EFRC Training Workshop
State-of-the-art Design of Reciprocating Compressor Systems

Reciprocating Compressor Drivers

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September 13th 2018

Outline

- Typical drivers
- Not so typical drivers
- Couplings
- Flywheels

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This session of the workshop will focus on the drivers used for reciprocating compressors in oil and gas industry applications.

Typical Drivers

- Natural gas fueled engine
- Electric motor

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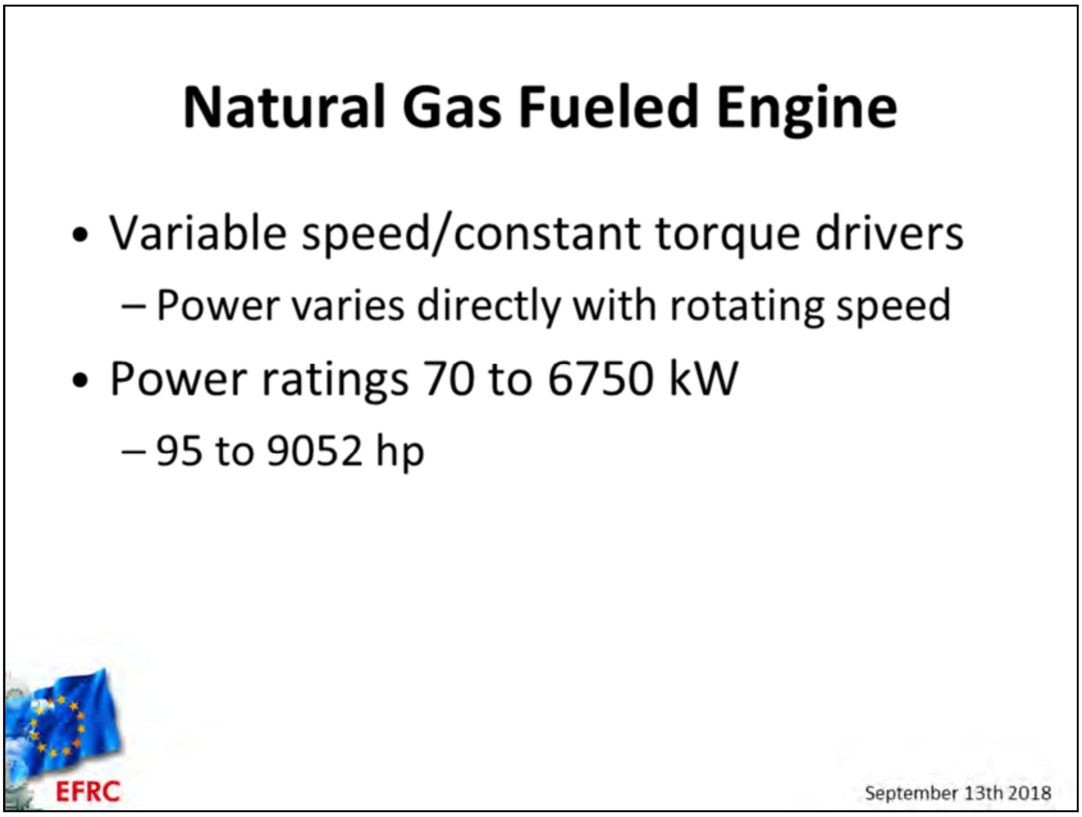
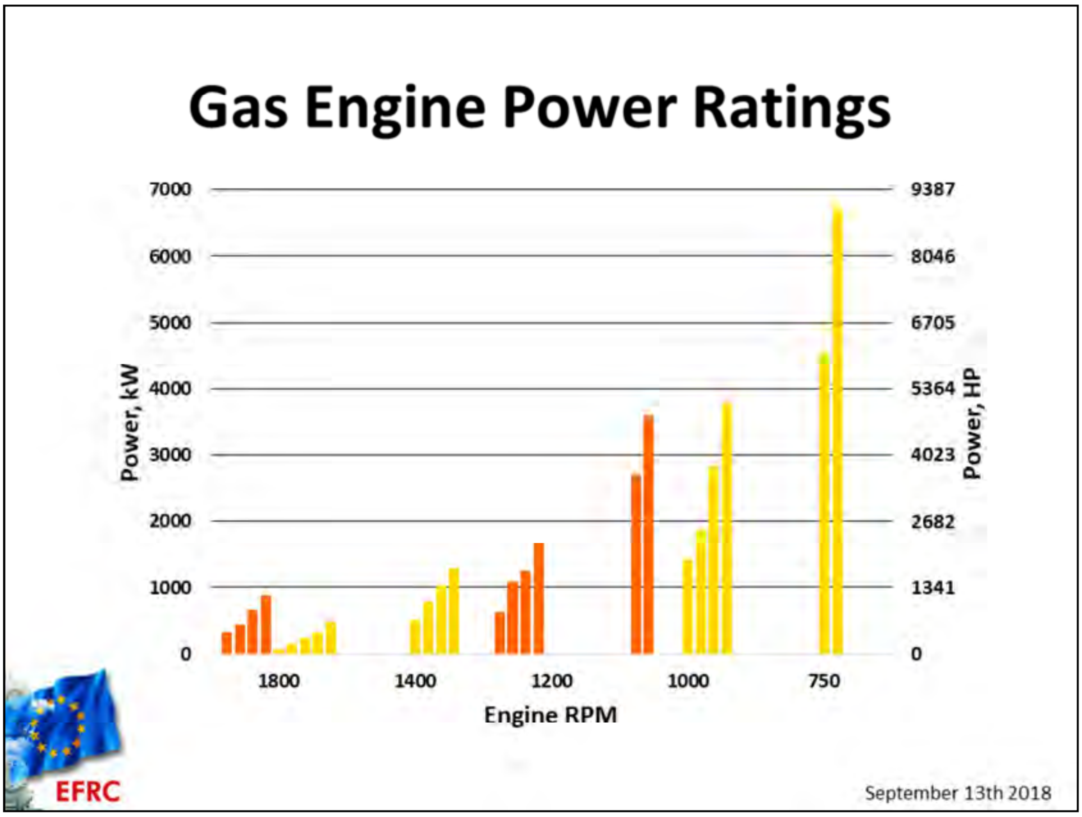
The most typical drivers are natural gas fueled reciprocating engines and electric motors. These two drivers likely account for 99% of the drivers.



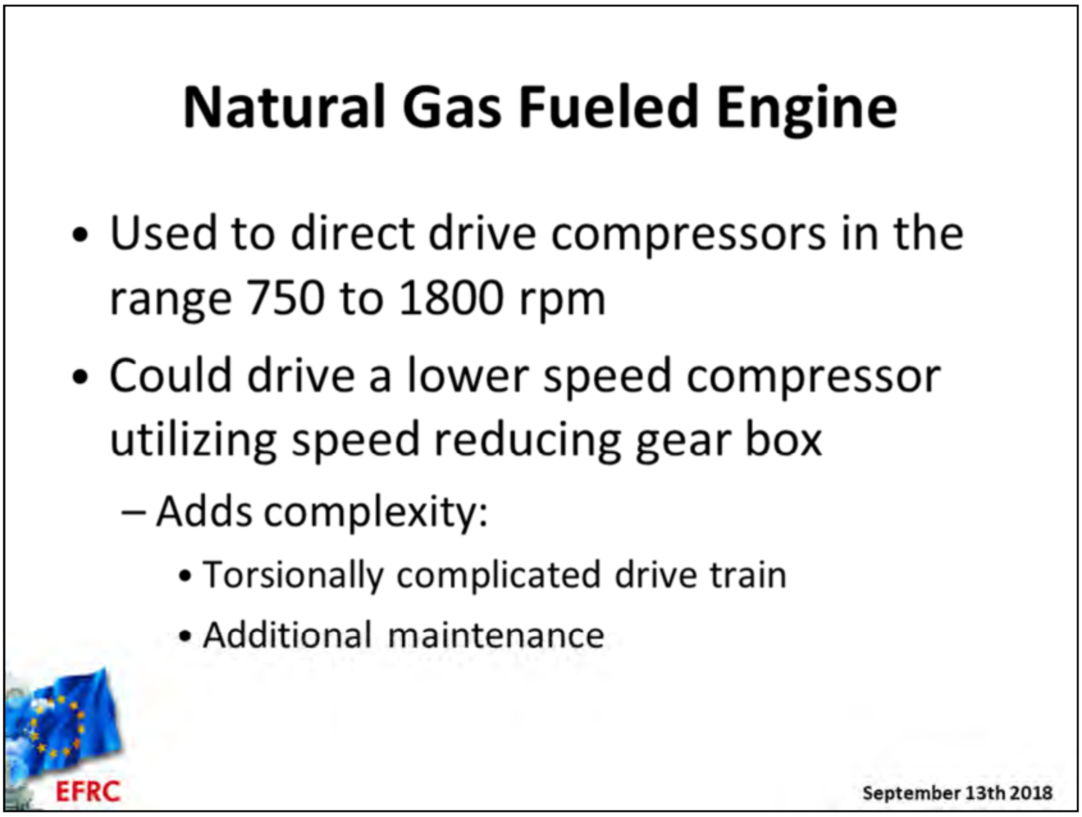
Natural gas fueled engines are variable speed/constant torque drivers – meaning the delivered power varies directly with rotating speed.

There are several manufacturers of these engines but the market is dominated by two American manufacturers. They cover a power range of 70 to 6750 kW (95 to 9052 hp).



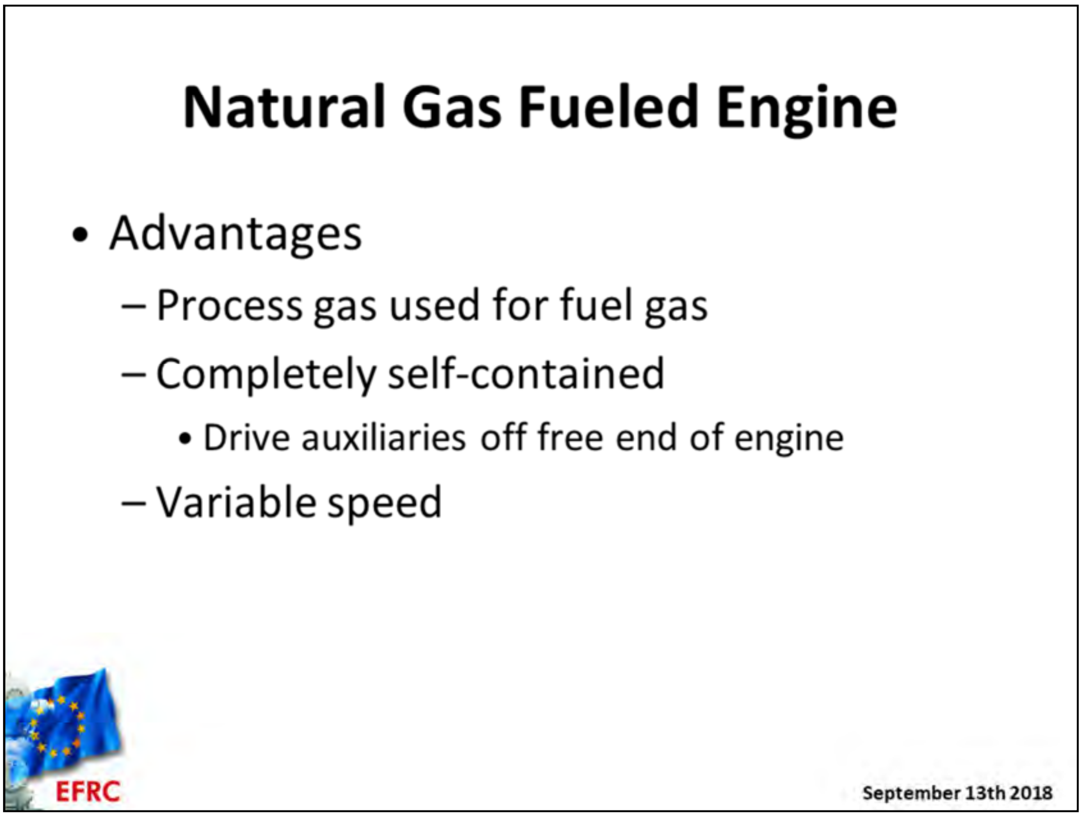
This chart plots the power of the engines available from these two manufacturers.

Note that as the rated engine rotating speed decreases the available power increases.



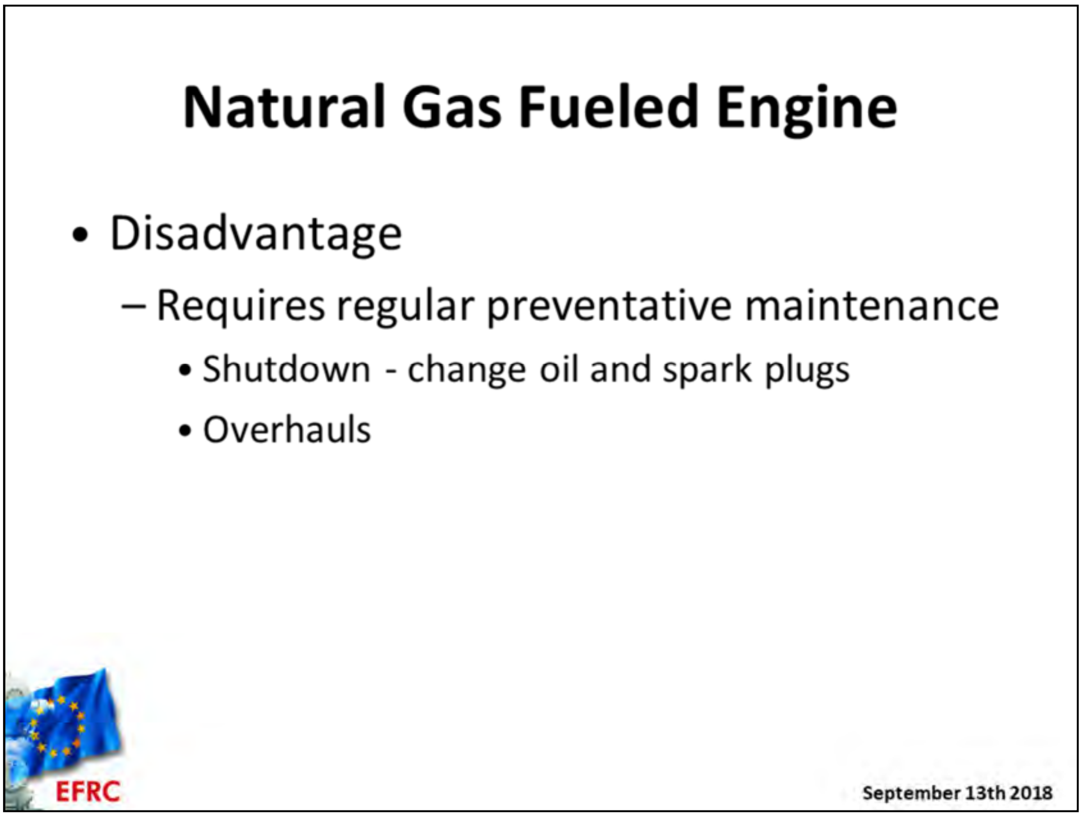
Natural gas fueled engines are quite often derivatives of engines that were originally designed as diesel engines. Most diesel engines are designed for power generation applications – meaning they are designed to run at electric 50 Hz and 60 Hz synchronous speeds, or 1800, 1200, 900 and 720 rpm for 60 Hz and 1500, 1000 and 750 rpm for 50 Hz. Therefore some compressors have been designed to run at these speeds so the engines can be direct connected to the compressor (no speed reducing gear box required). These compressors are generally known as “high-speed” compressors. These compressors have shorter strokes to achieve reasonable average piston speeds – in the 4.0 to 5.5 m/s range (800 to 1100 fpm).

Of course, a low speed long stroke compressor could be driven by one of these gas engines by utilizing a speed reducing gear box between the engine and compressor. This adds a component (the gear box) to the drive train making it more costly and complicated – especially torsionally. With this drive arrangement, a stiff coupling would be used between the engine and the gear box and a soft coupling between the gear box and compressor. The alternating torques of the recip compressor would cause rapid damage to the gear box without the soft coupling.



Natural gas fueled engines are most typically used in natural gas upstream (production) and midstream (natural gas plants) applications where the process gas (the natural gas that is being produced or refined) can be used for the engine fuel. This makes for a completely self-contained gas compression unit or system. No “outside” fuel source (like diesel fuel or electricity) is required.

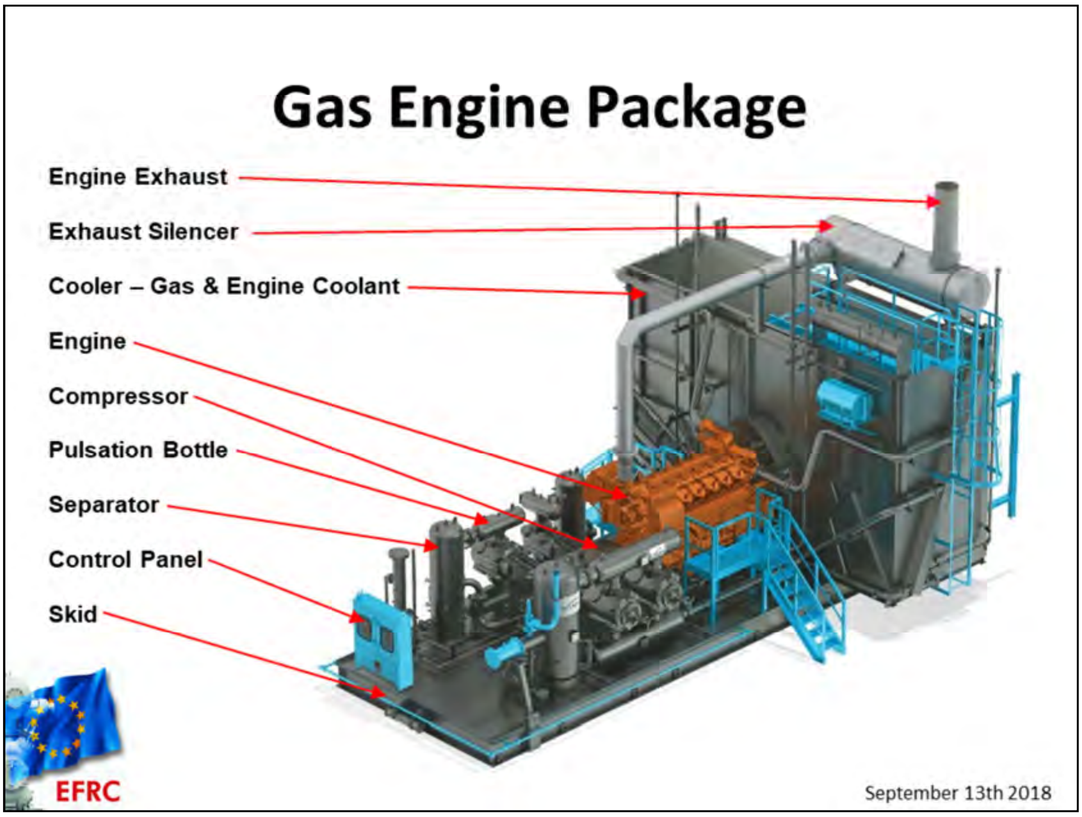
Gas engines are variable speed allowing speed control to be a primary capacity control method. The speed range is typically 20% or 25% percent. The variable speed range is limited by the design limits of the engine’s turbocharger and the effects of the turbocharger’s operation on the engine emissions and fuel economy.



A gas engine would never be used in a process application (a refinery for example) because the reliability requirements of that application could never be met with a gas engine.

A typical process application would require at least three years of completely uninterrupted run time from the compressor. A gas engine requires some very regular preventative maintenance – for example the oil in the engine crankcase must be changed roughly every three months. This means shutting down the engine to change the oil – never acceptable for a process application.

Gas engines also require some sort of overhaul every 25,000 to 50,000 hours. While this might be accommodated by a process application – the regular preventative maintenance will not.



This shows a typical natural gas fueled engine driving a reciprocating compressor as a “package” with the major components identified.

This “package” becomes a completely self-contained gas compression system. Only two connections must be made – process gas into the package and process gas out. Everything else that is required for this machine to operate is contained on this package.

Electric Motor

- Mostly fixed speed and constant torque
- Can be variable speed with adjustable speed drives
  - Variable frequency drive (VFD)
  - Are other devices to vary speed but not used to drive recips

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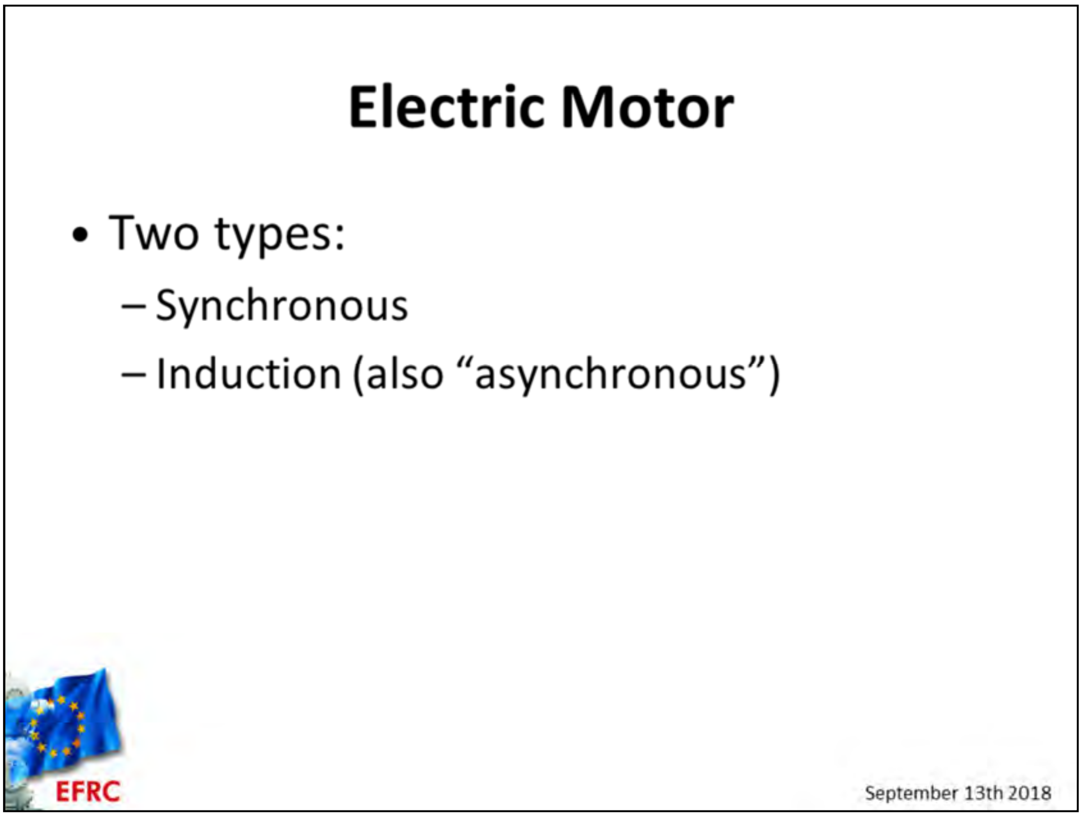
Electric motors are the next most common driver of oil and gas industry recips.

Most are fixed speed and all are constant torque.

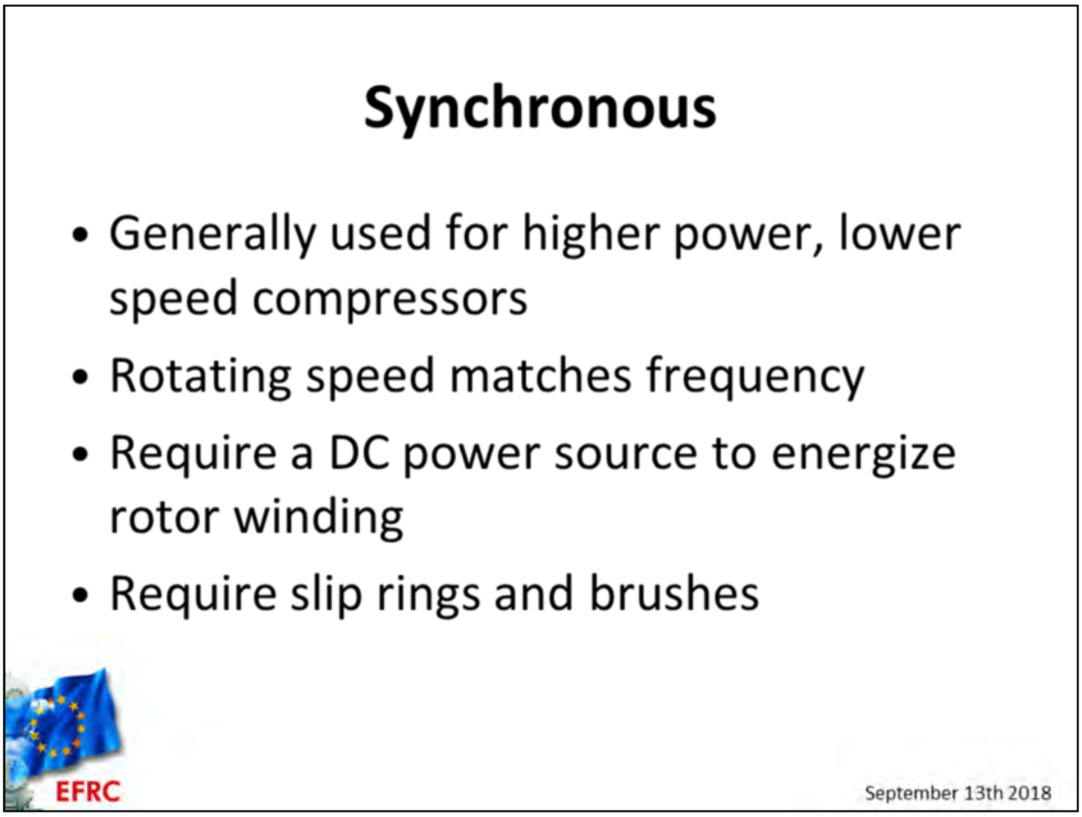
Some are variable speed and that is accomplished by using a variable frequency drive (VFD).

There some other devices that provide variable speed, electrical and hydraulic, but the VFD is the only one used for oil and gas industry recip applications.

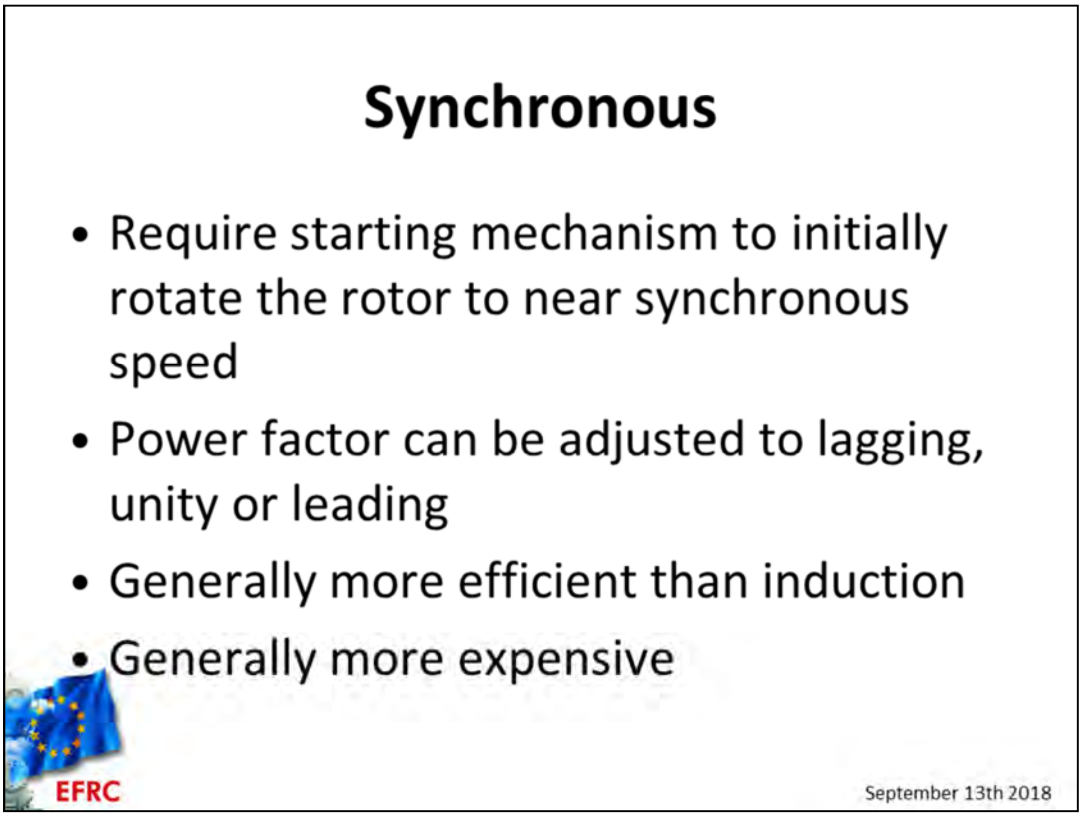


Two types of electric motors – synchronous and induction (also referred to as asynchronous).

How each works is beyond the scope of this training.



Synchronous motors tend to be used for higher power lower speed recips. Because of that, induction motors are much more common.



Because of all the extra components required in a synchronous motor it is generally more expensive. The efficiency advantage it has over an induction motor then evaluates to more operating cost savings making them easier to justify for higher power applications.

Induction

- Generally used for lower power, medium and higher speed compressors
- Rotating speed does not match frequency
  - 1% lower (1% “slip”)
- Always runs at lagging power factor

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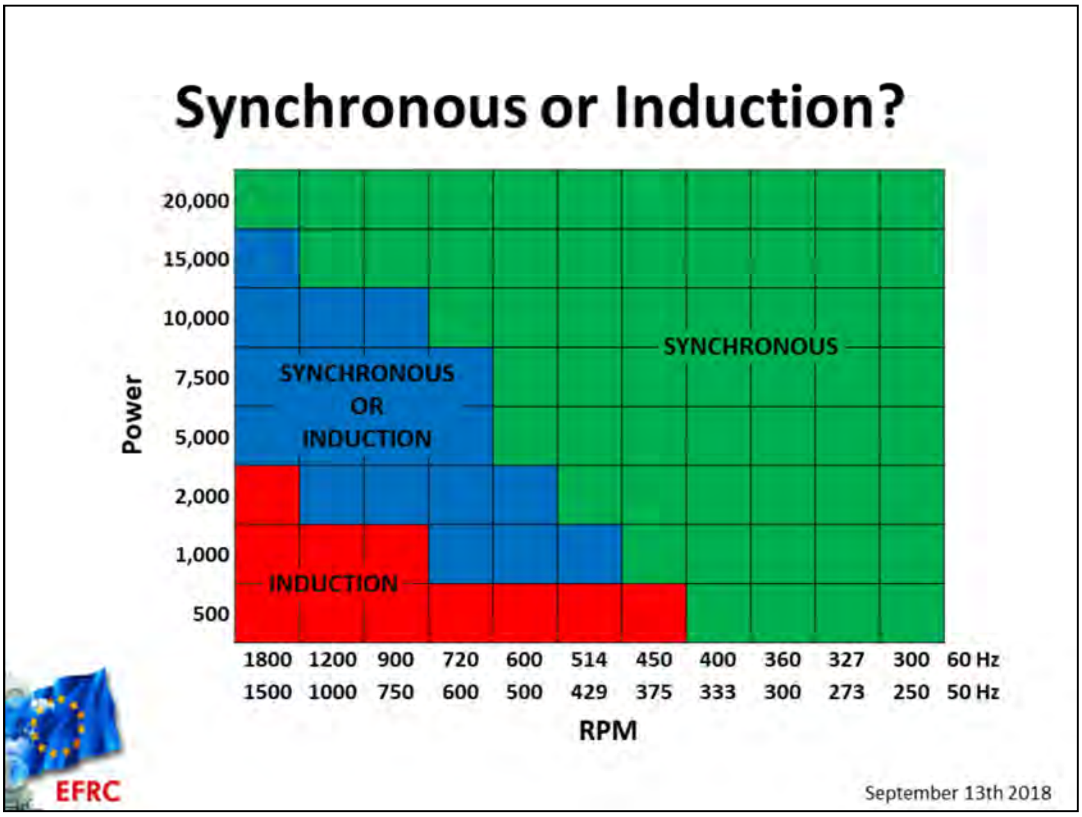
As mentioned previously, induction motors are much more common in oil and gas industry applications.

The real rotating speed of an induction motor is about 1% less than would be expected by the frequency of the power.



This is a chart that provides an idea of what type motor is used for a specific power and speed combination.

Rotating Speeds

	Synchronous		Induction	
No. of Poles	60 Hz	50 Hz	60 Hz	50 Hz
4	1800	1500	1782	1485
6	1200	1000	1188	990
8	900	750	891	743
10	720	600	713	594
12	600	500	594	495
14	514	429	509	424
16	450	375	446	371
18	400	333	396	330
20	360	300	356	297
22	327	273	324	270
24	300	250	297	248

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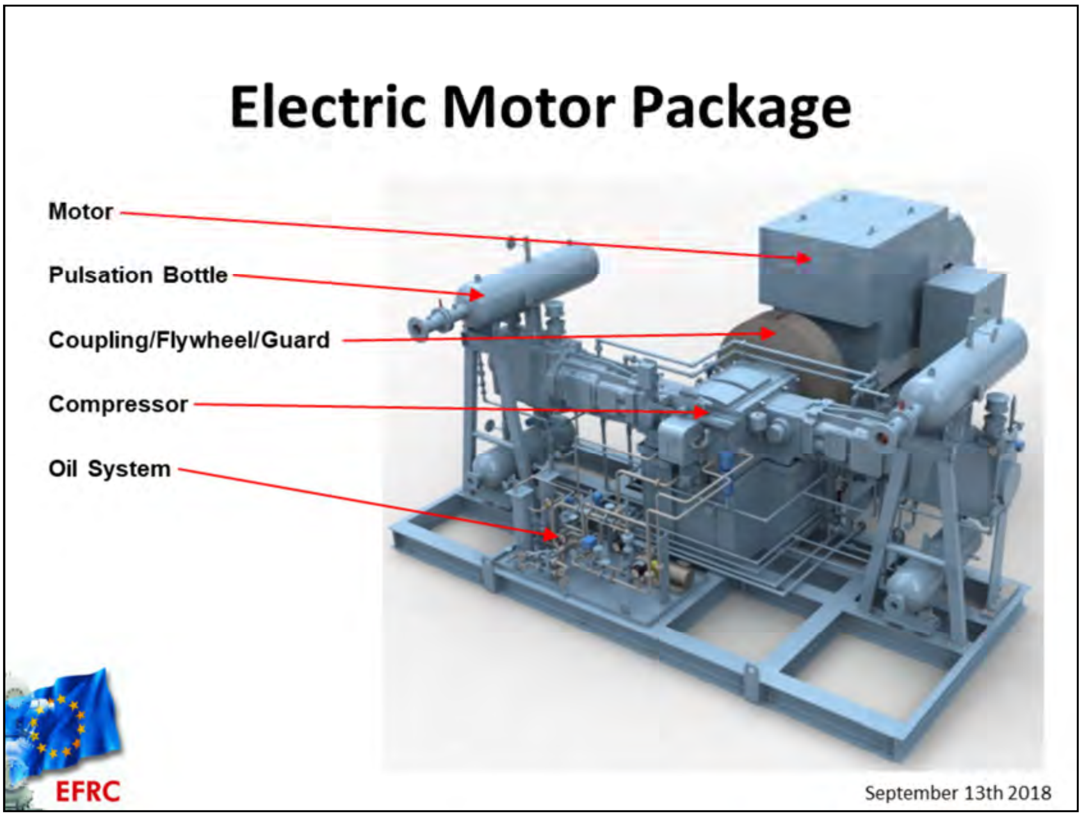
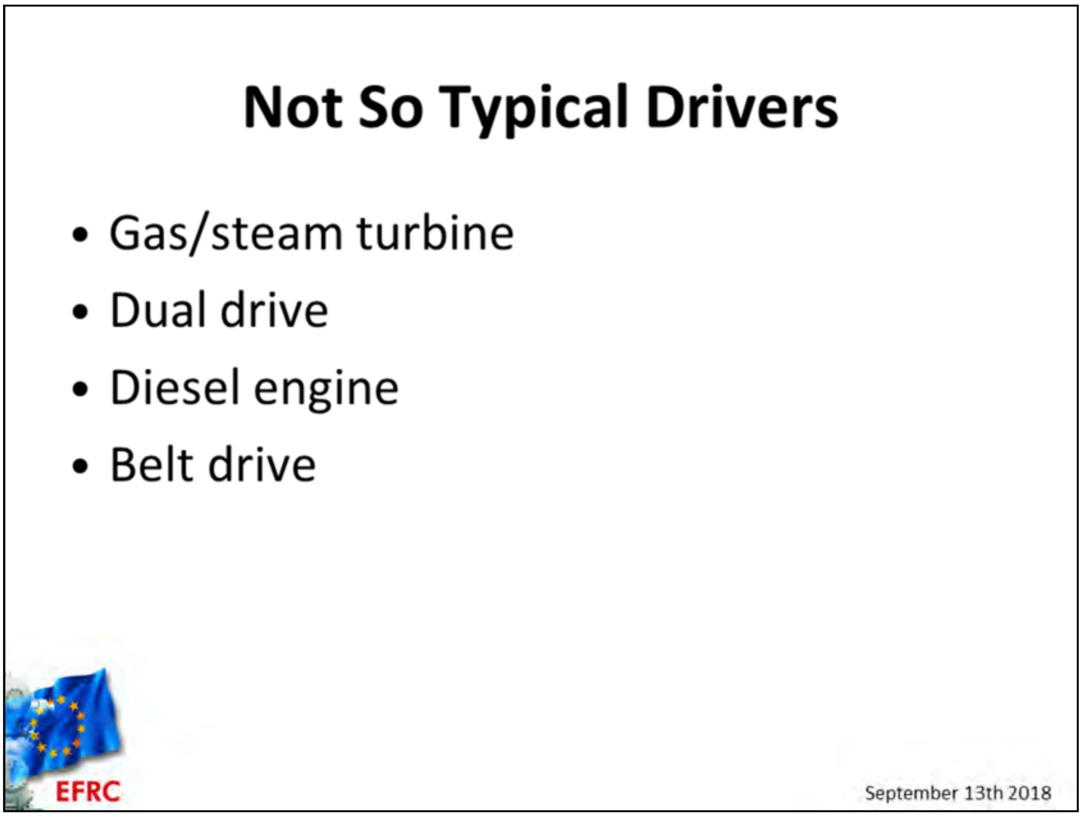
This table shows the rotating speeds of synchronous and induction motors for 50 Hz and 60 Hz frequencies. The numbers for the induction motors include the 1% "slip".



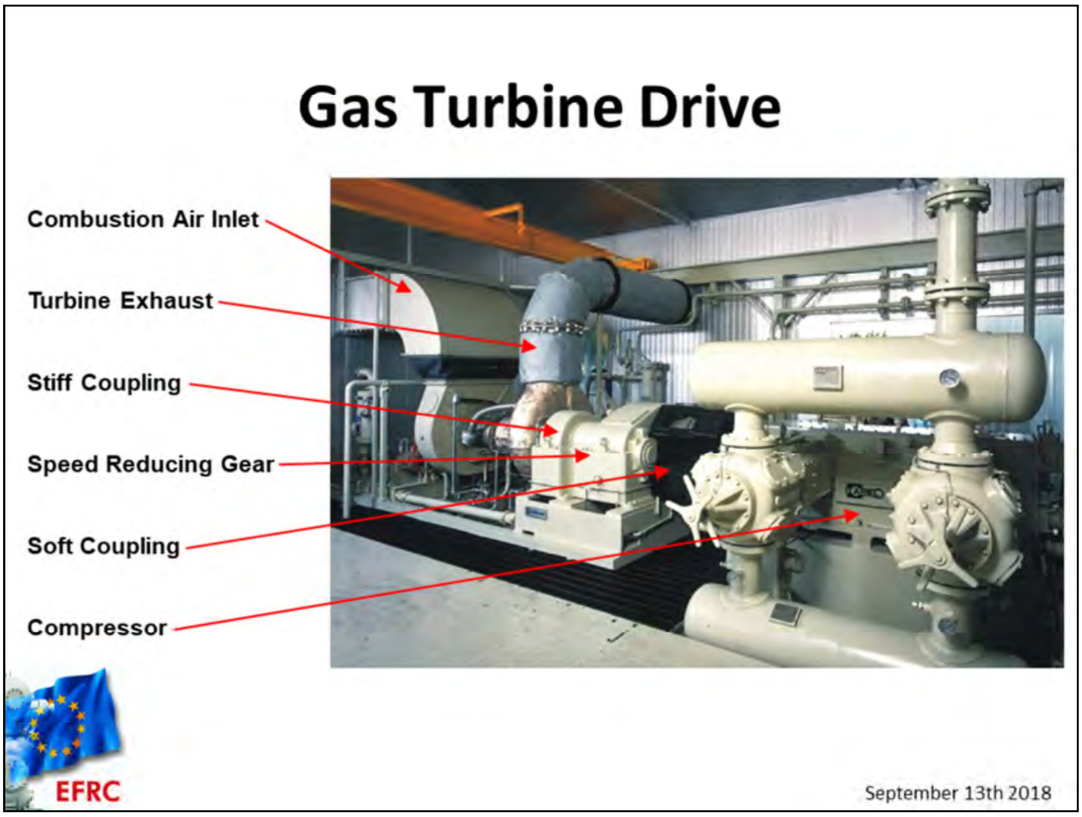
This is a drawing of an electric motor driven recip compressor package. Obviously very similar to a gas engine drive package.



There are other drivers that have been used for recips – gas and steam turbines, diesel engines, and belts.

A relatively new configuration is the dual drive.

All these drivers would be used in very unique situations.



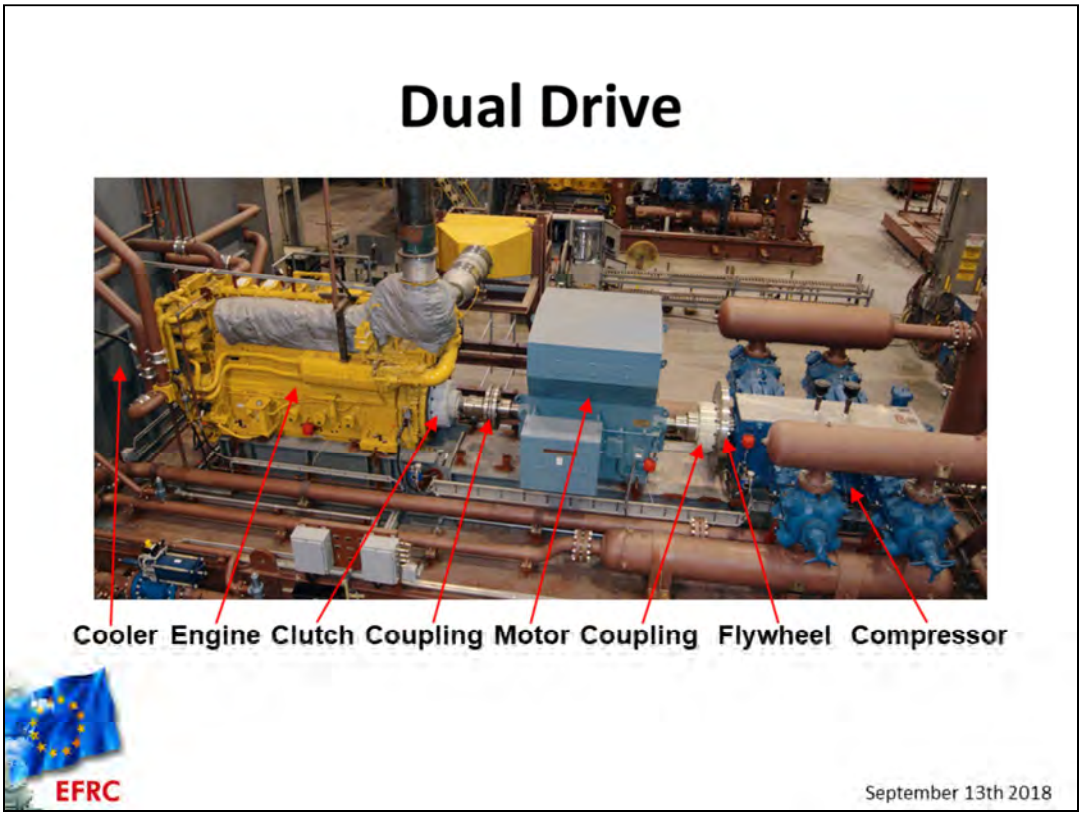
This is a photo of a gas turbine driving a recip compressor.

A speed reducing gear must be used to step down the speed from the turbine to the recip. This adds complexity to the drive train.

One of the reasons a turbine was preferred is that natural gas with a small quantity of H_2S can be burned in the jet engine. A reciprocating engine typically cannot accept any H_2S in the fuel gas.

Further, a gas turbine does not have the regular preventative maintenance requirements that a gas engine has.

A steam turbine drive is very similar to the gas turbine. Steam turbine drives were common when process facilities produced more steam than that required by the process so it could be used to drive rotating equipment. Not as common today as it was 40 or more years ago.

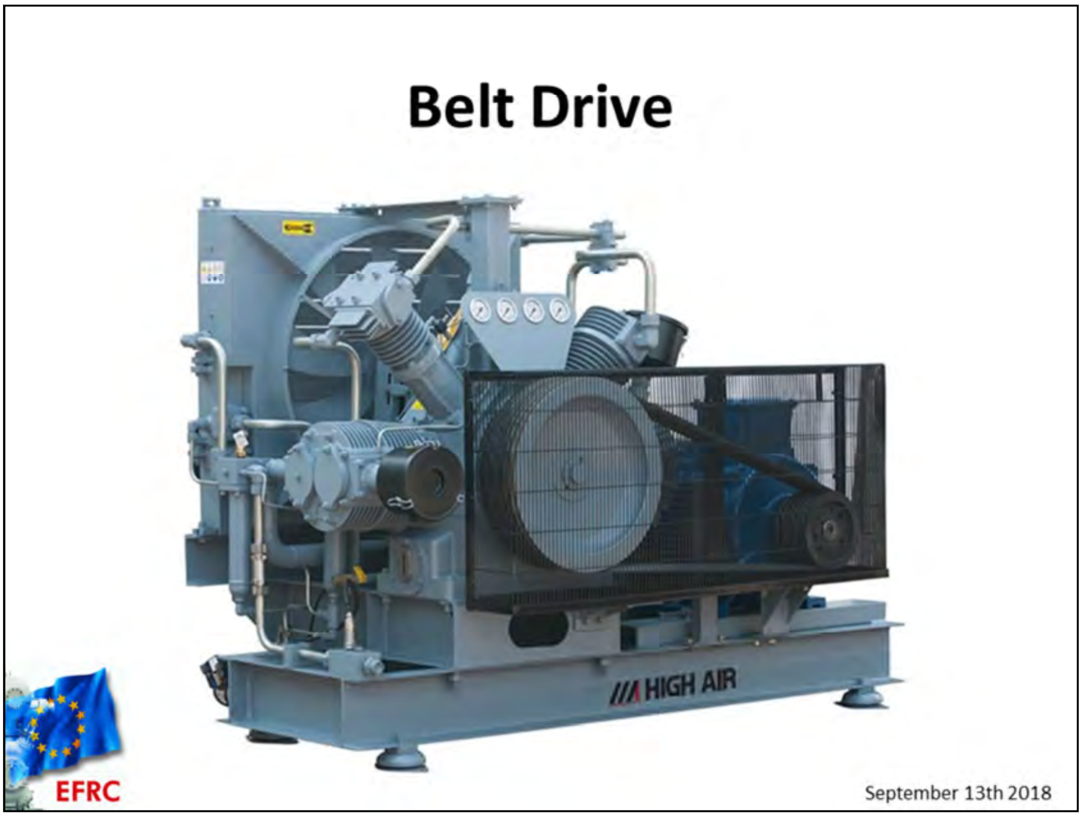


This is a very unique drive arrangement.

The compressor can be driven by either an electric motor or a gas engine. There is a clutch between the engine and the motor allowing the engine to be disengaged from the motor.

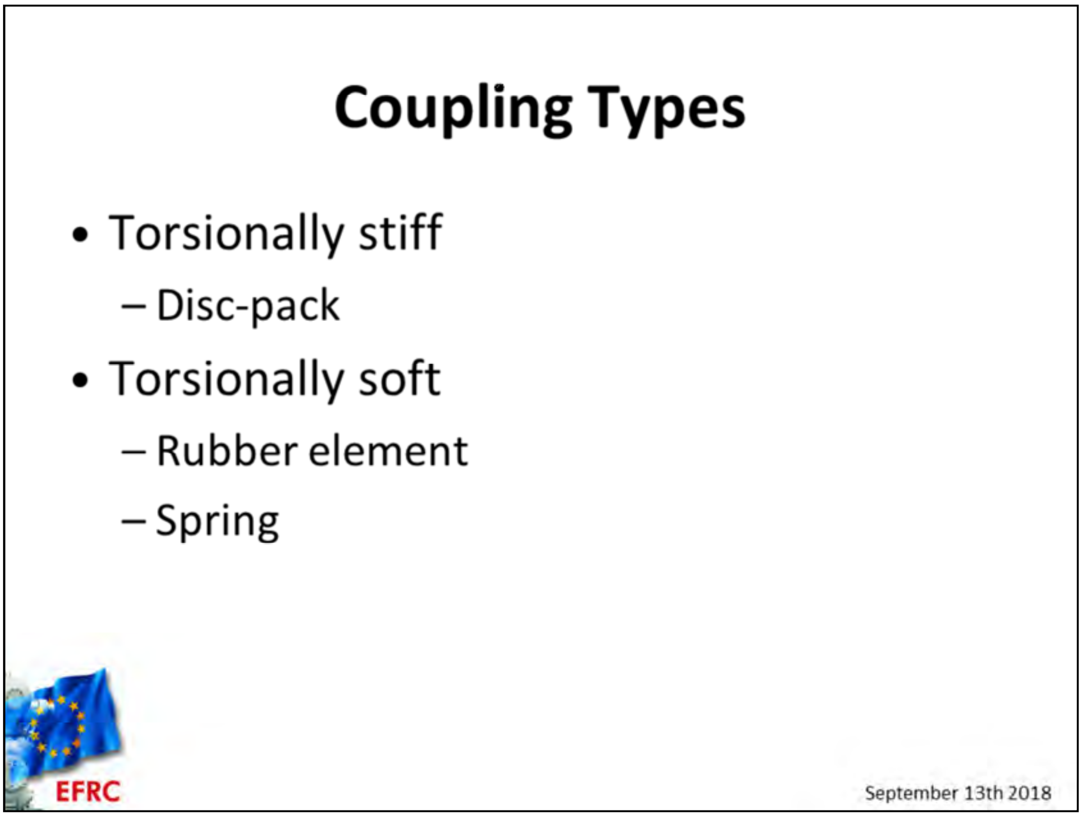
This arrangement is used to take advantage of the very low cost of electricity during the night or other periods of very low electric power demand.

The drive train is obviously complicated, but has the possibility to significantly lower operating costs.



Belt drive are very common with small recips – say below 75 kW (100 hp).

The belts put a side load on the first compressor main bearing so the compressor crankshaft and main bearings must be designed for this type of drive.



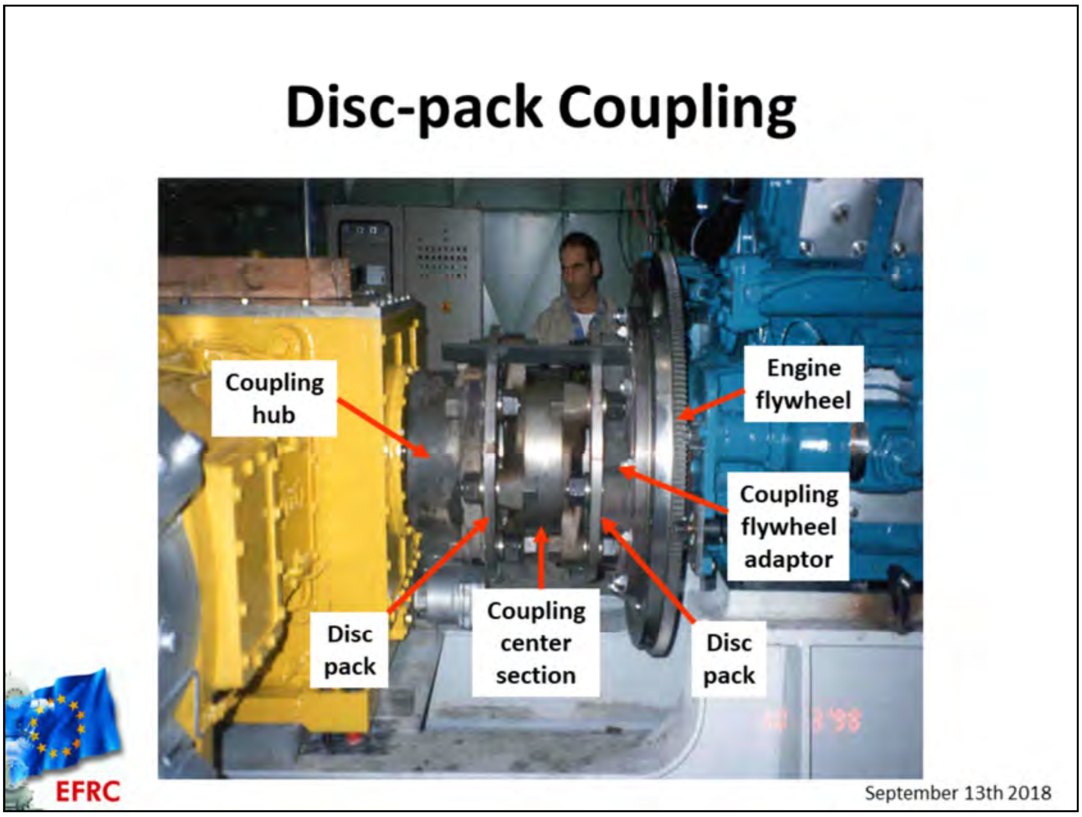
Couplings are an important element of the compressor drive system.

Couplings are generally categorized as being “stiff” or “soft”.

The most common coupling used for engine or electric motor drives is the torsionally stiff disc-pack style.

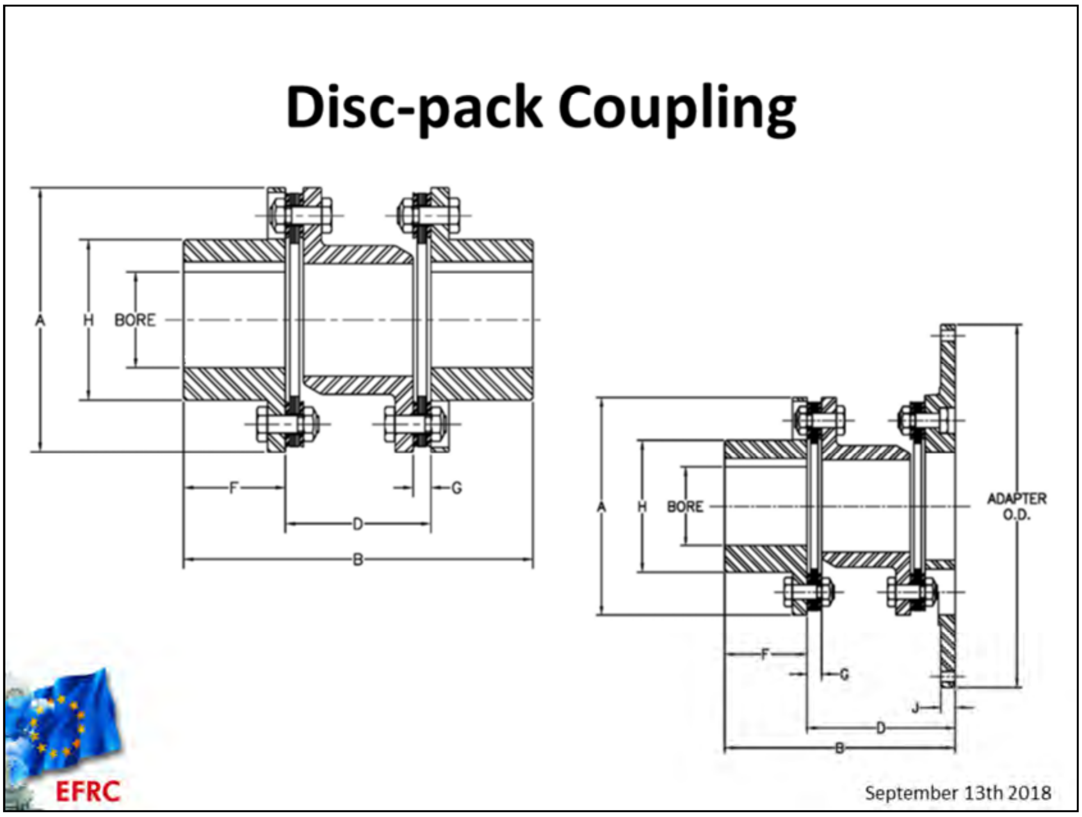
Torsionally soft couplings include rubber element and metallic (or spring) designs.

A torsional analysis is very important to perform for every recip/driver application. The analysis will define the required coupling type (stiff or soft), whether or not a flywheel is required, and provide a recommended size for a flywheel.



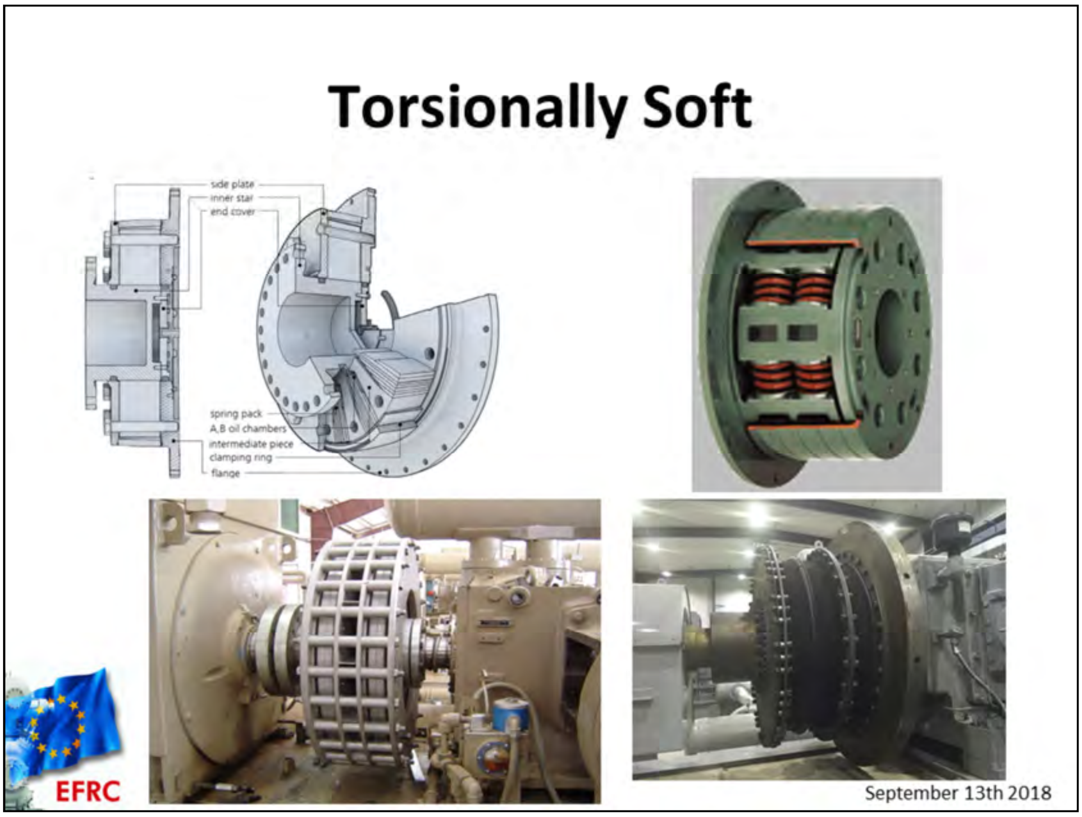
This is a photo of a disc-pack style coupling in an engine drive configuration.

The “disc-pack” is a stack of thin (about 9.5 mm, 0.03125 inch) metallic plates (or discs). The disc-pack is alternately attached to the hub and to the center section. This attachment method allows for some flexibility and small misalignment.



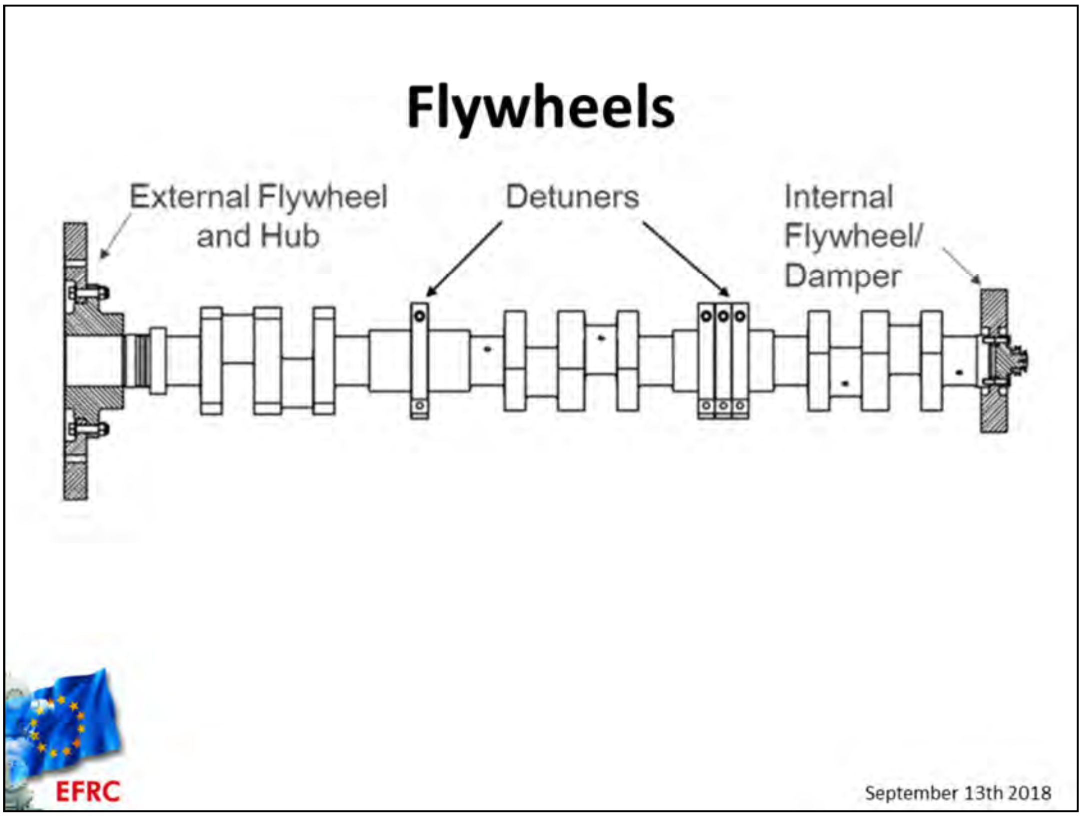
Generally two types of disc-pack couplings:

1) Hub and hub
2) Hub and flange. The flange allows connection to a flywheel, which is very common on engine drives.



Torsionally soft couplings generally are available in two types – elastomer element (or rubber) and metallic element.

Rubber element style will not work well in a recip application. The torque fluctuation generated by a recip will create significant energy in the coupling which, in one way, manifests as heat in the rubber elements. This heat causes the rubber to break down and eventually fail.



Flywheels are another important piece of the compressor drive train.

There can be three types of flywheels:
1) External o the drive end (most common)
2) Internal on the free end of the crankshaft
3) “Detuners”

Flywheels

- Used to move the resonant frequency off running speed
- Flywheel attached to the free end of the crankshaft is most effective
- Used to reduce speed oscillation

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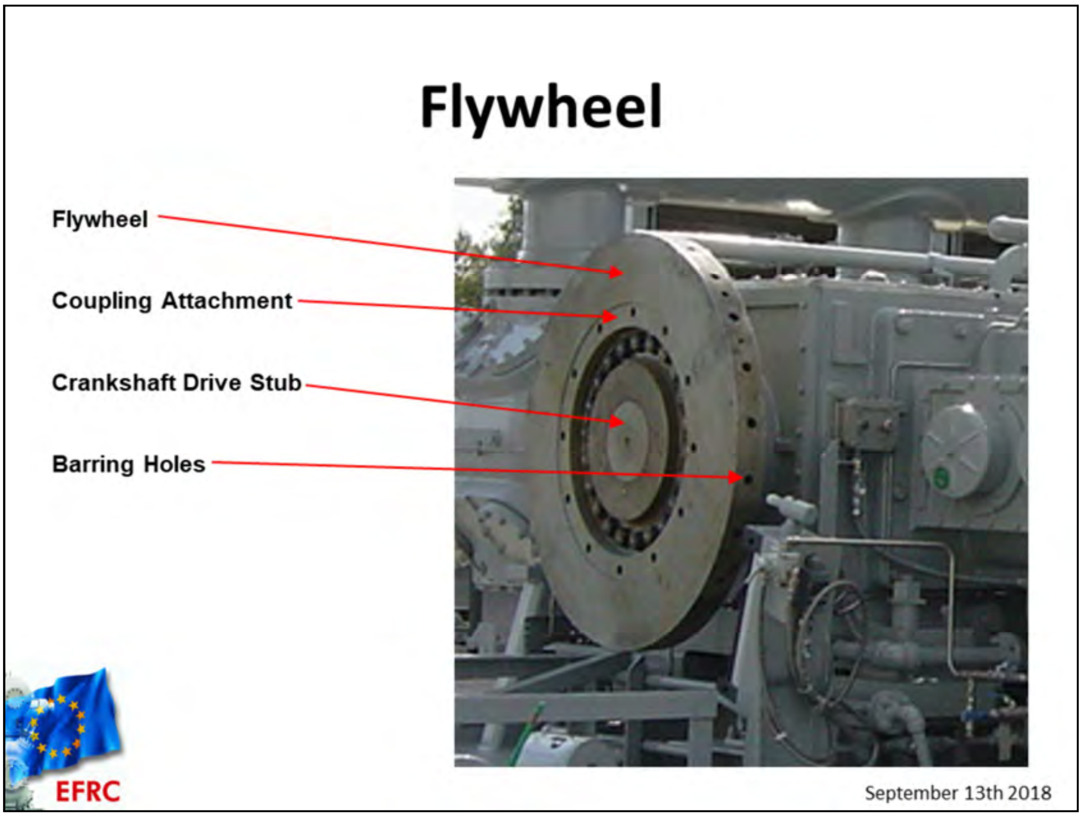
Fundamentally, the inertia of the flywheel moves the drive train resonant frequency off (or away from) the running speed.



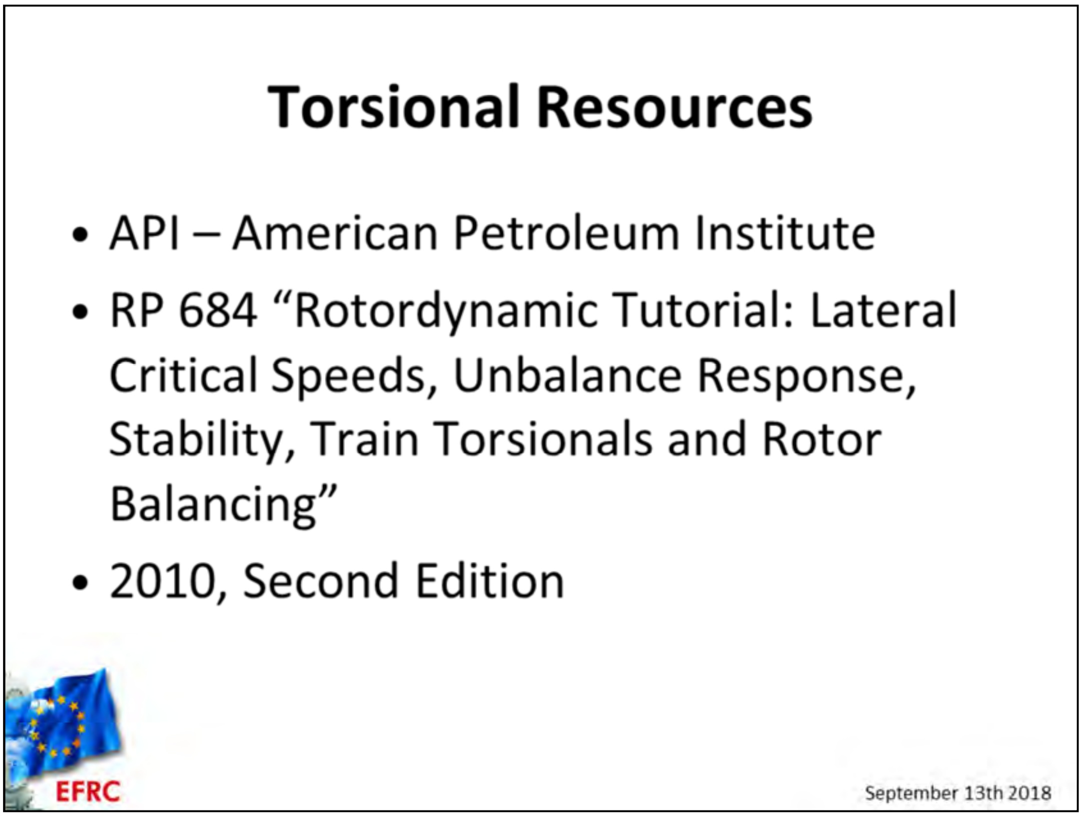
This is a photo of an external flywheel mounted on the drive end of a recip.

There a bolt circle of the face to accommodate attaching the coupling.

There are holes drilled radially into the outside diameter to provide for a barring over function.

Two industry resources exist to assist in better understanding torsional analysis:

One was published in 2015 by the Gas Machinery Research Council (GMRC) titled "Guideline and Recommended Practice for Control of Torsional Vibrations in Direct-Driven Separable Reciprocating Compressor "



The other was published by the American Petroleum Institute (API) titled "API RP 684 Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals and Rotor Balancing".

"RP" means recommended practice – it is not a standard.

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