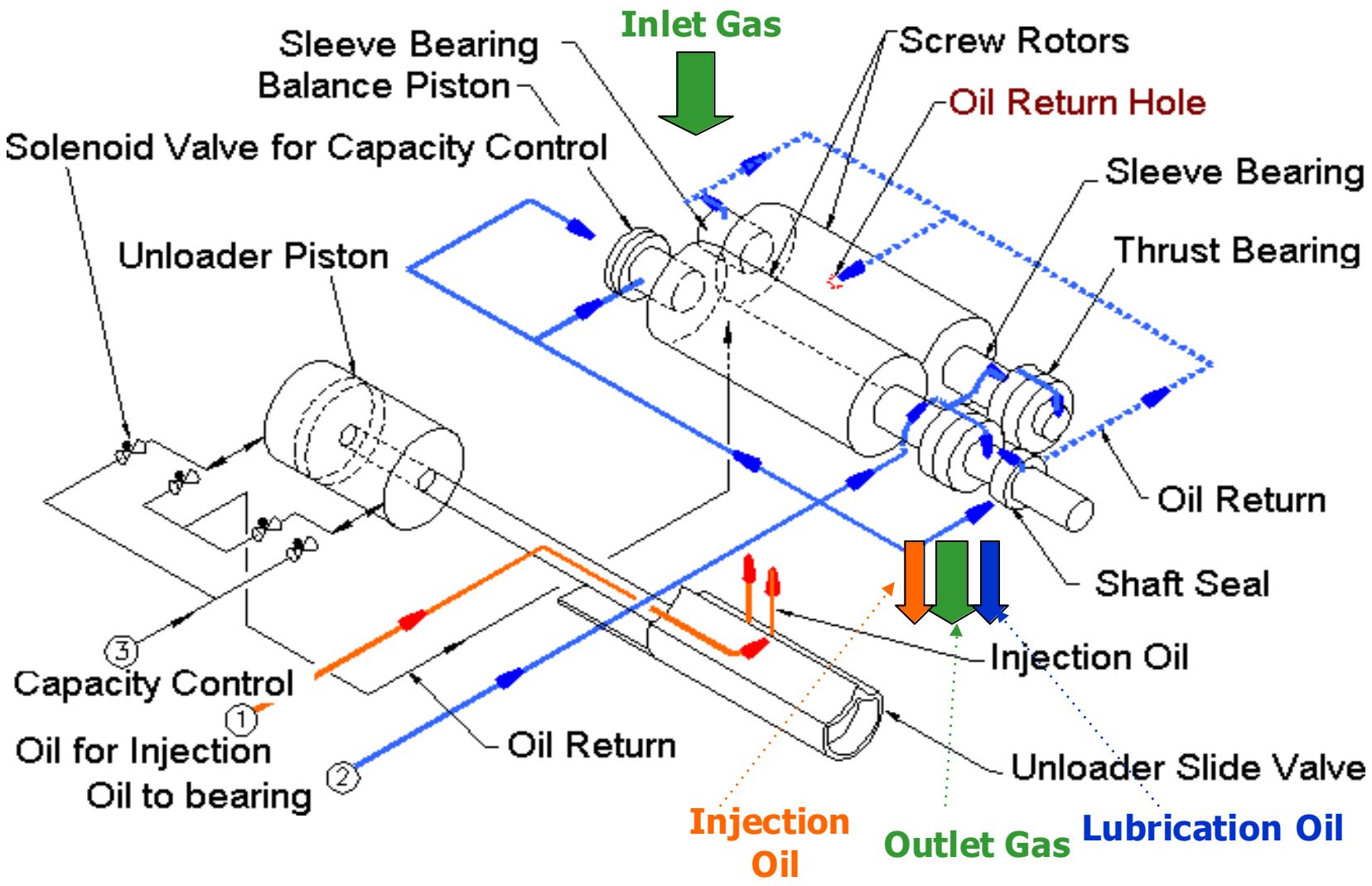
Capacity Control System

- All Mayekawa screw compressors include variable capacity loading
- This is achieved via a slide valve controlled by an unloader piston that can be used to control flowrate
- The slide valve will allow capacity variance down to approximately 20% of the compressor capacity without the need for recycling.

Slide Valve Operation



Lubrication – Oil Injection



4

Compressor Efficiency

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Mismatching Compression Ratio (Vi)

	Case 1 – Matching (Ideal Case)	Case 2 – Mismatching – Single Stage	Case 3- Optimizing- Compound
Suction Pressure (PSIA)	14.7	14.7	14.7
Discharge Pressure (PSIA)	145	350	350
Suction Temp (°F)	90	90	90
Heat capacity ratio (k)	1.30	1.30	1.30
System compression ratio (r)	9.86 : 1	23.8 : 1	23.8 : 1
Compressor compression ratio (r)	9.83 : 1	9.83 : 1	18.8 : 1
Flow (SCFM)	2693	2651	2905
Absorbed Power (HP)	811	2251	1127
Power/Flow (HP/SCFM)	0.30	0.85	0.39

Optimizing compression ratios plays an extremely important role in the total cost of ownership.

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5

Reliability Points

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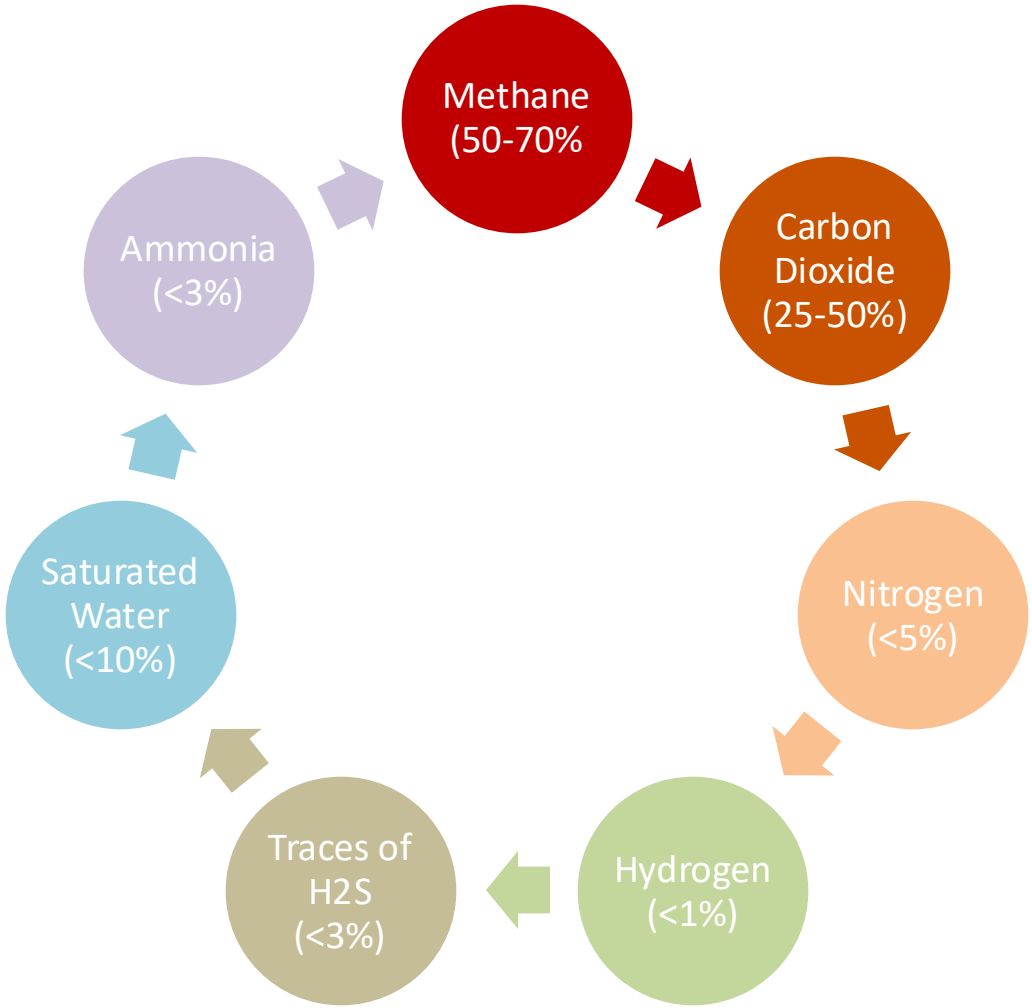
Biogas Composition



- Biogas composition is a major factor in selecting a suitable screw compressor.
- CO2 content must be analyzed to avoid condensation during compression, which can damage the compressor.
- The dew point of any water content must be analyzed to avoid the oil dilution at discharge.
- H2S and CO2 along with water condensation must be accounted for in material selection.
- Corrosion and bearing life are extremely important to consider in selecting the compressor for guaranteed reliability.
- Variation in the gas composition during the operation may lead to reliability issues.

Water Content

Biogas Composition

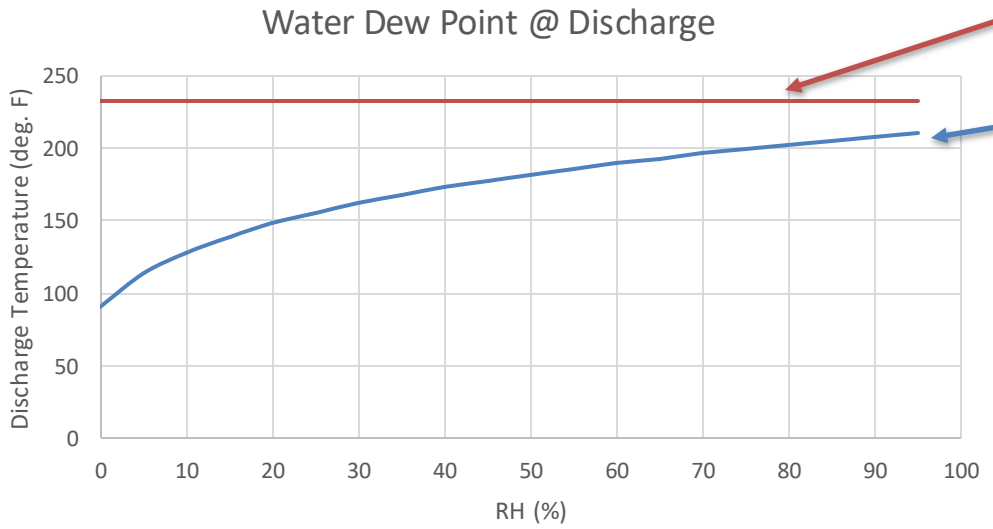
Gas	Mol %
CH4	60%
CO2	30%
Nitrogen	1%
Hydrogen	1%
H2S	3%
Water	4%
NH3	1%

Operating Conditions

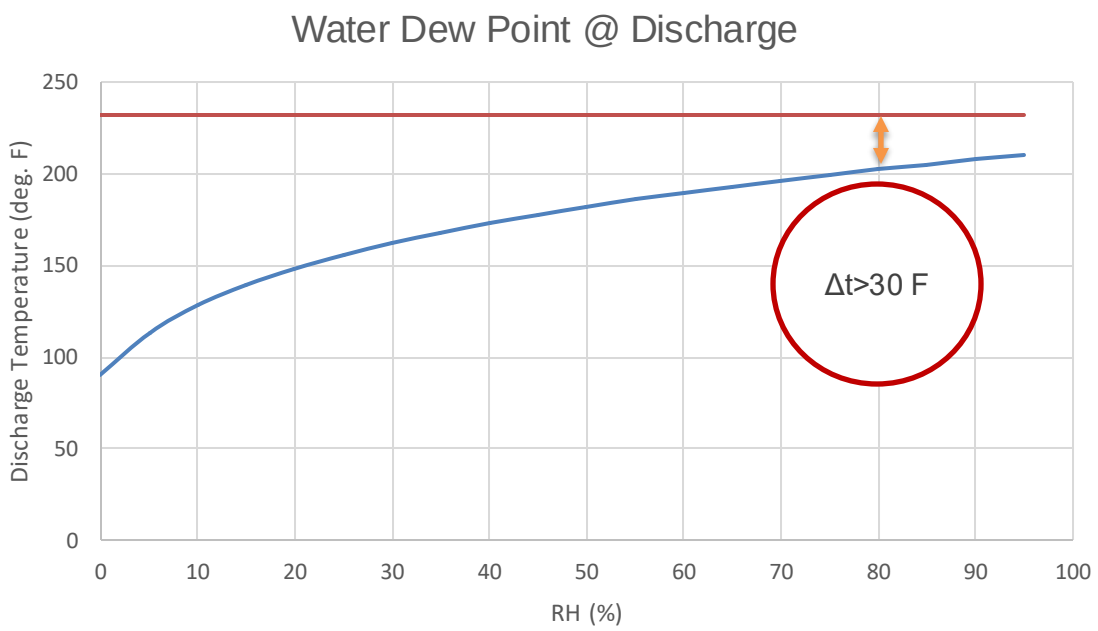
Parameter	
SP (PSIA)	14.7
DP (PSIA)	350
ST (PSIA	90
RH (%)	84

Fixed Vi Calculation

RUN NO.	1
PS 1st PSIA	14.70
PD 1st PSIA	57.16
PS 2nd PSIA	57.16
PD 2nd PSIA	298.93
TS 1st deg F	90.0
TD 1st deg F	176.0
TS 2nd deg F	176.0
TD 2nd deg F	*232.5
REL HUMIDITY %	84.0
DEW POINT OF WATER 1st deg F	131.0
DEW POINT OF WATER 2nd deg F	*201.7
INTERCOOLER HT REJ BTU/HR(x100	0.0
TD OUT-ACLR deg F	104.0
ACLR HT REJ BTU/HR(x100	255.3



Water Content



- High RH demands higher discharge temperatures (min >30 F of dew point) to avoid water condensation
- Water condensation causes oil dilution which affects the compressor's reliability and quality of compressed gas
- Water condensation causes acid formation (CO_2 &H_2S) which demands special materials to prevent corrosion
- High regarding thrust bearings shall be taken in order to guarantee the compressor reliability.
- discharge temps must be below critical point of thermal expansion and can increase thrust forces.
- Careful consideration: H_2S content must be considered to avoid sulfide stress cracking

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Material Compatibility: Example

Classification of Materials for Casings/Rotors/Valves	Compatibility with Sour Gases (H_2S)
Cast Steel	✓
Corrosion Resistant Cast Steel	✓
Cast Iron	✗
Ductile Cast Iron	△
Chrom Molybdenum Steel Forgings	✗

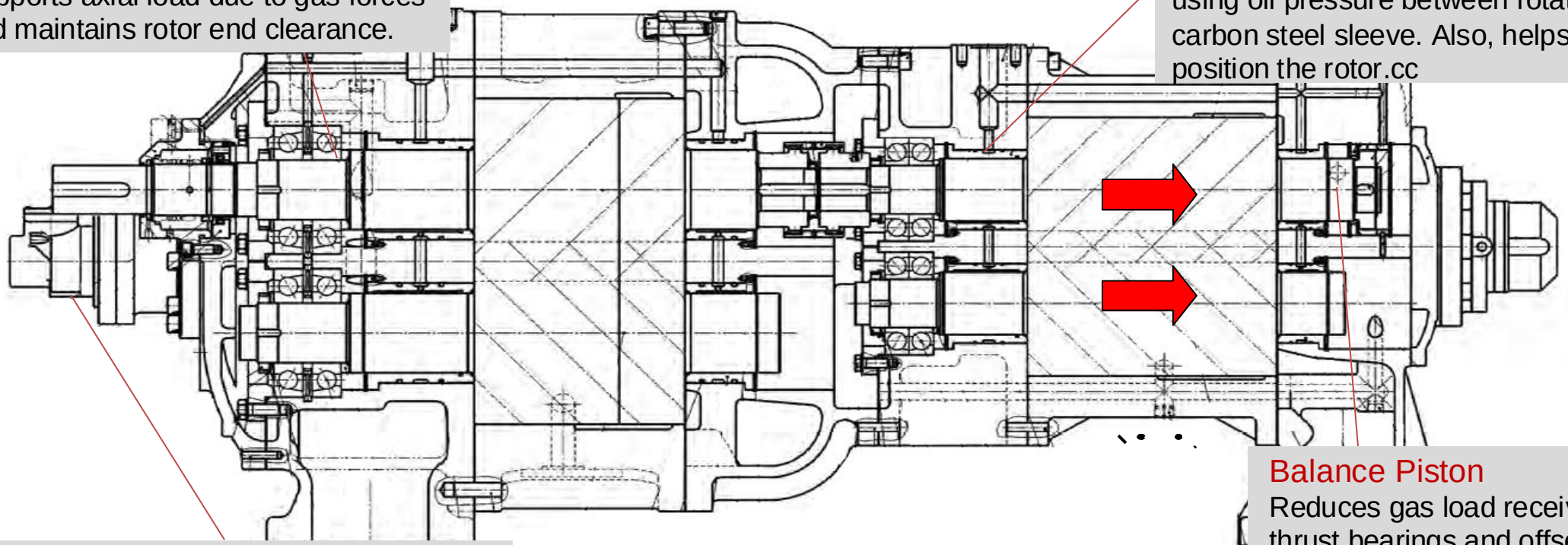
✓ Can be used after technical evaluation and internal/client approval
△ Can be used under some conditions, however not recommended
✗ Cannot be used

Consider the **material compatibility of chosen compressors** with your existing biogas technologies to avoid sulfide stress cracking → machine corrosion.

Important Elements in Handling Forces

Thrust Bearings
Supports axial load due to gas forces and maintains rotor end clearance.

Radial Bearings (AKA side bearings)
Supports the gas load in the radial direction using oil pressure between rotating shaft and carbon steel sleeve. Also, helps to properly position the rotor.cc



Hydraulic Piston

Mechanical Seals
Prevents the leakage of gas and oil inside the compressor to the atmosphere.

Balance Piston
Reduces gas load received by the thrust bearings and offsets load with hydraulic pressure in opposite direction, thus extending the life of the thrust bearings.

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The Total Cost Of Ownership

Total Cost of Ownership (7 Years)

Example: You are choosing between a single stage and compound compressor for your next project.

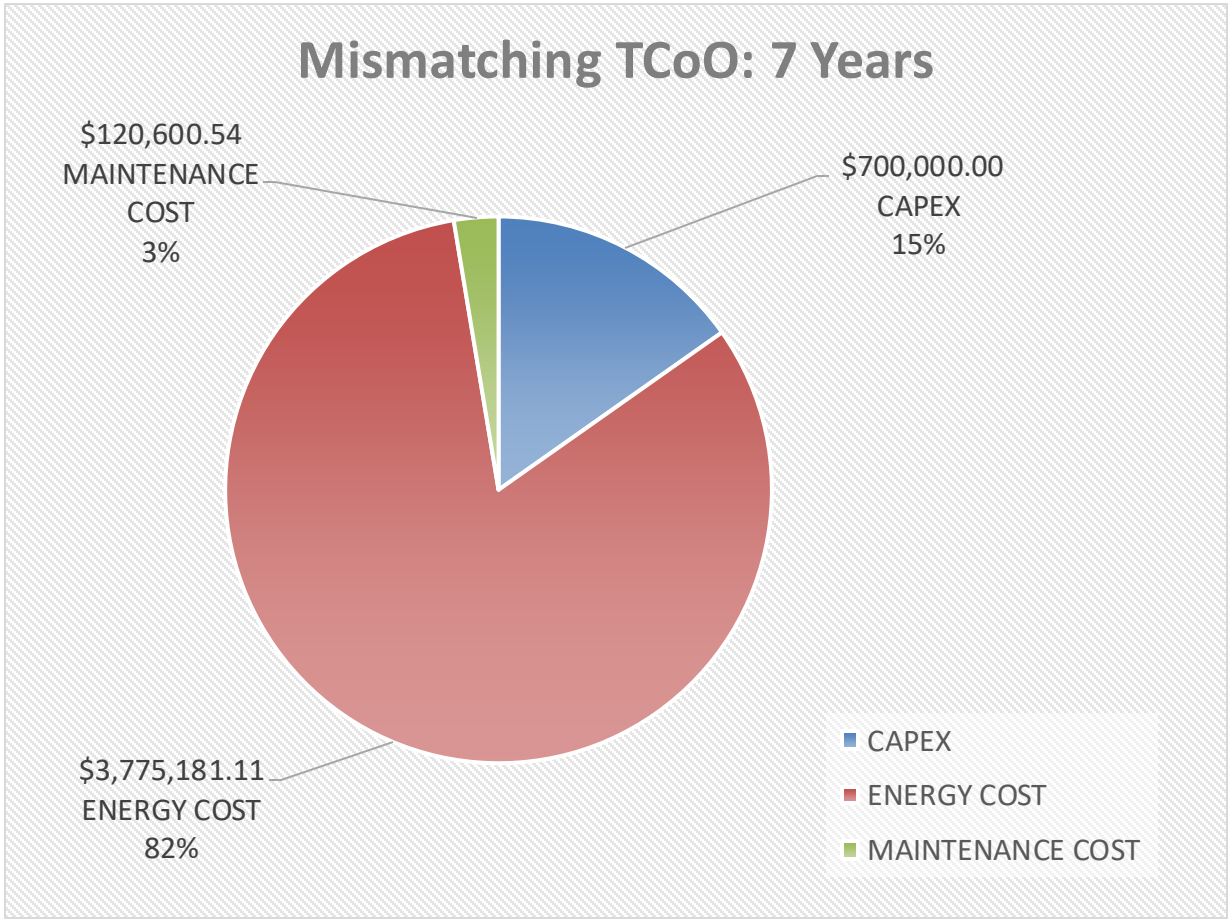
What costs are important when deciding?

Considering as Premises

- *Cost Of Capital:* 8%
- *Energy Price*: 0.05 $/KWh
- *Maintenance Cost*: USD 30,000/ year (starting on year 03)

	Mismatching – Single Stage	Optimizing – Compound
System Cost (CAPEX)	$700,000	$950,000
Energy Costs	$3,775,181	$1,890,106
Maintenance Costs	$120,600	$65,495
Total	$4,595,781	$2,905,602
Energy/Total Cost	82%	65%
Discharge Pressure (PSI)	350	350
Flow (SCFM)	2674	2905
Absorbed Power (HP)	2251	1127
Power/Flow (HP/SCFM)	0.85	0.42

Total Cost of Ownership: Mismatching (7 Years)



Energy costs accounts for **82%** of the total cost of ownership.

Minimizing energy costs allows for a **higher return on investment** earlier in the ownership timeline.

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Total Cost of Ownership Comparison

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CAPEX	$700,000	$950,000
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Spending an additional **$250,000** on a compound compressor instead of a mismatching compressor results in **savings of $1,690,179 over 7 years** of maintenance and energy costs – while providing a **higher, more efficient power flow.**

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SCV SERIES

- 13 Models from 244 – 3355 cfm
- Variable Vi mechanism
- Cast iron casing
- Rotors in Ductile iron or forged steel
- Thrust Bearings : Ball or Tilting Pad
- Sleeve type radial bearings
- Single, double or API seal
- Gas & Refrigeration

J SERIES

- Automatically Variable Vi mechanism
- Cast iron, Cast Steel Casing (API 619)
- Ductile Iron or Forged Steel Rotors
- Stepless Capacity Control 25%-100%
- Thrust Bearings : Ball or Tilting Pad
- Sleeve type radial bearings
- Single, double or API seal
- Gas & Refrigeration

UD SERIES

- Wide Capacity Range: 116 – 9182 cfm
- API 619 compliance
- Cast Iron, Cast Steel Casing
- Ductile Iron or Forged Steel Rotors
- Stepless Capacity Control
- Thrust Bearings : Ball or Tilting Pad
- Sleeve type radial bearings
- Single, double or API seal
- Gas & Refrigeration

GH SERIES

- High Pressure : 870 PSI
- Rotor Profile 5:7
- Cast Steel casing
- Ductile Iron or Forged Steel Rotors
- Stepless Capacity Control
- Thrust Bearings : Ball or Tilting Pad
- Sleeve type radial bearings
- Single, double or API seal
- Gas & Refrigeration

New

360GV

- Range from 4000 to 6000 CFM
- Nodular Cast Iron Casing
- Forged Steel Rotors
- Oil Injected Labyrinth Seals
- Stepless Capacilty control 20%-100%
- Anti Friction Radial Bearings.
- No external oil pump required.
- Auto Vi control
- Speed from 600 to 3600 RPM

C SERIES

- Two stage in one compressor
- More efficiency for high compression ratios
- Wide range: 216 – 9182 cfm
- API 619 compliance
- Cast Iron, Cast Steel Casing
- Ductile Iron or Forged Steel Rotors
- Stepless Capacity Control
- Thrust Bearings : Ball or Tilting Pad
- Sleeve type radial bearings
- Single, double or API seal
- Gas & Refrigeration

Conclusions

- Energy cost accounts for approximately 80% of the total cost of ownership. Mayekawa can offer excellent solution with the C-Series (double stage with just one motor).
- Compression ratios higher than 12:1 leads to a double stage system (compound).
- Gas composition, pressure and temperature analysis is crucial in customizing optimum & reliable compressors.
- Water content and its dew point temperature must be analyzed for gas quality, materials and reliability.
- Mayekawa will help find you the perfect custom screw compressor for the biogas treatment you need.

Mayekawa Maintenance Across North America

Thank You

Carlos Falsiroli

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BIOGAS AMERICAS
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April 28-30, 2025
Colorado Convention Center
Denver, CO