

Anode Gas Recirculation Blower Performance for the Balance of Plant Engineer

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Balance of plant components, such as recirculation blowers for PEM fuel cell systems see ever increasing performance demands due to increasing temperature requirements and wider variations in pressure and fluid density. In terms of refinement and improvement of the state-of-the-art, issues involving the balance of plant are on par with those of immediate PEM fuel cell technologies.

Anode recirculation processes involve a wide range of gas mixtures of nitrogen, hydrogen, and water. As part of the drive to improve efficiency, anode recirculation performance is enhanced by recirculation blowers. Not obvious demands on the blower performance requirements are driven by widely varying head rise and flow requirements. In addition, the presence of water poses operational challenges as well.

Although blower manufacturers are used to consulting on process schemes to help customers optimize the final specifications, they also recognize that fuel cell manufacturers have proprietary process parameters which are confidential. Blower manufacturers are then left to respond to the finite process conditions provided, which often appear to be overstated. The result can be an extreme blower design, which can drive cost up and reliability down.

The ability of the fuel cell engineers to recognize process impacts on equipment and in turn for the blower manufacturers to meet the varied process challenges can improve with better communication of the equipment requirements in machinery language, expressed in industry standard terminology and nomenclature.

This paper provides an overview of process parameters and the industry standard nomenclature most beneficial to blower manufacturers when sizing and analyzing a blower's performance for specific fuel cell processes. The paper also provides an understanding of fundamental blower operating characteristics. As anode gas recirculation conditions vary, knowledge of blower operating characteristics will provide guidance to fuel cell engineers so that blower performance can be modeled; the benefit being insight as to what is and is not possible for centrifugal blowers.

For example, a Hydrogen recirculation process which undergoes changes from conditions A to B translates into the following required operational changes for an Anode recirculation Blower:

Process Constants:

Inlet Pressure – P1: 27.0 PSIA
Inlet Temperature – T1: 160 Deg. F
Discharge Pressure – P2: 29.6 PSIA
Flow: 0.16 mols/sec
Impeller Dia. – 4.6 in.

	Condition A	Condition B
Nitrogen (mole %)	28 %	2 %
Hydrogen (mole %)	65 %	95 %
Water (mole %)	7 %	3 %
Density – Lbm/Ft ³	0.04230	0.01224
Total Dynamic Head – Feet-Lbf/Lbm	8,365	28,907
Actual Flow – Ft ³ /min.	5,211	5,232
Blower Speed – RPM	32,000	59,600
Blower Motor Power – HP	1.22	0.59

The change from condition A to B, which drives the significant increase in the Total Dynamic Head of the machine typically translates into greater bearing wear, shorter life between service and refurbishment cycles, more sophisticated design and speed control electronics, and more costly and exotic materials.

This paper provides straight forward calculations, performance curves, and empirical charts which allow fuel cell engineers to estimate the impact of recirculation process changes on blower design and operating performance.

The ultimate goal of the paper is to provide practical analytical tools to fuel cell engineers regarding the operation and capability of anode gas recirculation blowers such as straight forward calculations, performance curves, and empirical charts.

Dynamic Head

$$\Delta h = [\gamma/(\gamma-1)] \times RZ \times T_1 \times [(P_2/P_1)^{(\gamma-1)/\gamma} - 1]$$

Adiabatic Exponent

$$\gamma = (C_p/C_v)$$

Gas Constant (Adjusted by Compressibility Factor)

$$RZ = [(P_1 \times 144)/(T_1 \times \rho_1)]$$

Operating Parameters

T₁ = Inlet Temperature (R)

P₁ = Inlet Pressure (PSIA)

P₂ = Discharge Pressure (PSIA)

ρ₁ = Inlet Density (lbm/ft³)

Δh = Dynamic Head [(lbf×ft)/lbm]

C_p = Specific Heat (Constant Pressure)

C_v = Specific Heat (Constant Volume)

Establish Anode Operating Point Blower Characteristics:

• For a total number of gas constituents 'n' (N₂, H₂O, H₂ etc), calculate the Blower Inlet gas mixture molecular weight:

$$MW = \sum_{i=1}^n (\text{mole } \%)_i \times MW_i = 10.415 \text{ g/g-mole}$$

• Find R*Z using the calculated MW from the Chart. R*Z = 148.4 ft · Lbf / Lbm · °F

• Find the Partial Pressures of each gas constituent:

$$P_{P_i} = P_1 \times (\text{mole } \%)_i$$

• Find ρ₁ for each constituent from Thermodynamic Tables for T₁ and P_{P_i} of each constituent.

$$\rho_1 = \sum_{i=1}^n \rho_i = 0.04230 \text{ Lbm/ft}^3$$

• For the mass flow required (m dot), calculate the inlet "actual flow" (Q dot) into the Blower:

$$m \text{ dot} = 0.16 \text{ g} \cdot \text{mols/sec} \times 10.415 \text{ g/g-mole} \times 1 \text{ Lbm/453.6 g}$$

$$m \text{ dot} = 0.003674 \text{ Lbm/sec}$$

$$Q \text{ dot} = \frac{m \text{ dot}}{\rho_1} = \frac{0.003674 \text{ Lbm/sec}}{0.04230 \text{ Lbm/ft}^3} = 0.08685 \text{ ft}^3/\text{sec}$$

$$Q \text{ dot} = 0.08685 \text{ ft}^3/\text{sec} \times 60 \text{ sec/min} = 5.211 \text{ ft}^3/\text{min}$$

• Calculate the **Dynamic Head** for the required Operating Condition:
NOTE: γ = 1.394 for most all warm H₂ operating conditions:

$$\Delta h = (\gamma/(\gamma-1)) \times R*Z \times T_1 \times [(P_2/P_1)^{(\gamma-1)/\gamma} - 1]$$

$$\Delta h = (1.394/1.394-1) \times 148.4 \text{ ft-Lbf/Lbm-}^\circ\text{F} \times (160^\circ\text{F} + 459.67) \times [(29.6/27.0)^{(1.394-1)/1.394} - 1]$$

$$\Delta h = 8,565 \text{ feet (Lbf/Lbm)}$$

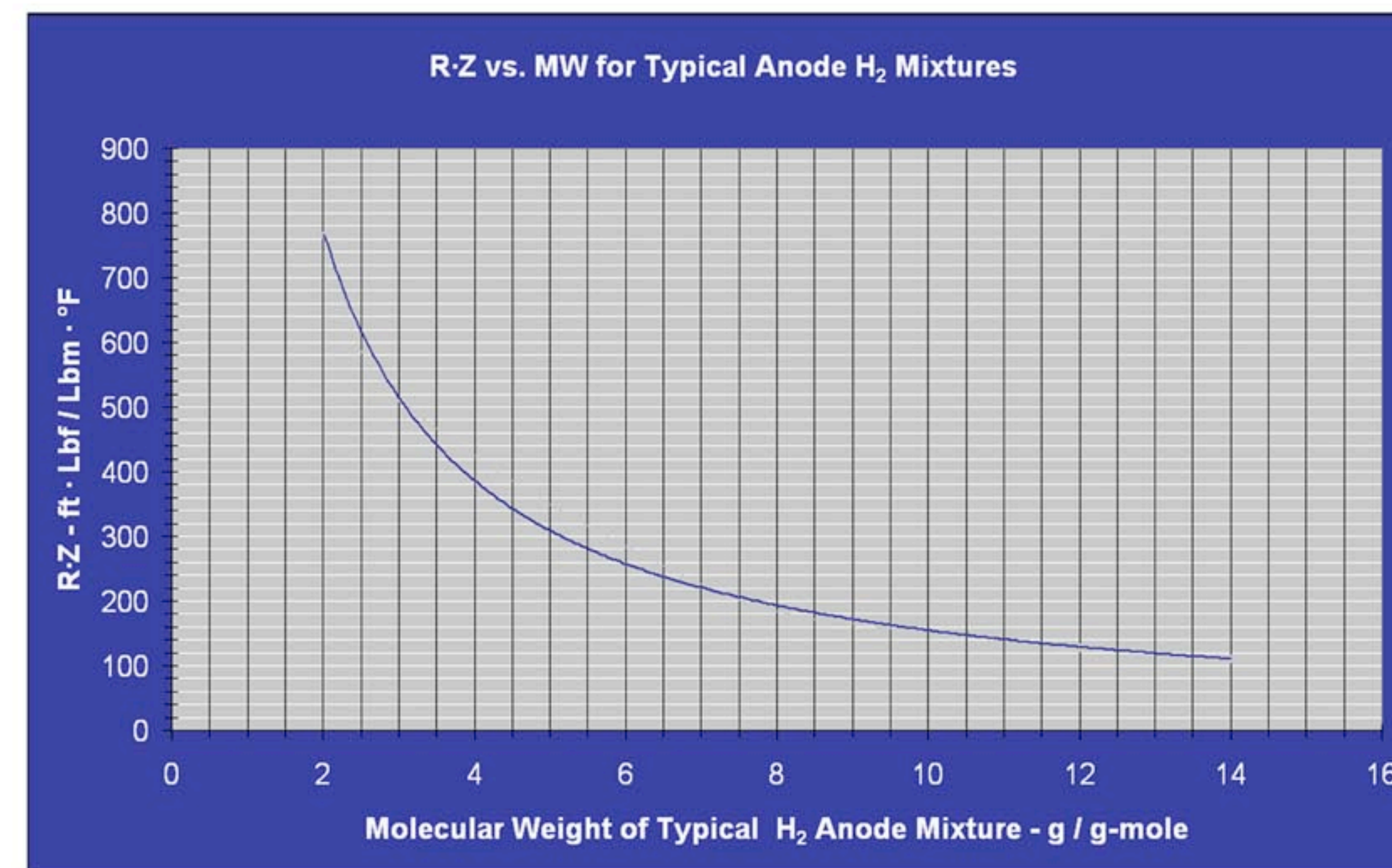
• Assume an impeller diameter (D₂) of 4.6 in. Calculate impeller tip speed U₂:

$$U_2 = (\Delta h \times 32.2 \text{ ft/sec}^2 / 0.69)^{0.5} = 632.2 \text{ ft/sec}$$

• Calculate the design Speed (N) of the Blower:

$$N = U_2 \times 720 / (D_2 \times \pi) = 632.2 \text{ ft/sec} \times 720 \text{ (sec-ft/in-min)} / (4.6 \text{ in} \times \pi \text{ rad/rev}) = 32,000 \text{ RPM}$$

** With N, Q dot, and Δh – Model the Blower Performance Using the % Head vs. % Actual Flow Performance Curve.



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