

Use, Abuse, & Cautions for Using VFDs on Main Mine Fans

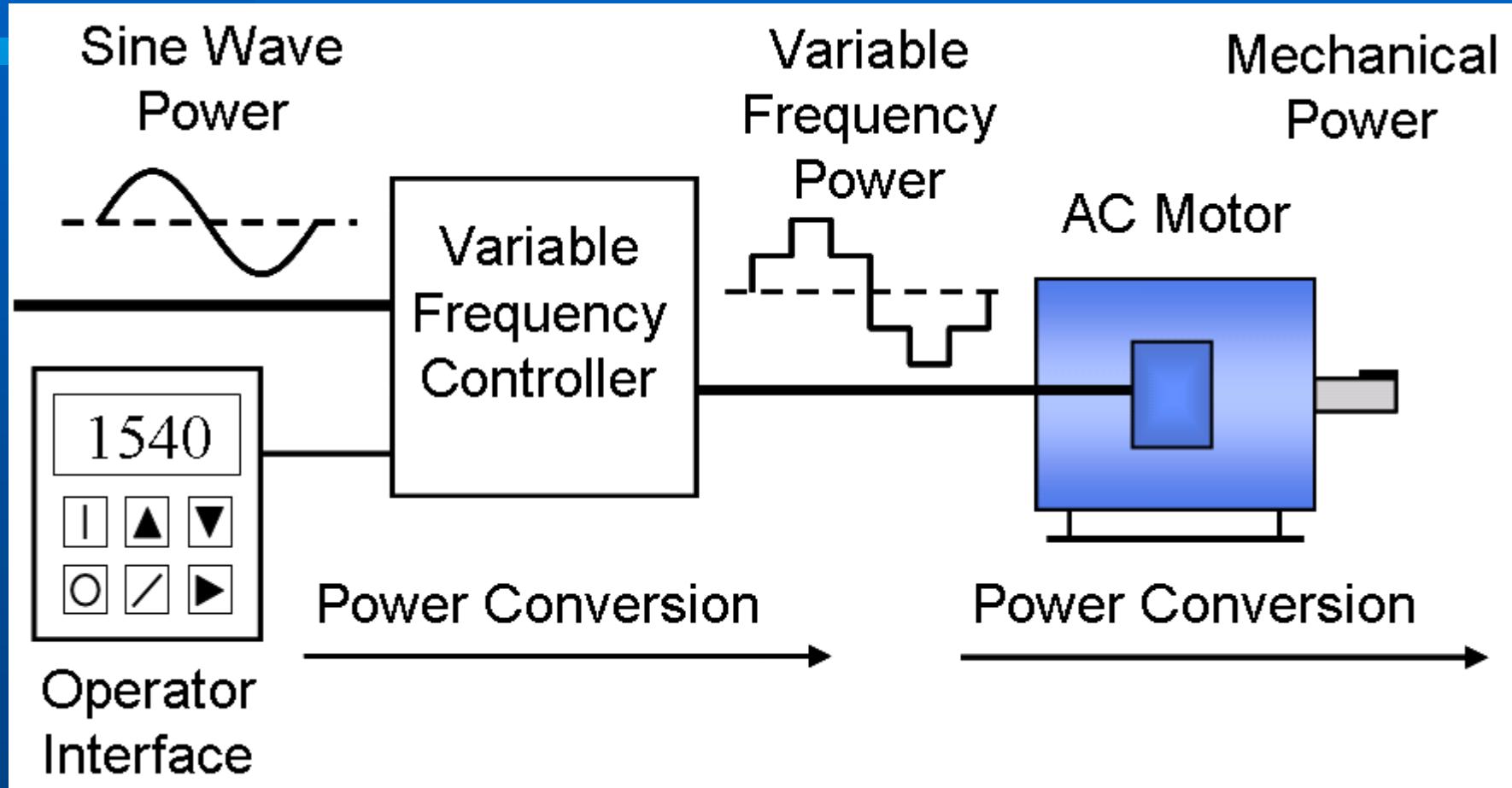
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What is a VFD?

- “Variable Frequency Drive”
 - *Other names could be:*
 - **adjustable-frequency drive;**
 - **“variable-voltage/variable-frequency (VVVF) drive”;**
 - **variable speed drive;**
 - **AC drive;**
 - **micro drive or**
 - **inverter drive.**

What is a VFD?



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What is a VFD?

- **“Variable Frequency Drive”**
 - Rectifier bridge converter (AC to DC)
 - Direct current (DC) link
 - Inverter (DC to AC)
- **Some advantages:**
 - Filtered DC is converted to AC
 - Provide higher power factor
 - Provide lower harmonic distortion
 - Longer motor life
 - Higher efficiency

What does a VFD do for a Mine Fan?

- Adjusts the speed of the motor
- Extends the life of the motor
- *Allows the fan to be operated at more efficient settings and speeds, saving:*
 - Power costs
 - Wear and tear on the fan
 - Reduced need for down-time & blade angle changes

What does a VFD do for a Mine Fan?

- Today, we are mainly interested in:
- Law 1: With SPEED Change:
(density and diameter constant)
 - Quantity changes DIRECTLY
 - Pressure changes as the SQUARE
 - Power changes as the CUBE
 - Efficiency is CONSTANT

What does a VFD do for a Mine Fan?

Fan Law 1: With SPEED (n_x) Change:

- Quantity: $Q_2 / Q_1 = n_2 / n_1$
- Static Head: $P_{s2} / P_{s1} = (n_2 / n_1)^2$
- Power at Motor: $HP_{m2} / HP_{m1} = (n_2 / n_1)^3$
- Efficiency: $Eff_2 = Eff_1$

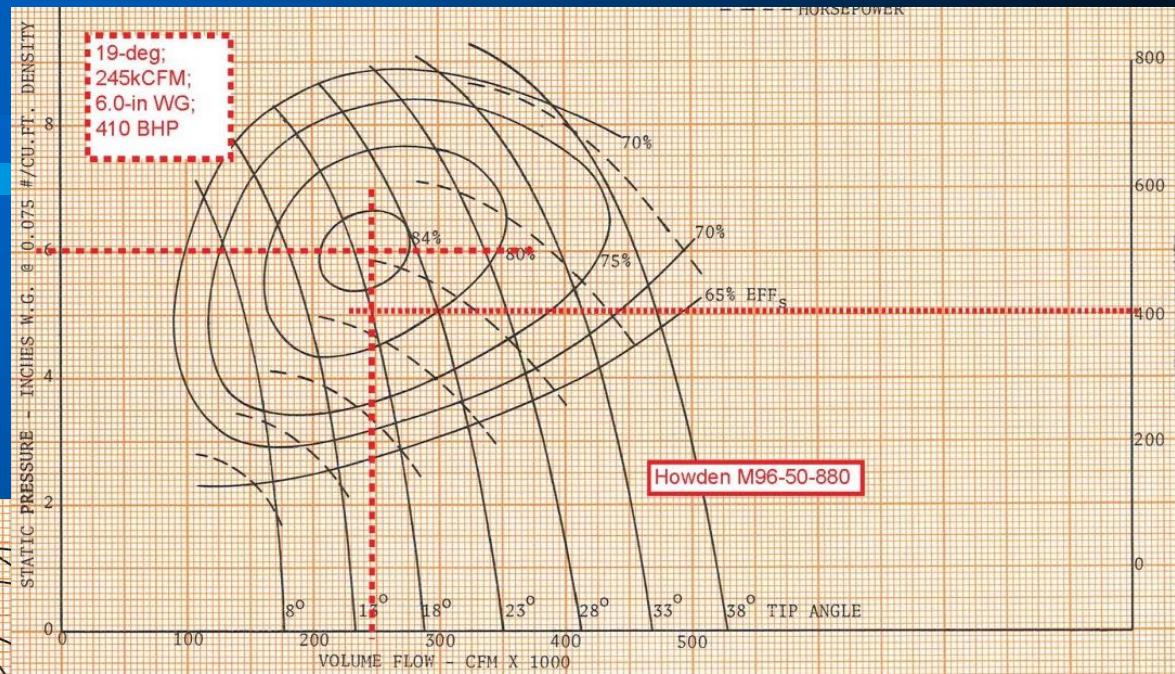
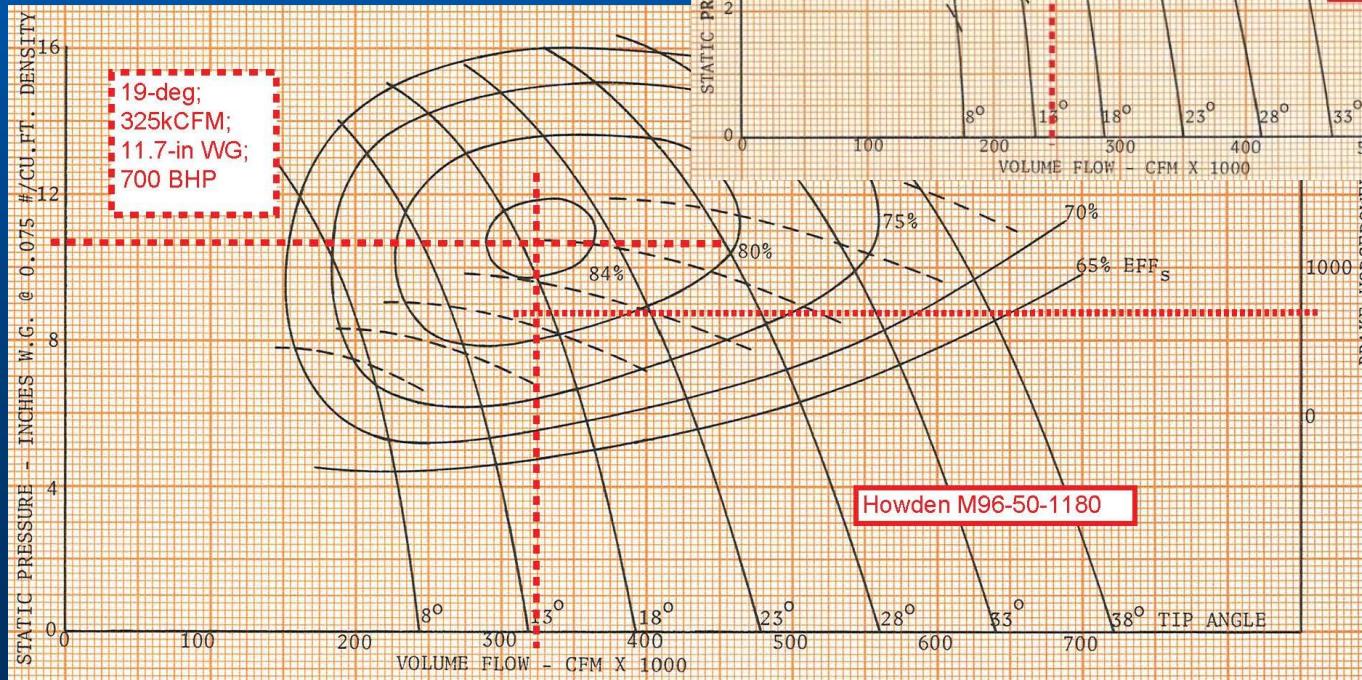
Some VFD benefits:

- The ease of changing speed with a button or knob instead of changing blade angle:
 - Reduces outages for blade changes
 - Ease of minor adjustments
- Power system stability at start-up (limiting in-rush current)
- Reduction in power system harmonics and effect
- Efficiency

Some VFD benefits:

- Power efficiency is a balance between the power used by the VFD unit (turned to heat) and the increased efficiency of the fan.
- With axial fans, it is a matter of working in the “sweet spot” as much as possible and saving up to 25% at times on power costs.

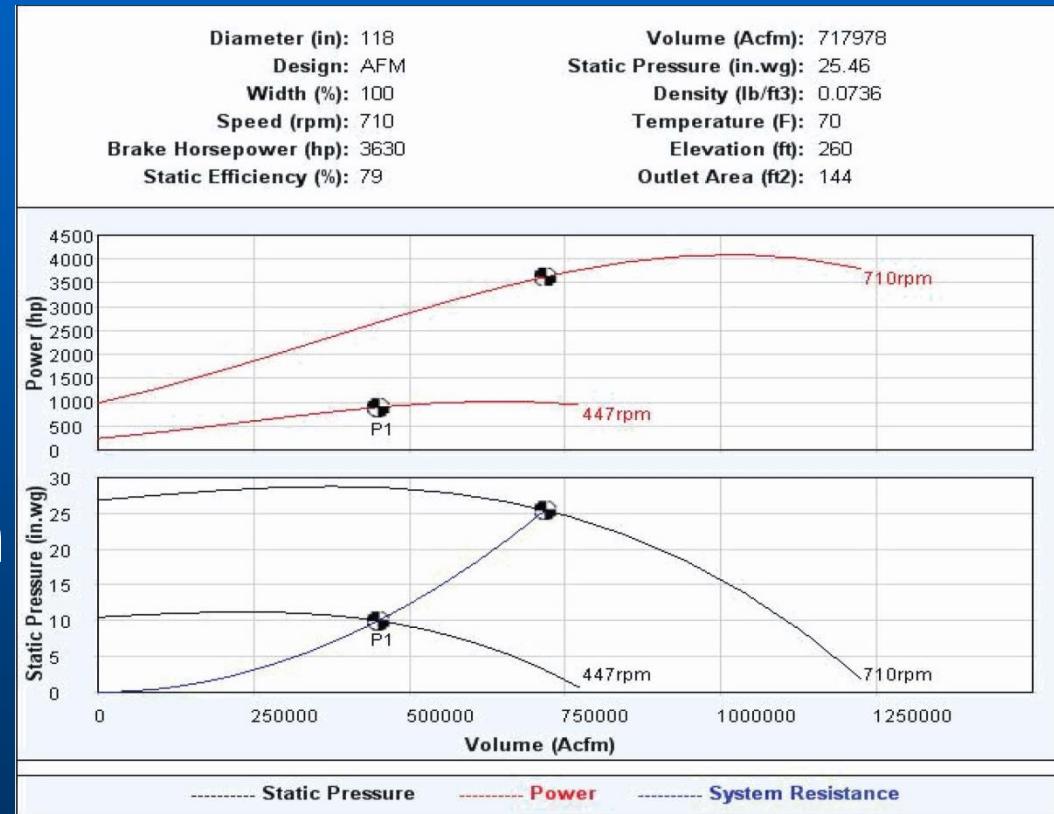
What does a VFD do for a Mine Fan?



Reference:
Howden Fans

Some VFD benefits:

- With centrifugal fans, the operating point can be selected with a damper, which is as much as a savings up to 50% at times on power costs.



Some VFD “cautions”:

- Temptation: change fan speed while people are working UG
 - §75.324 *Intentional changes in the ventilation system.*
 - What is an “intentional change” to the ventilation system?
 - (1) Alters air current that could materially affect the safety or health of persons in the mine; or
 - (2) Affects section ventilation by 9,000 cubic feet per minute of air or more
 - [(3) Affects direction of the air]

Some VFD “cautions”:

- **Ounce of Prevention: Key or Code Lock on VFD Controls**
 - Limit who has keys or codes
 - Require someone to go to the fan to change speeds?
 - Potential for hacking
 - Log changes in fan examination books

Some VFD “cautions”:

- **Ounce of Prevention: Harmonic Resonance**
- **Every object has a natural frequency**
 - “Galloping Gertie,” the Tacoma Narrows Bridge
- **In mine fans there are natural frequencies that can result in damage**
- **It is important to not operate the fan for any significant period of time at these frequencies**

Some VFD cautions:

- VFD tuning was causing floating shafts to fail



Some VFD “cautions”:

- **Other Ounces of Prevention:**
 - Careful about running motors too slowly: they may overheat due to low air flows.
 - Keep the VFD AC operating properly – keep it cool (filters, doors, vents, etc.).
 - Monitor temperature in VFD enclosures with a fan monitoring system, sound alarms when higher levels are reached.
 - Sound a caution when over- or under-speeding the motor for extended periods.

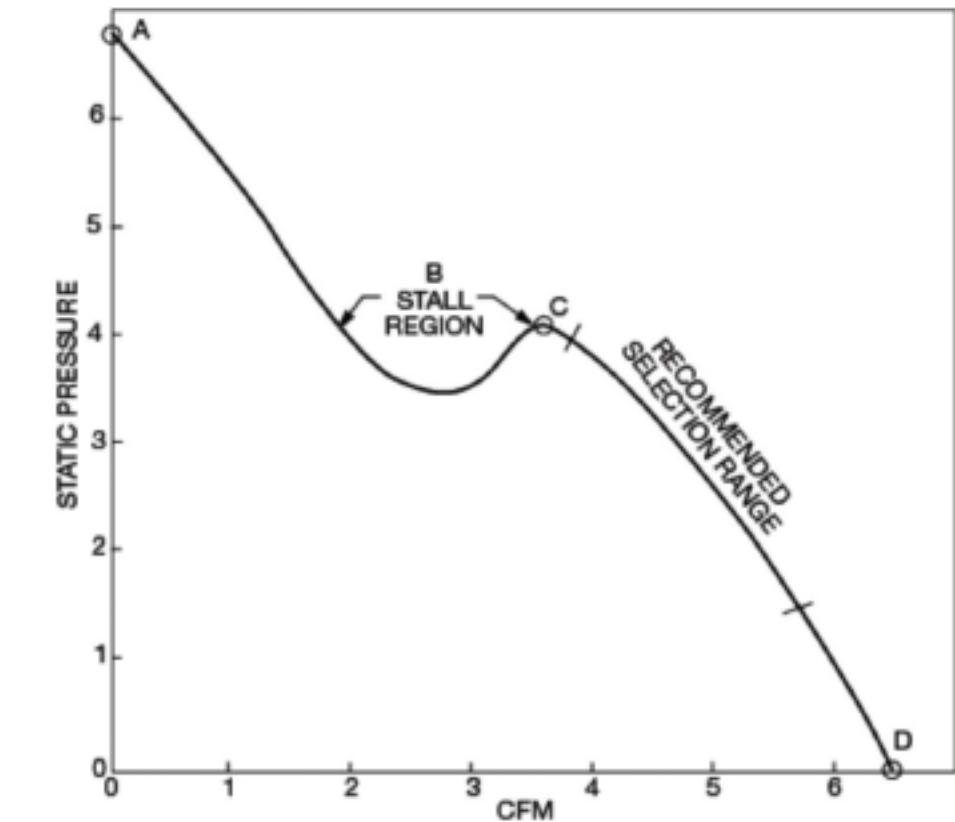
A Cautionary Tale:

- **It is common to want to set blades where they will “never need to be touched,” then adjust with the VFD!**
- **This is a management decision that may chose to ignore:**
 - Power costs
 - Efficiency
 - Motor damage (over heating at slow speed)
 - Resonance/ harmonics

A Cautionary Tale:

- It is possible to operate the fan at such a speed that it is operating “behind” the stall section of the curve.

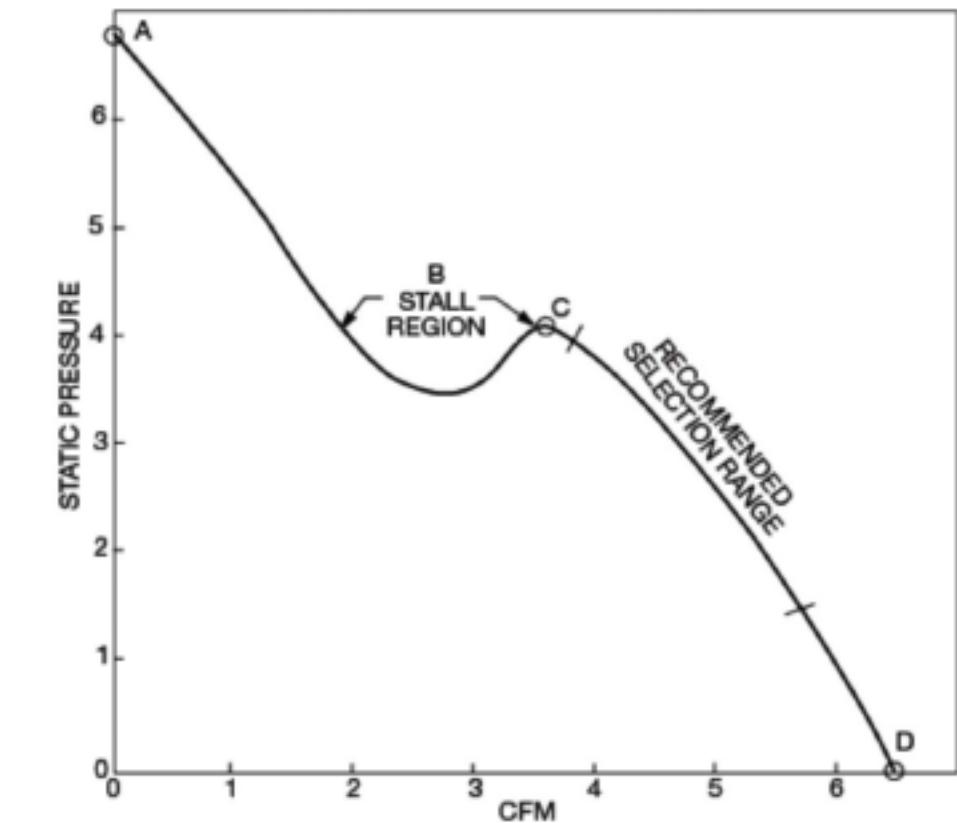
Figure 1. Static Pressure Curve, Vaneaxial



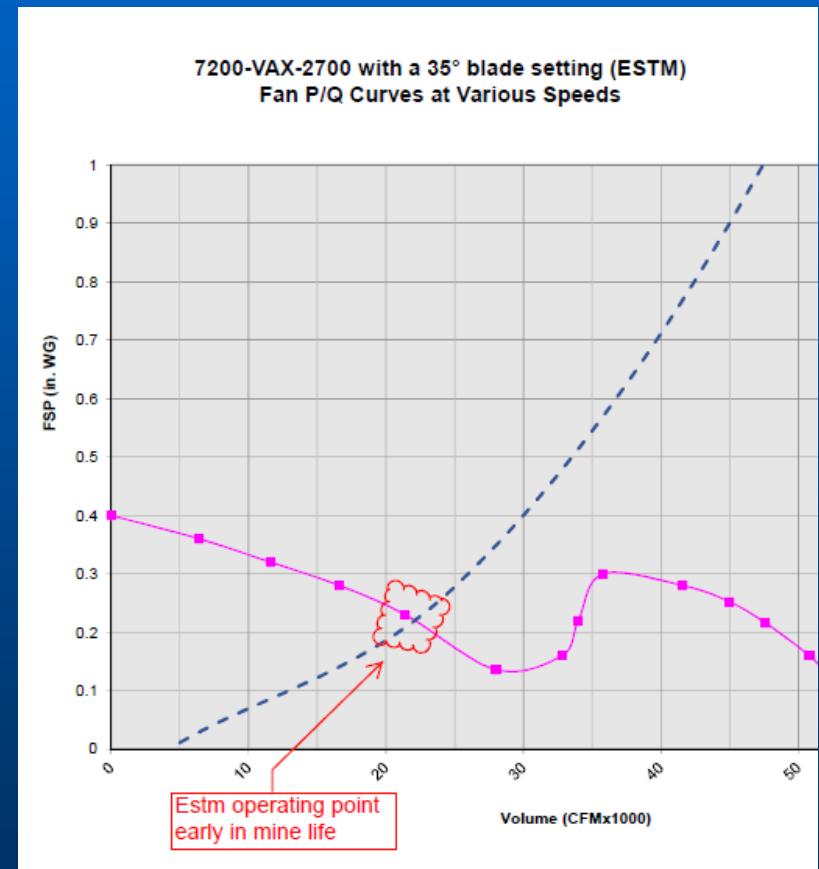
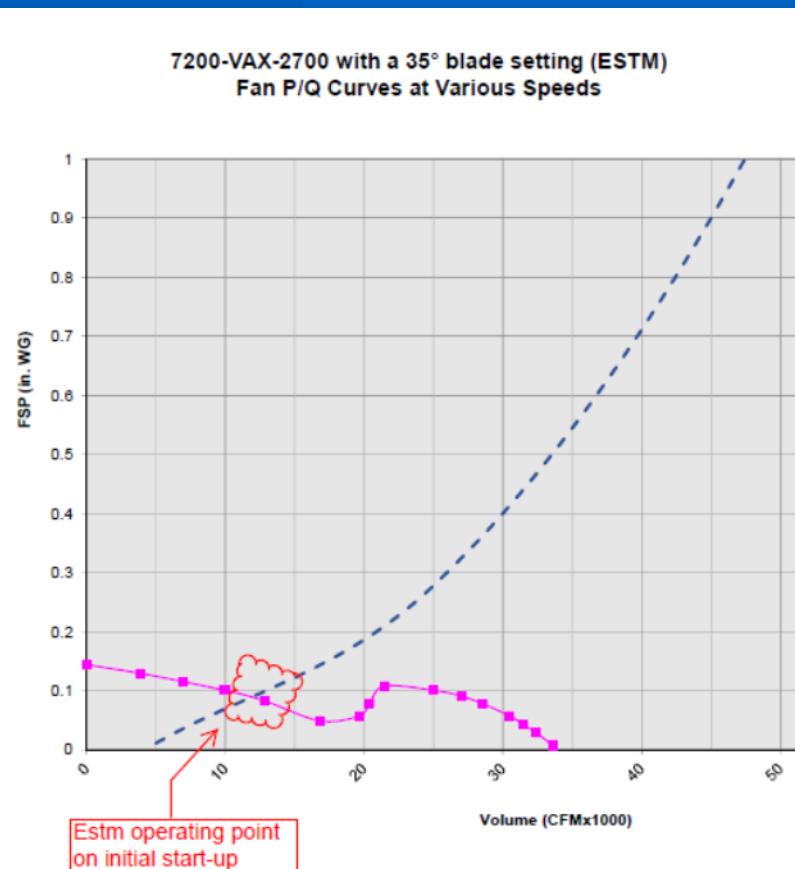
A Cautionary Tale:

- Incremental increases in speed cause the operating point to, eventually, go into the stall range.

Figure 1. Static Pressure Curve, Vaneaxial

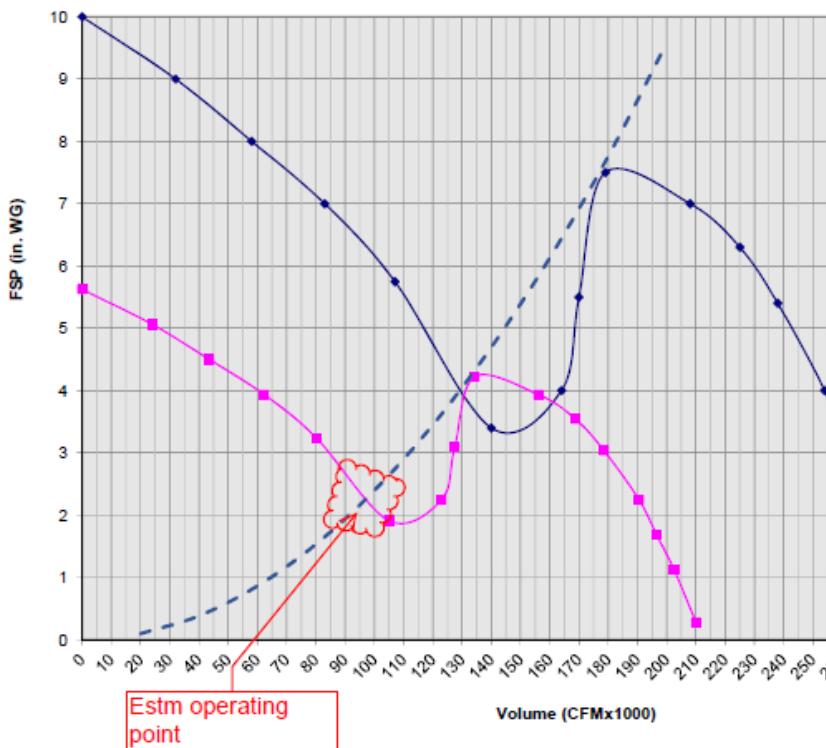


A Cautionary Tale:

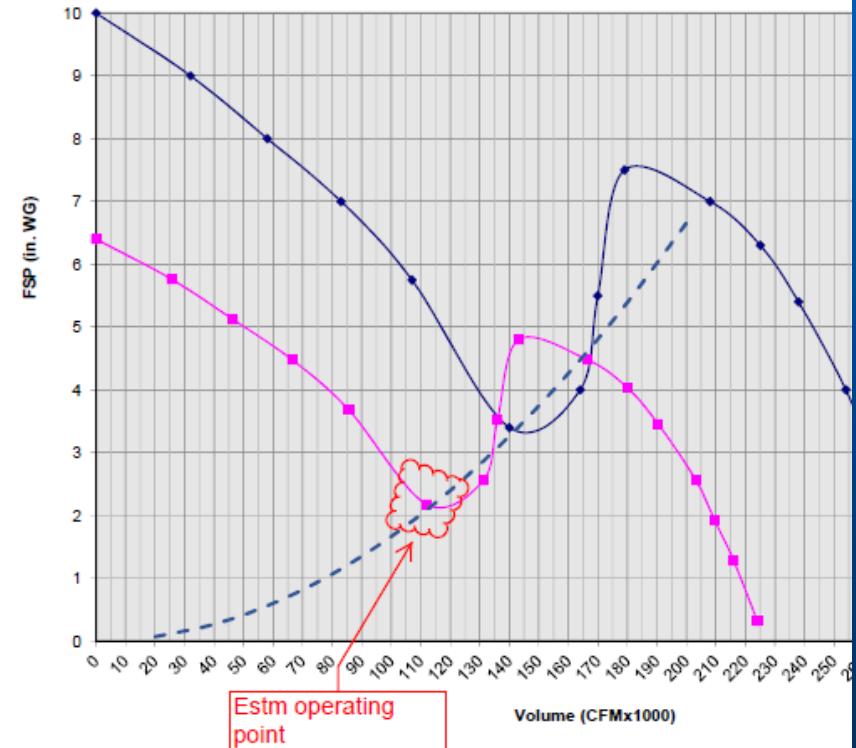


A Cautionary Tale:

7200-VAX-2700 with a 35° blade setting (ESTM)
Fan P/Q Curves at Various Speeds



7200-VAX-2700 with a 35° blade setting (ESTM)
Fan P/Q Curves at Various Speeds



A Cautionary Tale:

- Results were not good!



To Sum Up . . .

- A mine fan w/ VFD is great, but:
- Understand Motor & VFD needs:
 - Cooling, operating control, etc.
- Understand mechanical limits:
 - Harmonics
- Understand the fan:
 - Operating zone, stall zones, NVP, and fan curve

To conclude . . .

- **Understand the operating environment:**
 - MSHA regulations (intentional air change)
 - Unauthorized Access (hacking, careless (or other) employees)

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Thank-you for your kind attention

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