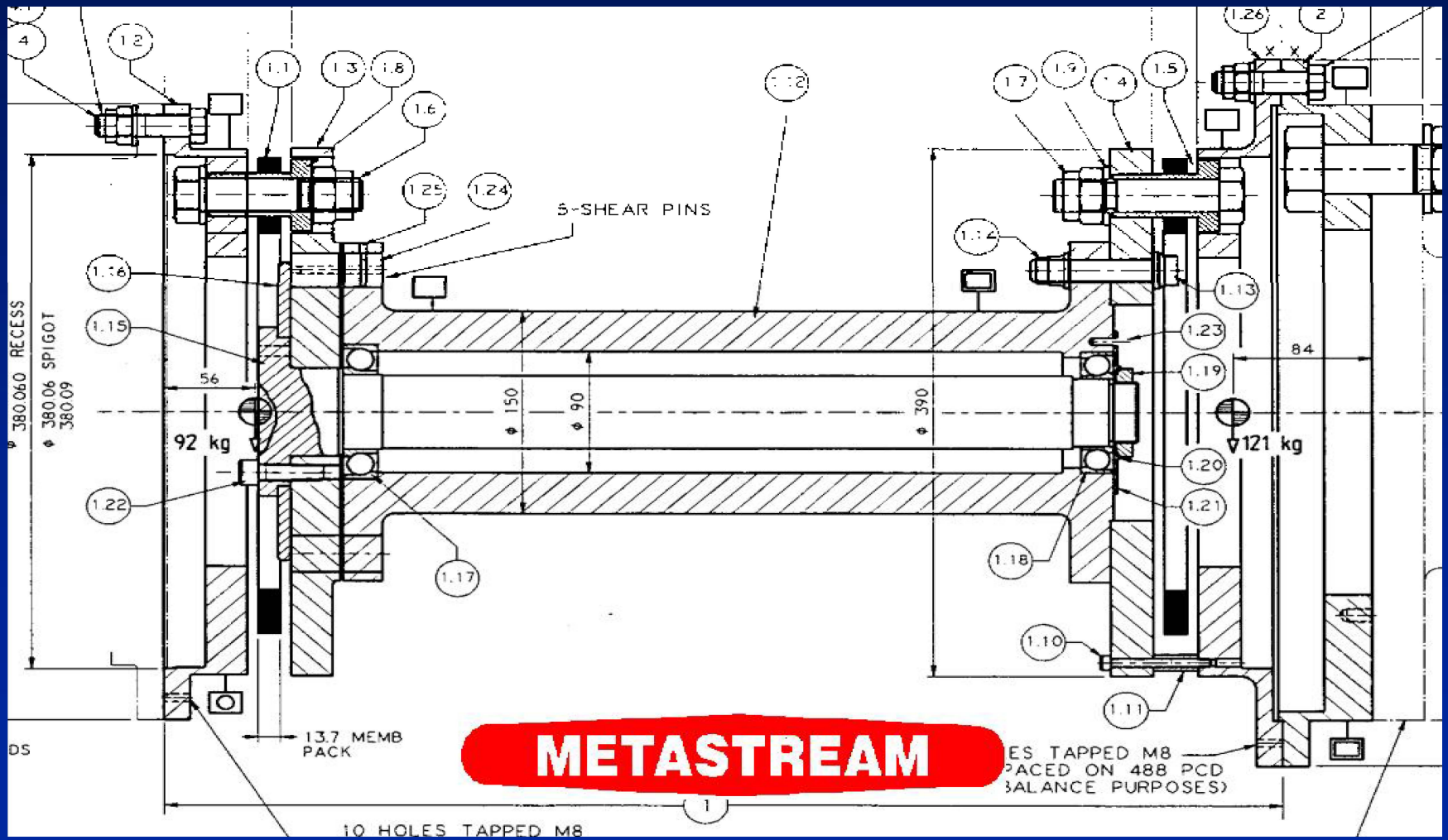
John Crane Flexibox



Introduction to Couplings

The Overlooked Component

Contents

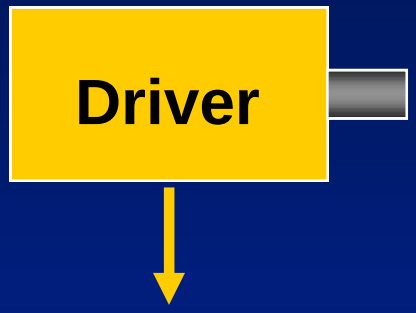
- **Introduction**
- **Types of coupling in use**
- **Membrane couplings**
  - Disc type
  - Diaphragm style
- **API Reliability and Safety issues**
- **Good Alignment practices**
- **Special designs**
- **Conclusion**

Introduction

Introduction

Introduction

Introduction

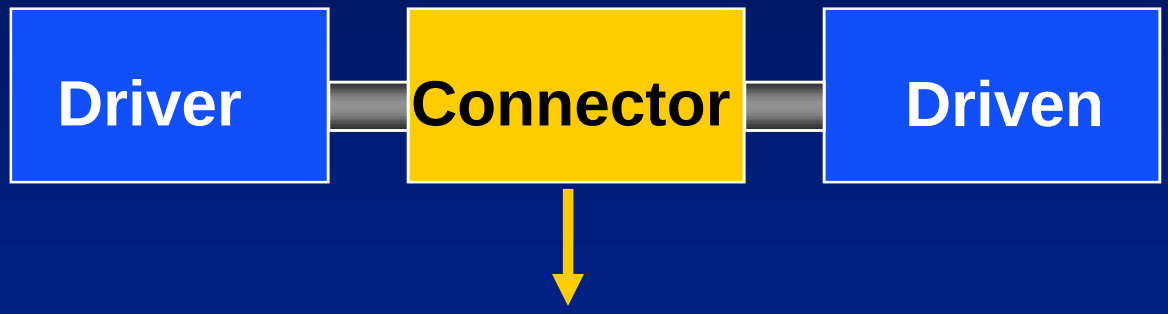


- Turbines - Gas & Steam
- Reciprocating engines
- Hydraulic motors
- Electric Motors

Introduction

- Pumps
- Generators
- Fans
- Marine
- Other machinery

Introduction



- Couplings
- Modifiers

Introduction

Couplings

- **Rigid**
- **Flexible**
  - Gear
  - Universal Joint
  - Spring Grid
  - Chain
  - Rubber Tyre
  - Rubber Block
  - Pin & Bush
  - Elastomeric
  - Membrane
  - etc.

Modifiers

- **Gearbox**
- **Fluid Coupling**
- **Variable Speed**
- **Belts**
- **Chains**
- **Powder**
- **Flywheel**

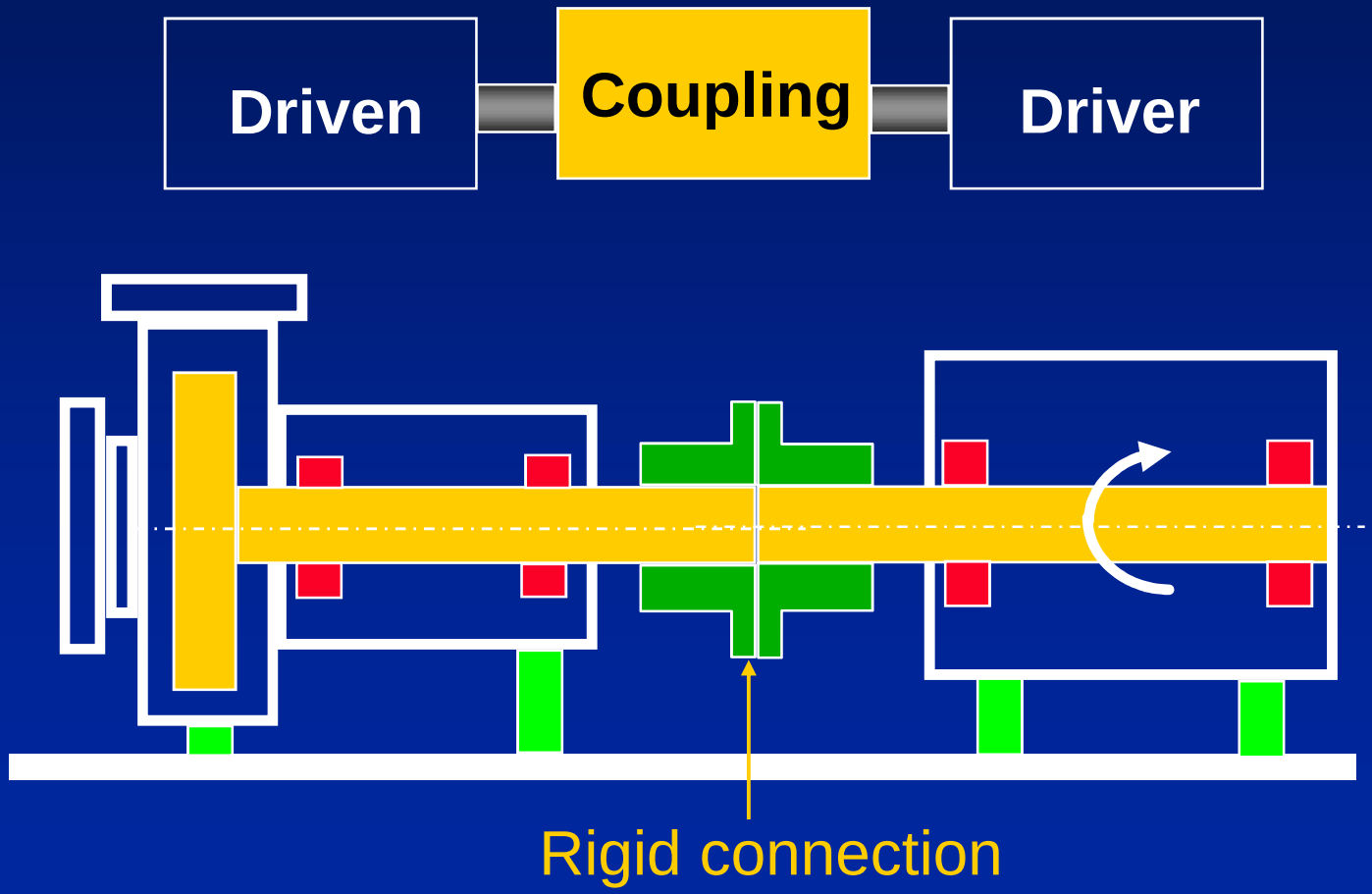
Introduction

Function of a shaft coupling

- Transmit Power or Torque
  Duties from < 0.1 kW to > 100 MW
- Transmits rotation
  Speeds from 0 to 80,000 rev/min
- Absorbs / reduces shock torque loads (optional)

Introduction

In the beginning ...

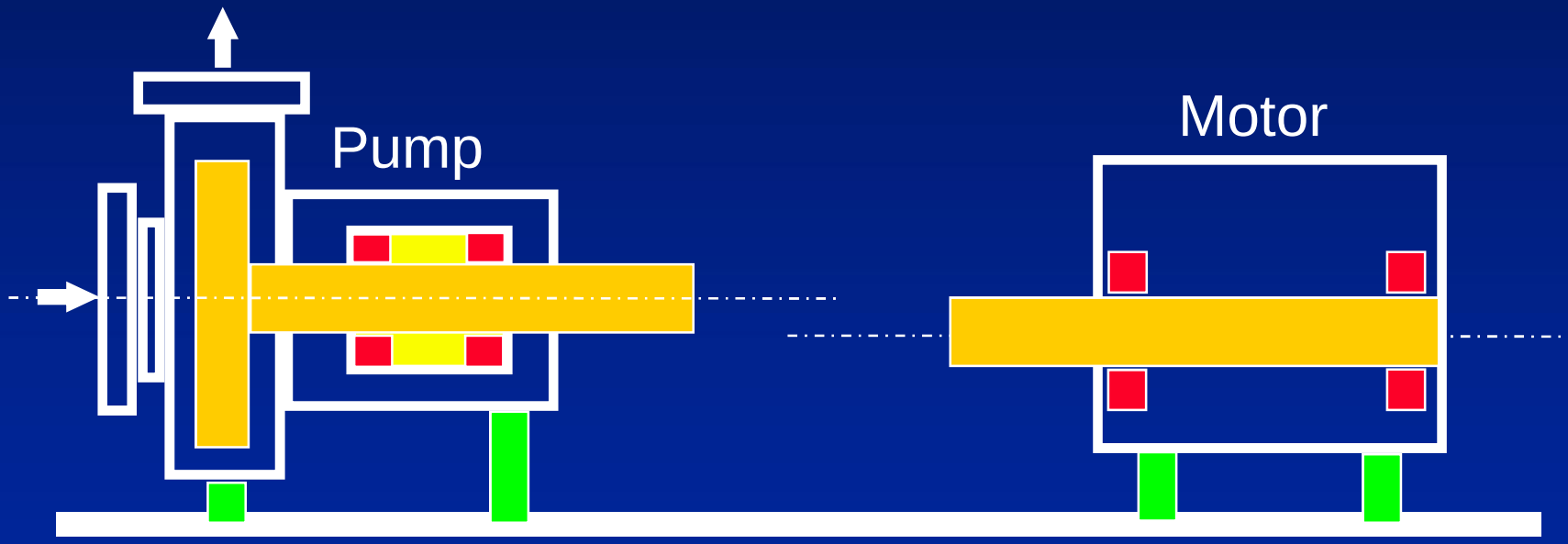


Introduction

But ……..

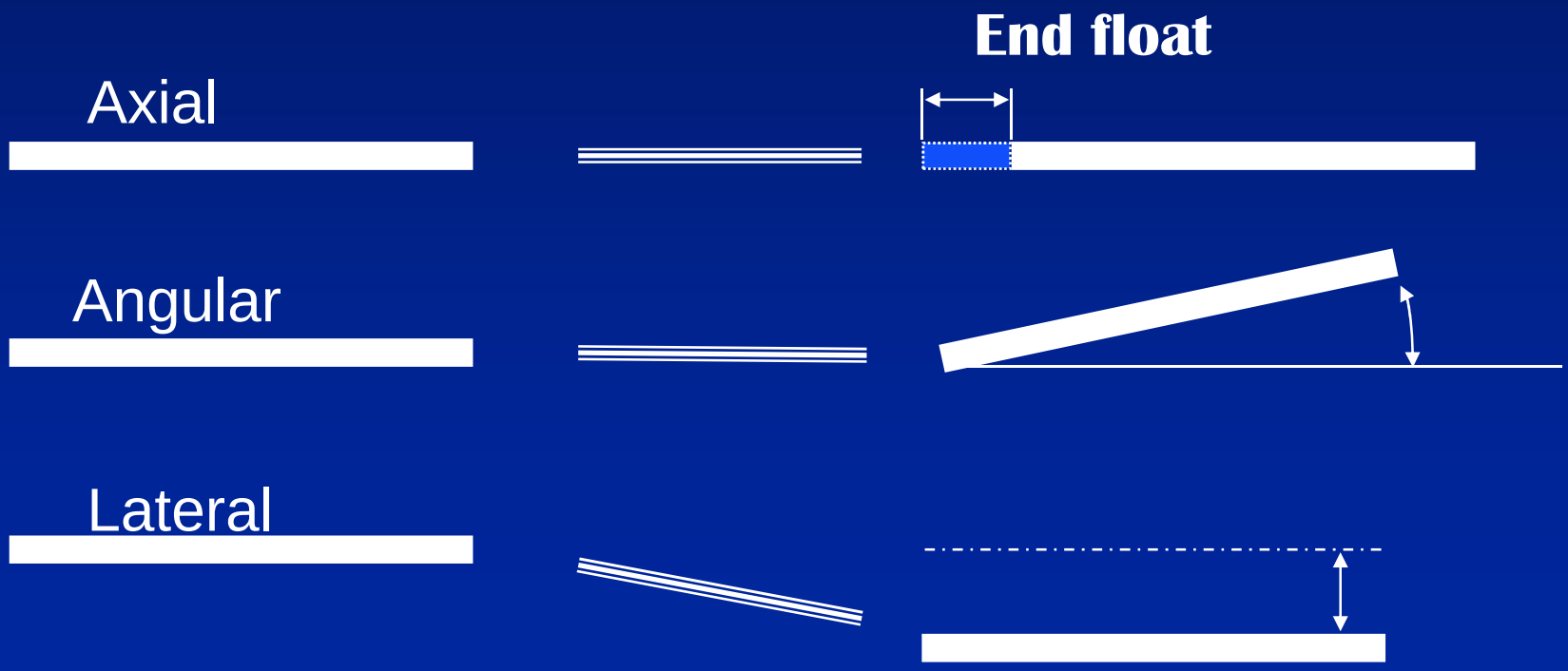
Introduction

But ……..
Misalignment exists



Introduction

- Transmit torque and speed
- Accommodates misalignment and end float



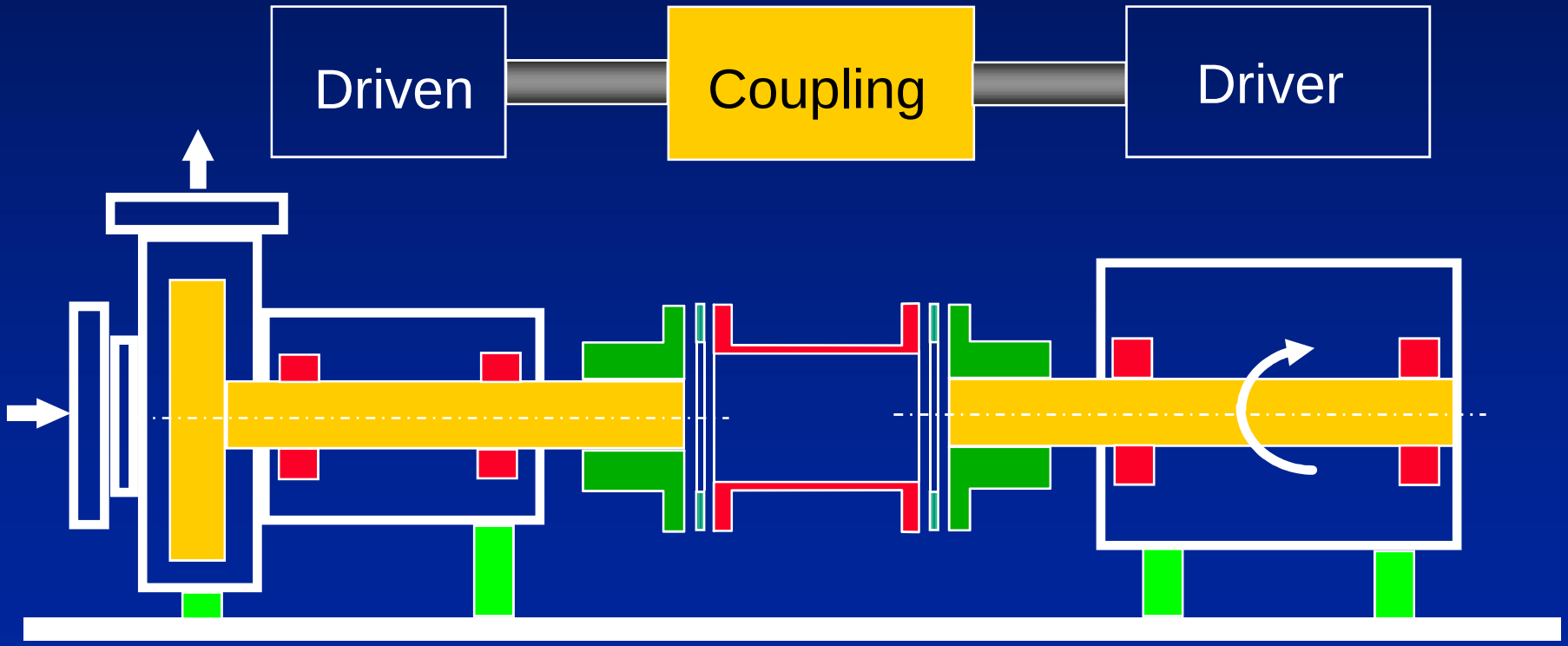
Introduction

Why Misalignment ?

- Initial residual alignment
- Thermal expansions - axial
  - vertical
  - horizontal
- Pipe strain
- Clearance or float in bearings - axial
  - radial
- Foundation movements
- Earthquakes
- etc

Introduction

Flexible elements introduced



Contents

- **Introduction**
- **Types of coupling in use**
- **Membrane couplings**
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- **Special designs**
- **Conclusion**

Types of Coupling

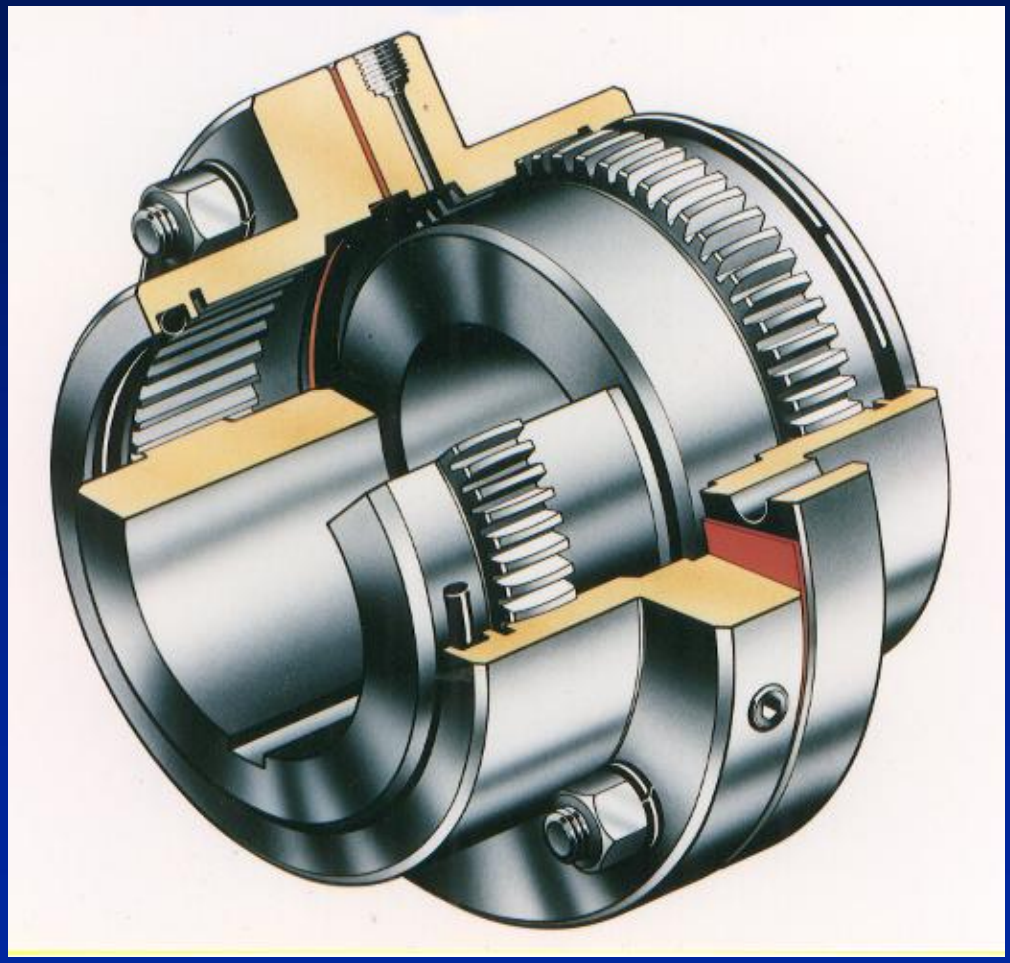
- **Rigid - not flexible**
- **Flexible**
  - Mechanical
    - Gear (TR)
    - Universal joint (TR)
    - Spring grid
  - Elastomeric
    - Jaw - compression and shear types
    - Tyre and similar types
    - Pin & bush
    - Rubber block
  - Membrane (TR)
    - disc
    - diaphragm

TR = torsionally rigid

Types of Coupling

Gear type

- Lubrication essential
- Will wear out
- Needs maintenance
- Torsionally rigid
- Medium initial cost
- High torque capacity



Types of Coupling

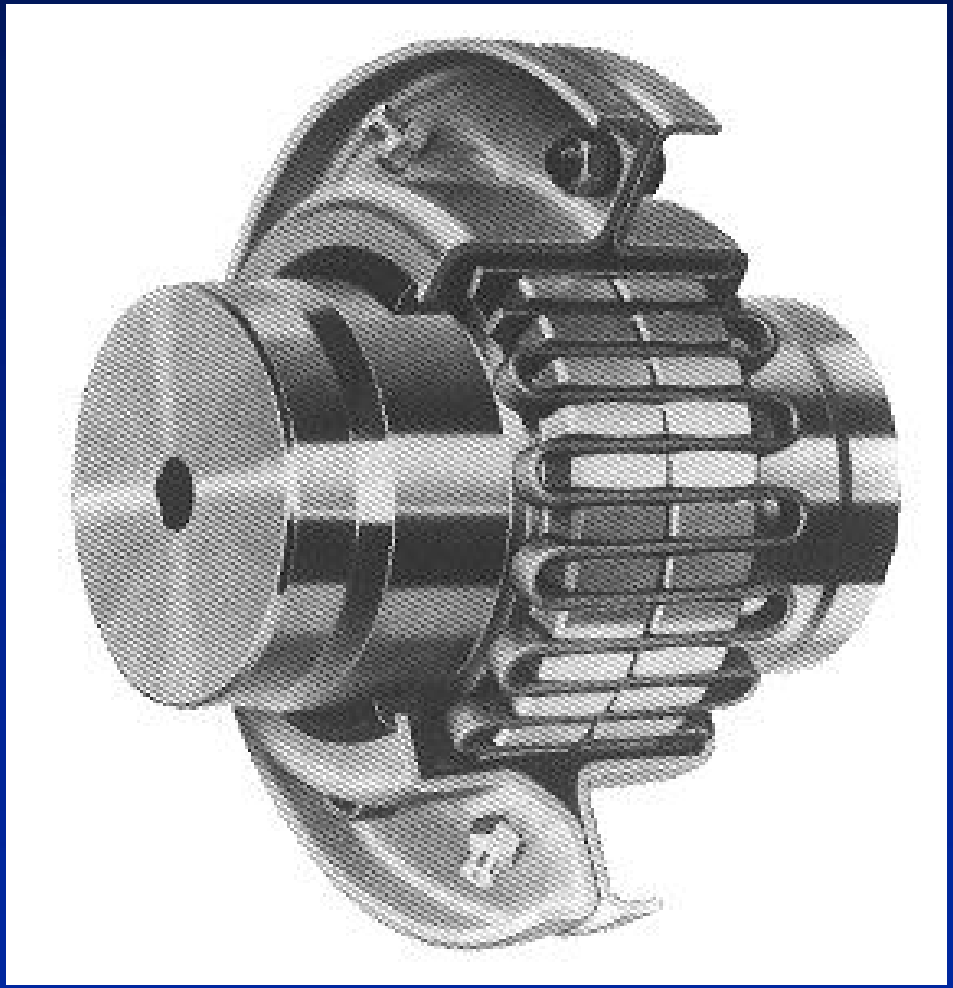
Universal Joint

- Lubricated
- Can wear out
- Splines for end float
- Low initial cost
- Not high speeds
- Not high powers

Types of Coupling

Spring Grid

- Lubrication essential
- Will wear out
- Needs maintenance
- Torsional resilience
- Medium initial cost
- Not high speeds
- Not high powers



Types of Coupling

Elastomer in shear tyre

- No lubrication
- Can wear / degrade
- Some torsional resilience
- Medium initial cost
- Not high speeds
- Not high powers

Types of Coupling

Elastomer in compression or jaw

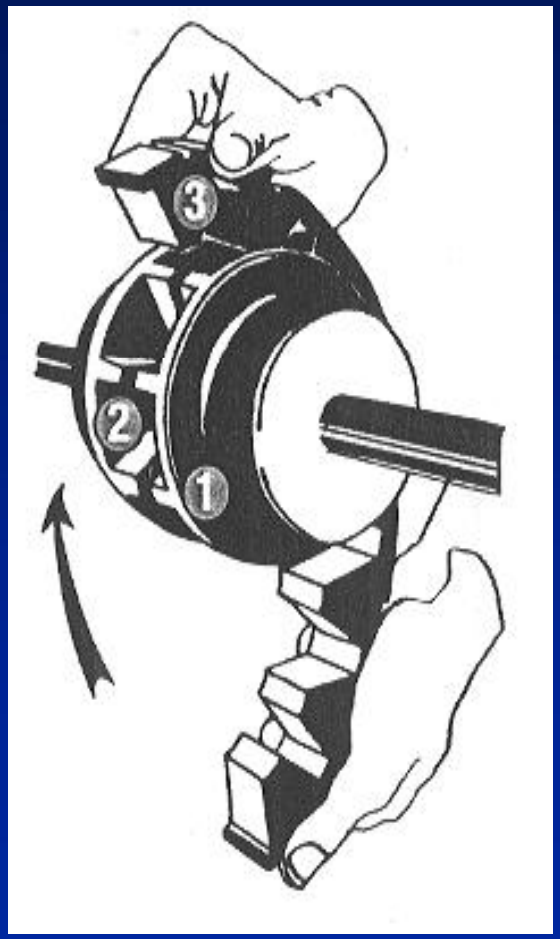
- No lubrication
- Can wear / degrade
- Some torsional resilience
- Low initial cost
- Not high speeds
- Not high powers

Types of Coupling

Elastomer in shear - spline sleeve

- No lubrication
- Can wear / degrade
- Some torsional resilience
- Medium initial cost
- Not high speeds
- Not high powers

Types of Coupling

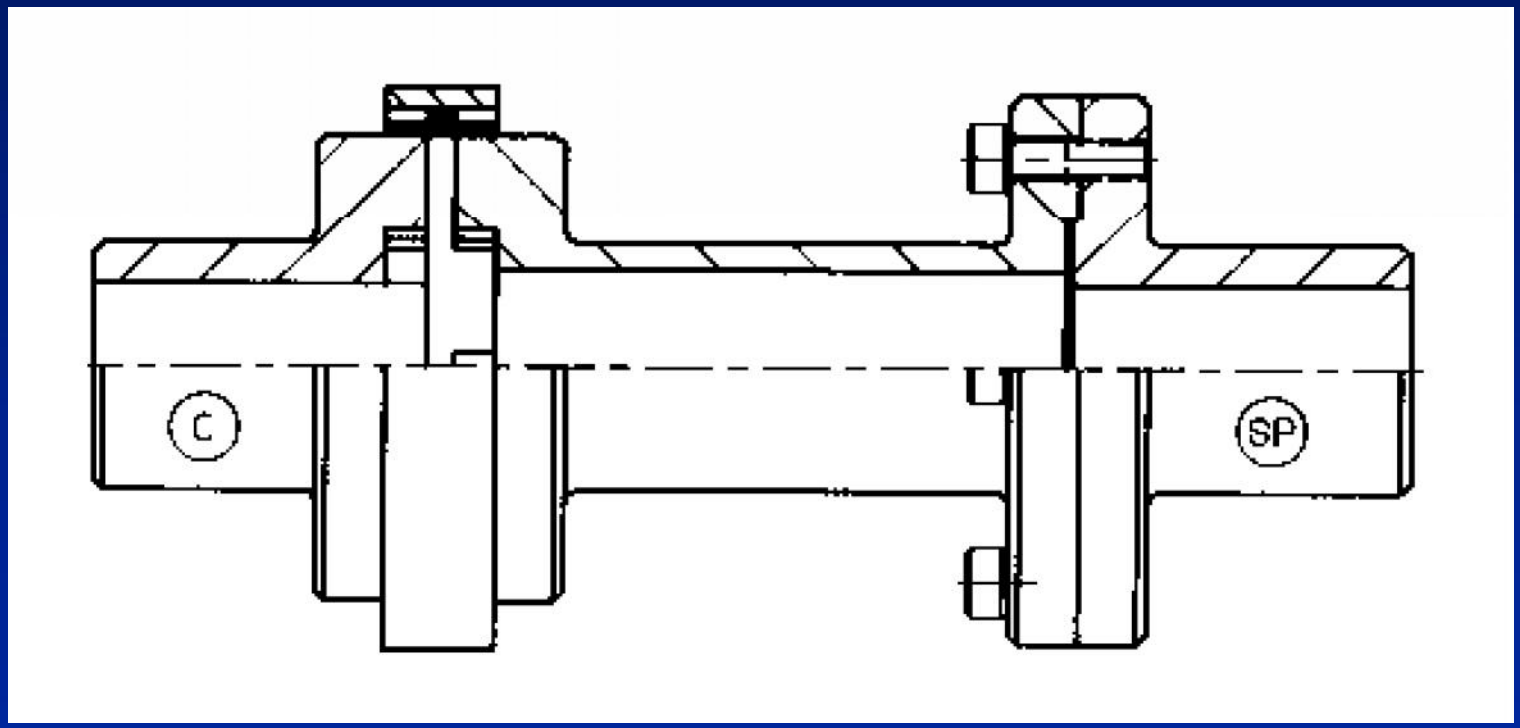


Elastomer in shear jaw type

- Maintenance without moving hubs or equipment
- Can rotate hubs independently for motor test
- No metal to metal contact
- Limited torque range

Types of Coupling

Elastomeric - spacer types



Spacer does not give additional misalignment capacity

Types of Coupling

Pin and Bush coupling

- Old technology
- Wears fast
- Low initial cost
- Not high speeds
- Not high powers

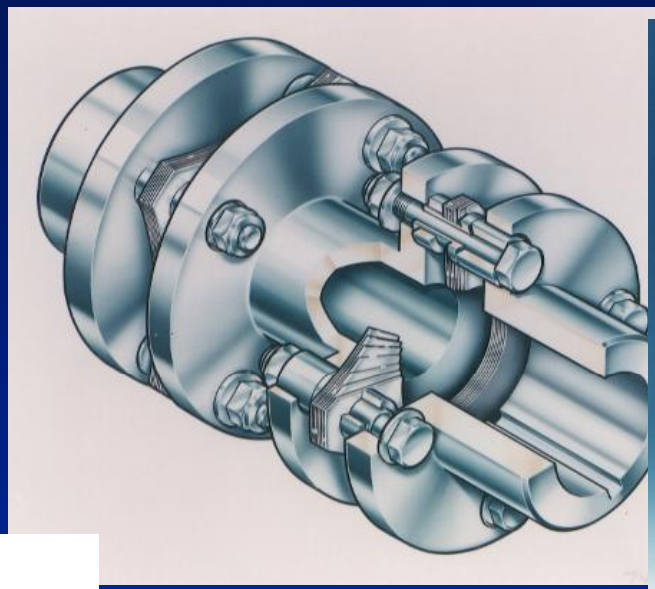
Types of Coupling

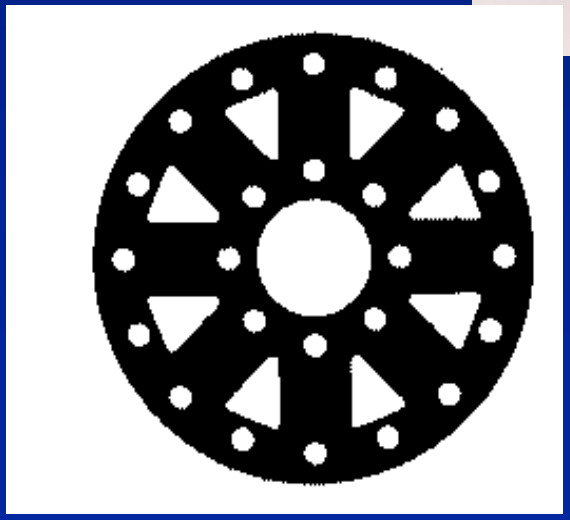
Rubber Block

- Diesel drives
- No lubrication
- Can wear / degrade
- Torsional resilience
- Higher initial cost
- Not high speeds

Types of Coupling

Membrane Couplings



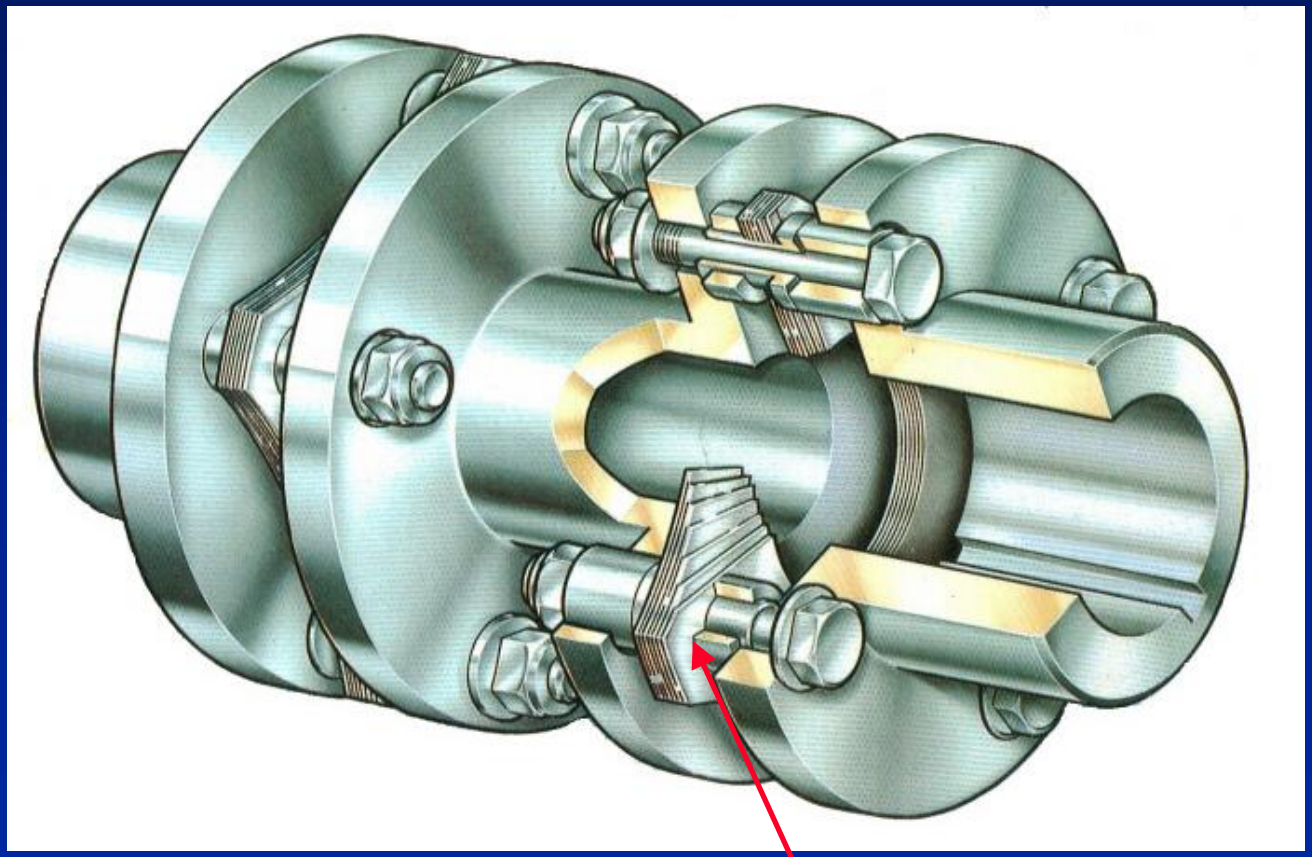


Disc

Diaphragm

Types of Coupling

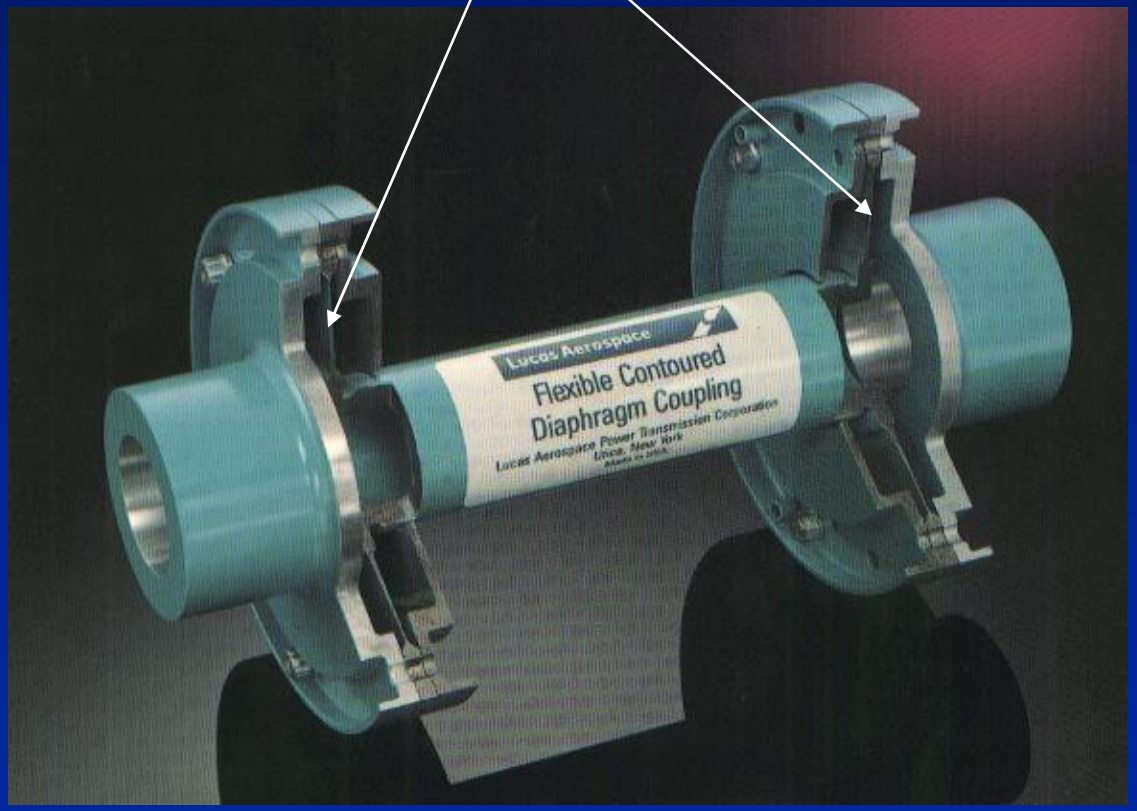
Assembled Disc Coupling



Types of Coupling

Contoured Single Diaphragm type

Diaphragm membranes



Types of Coupling

Membrane Couplings

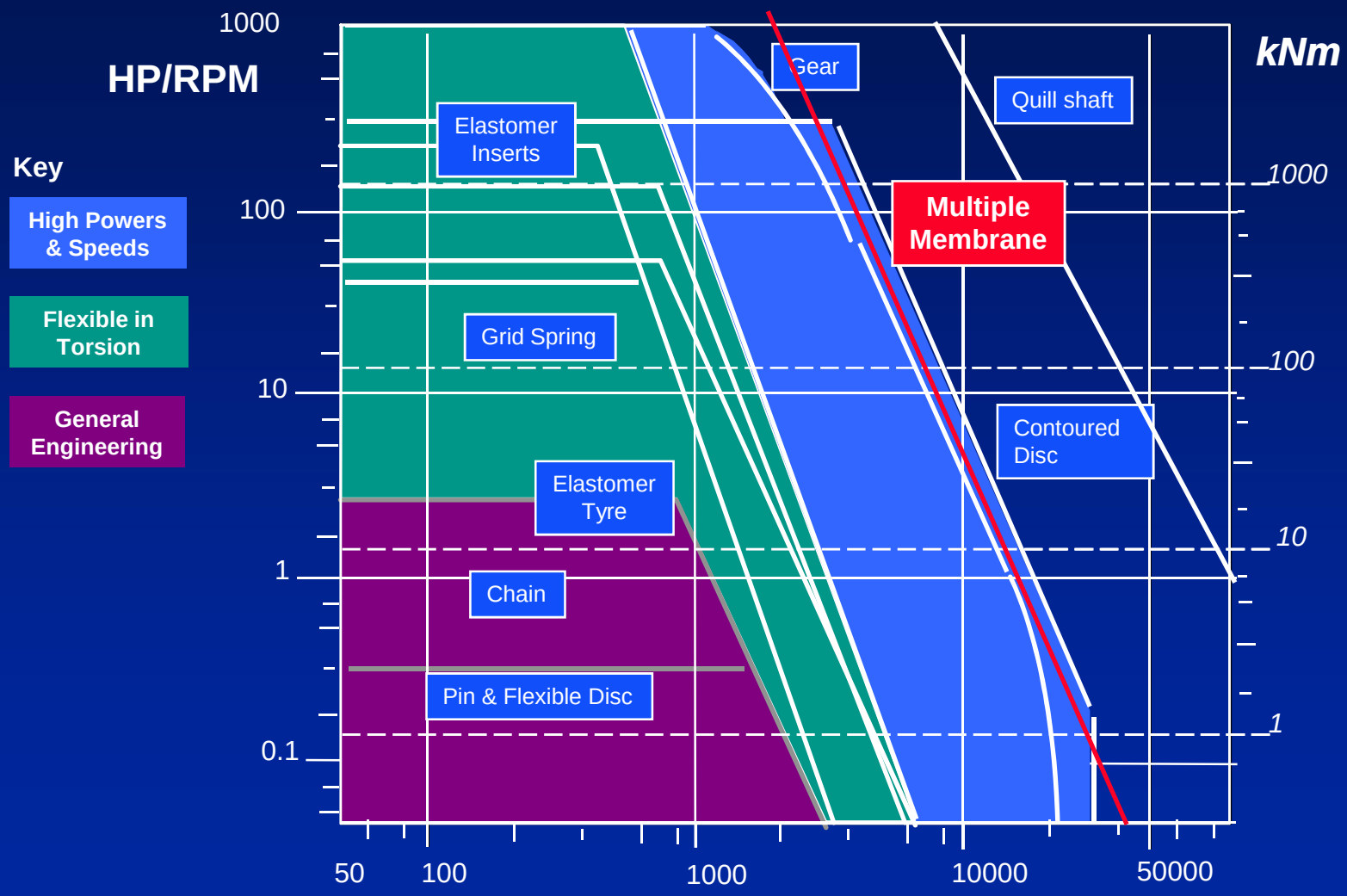
- Transmit torque through tension or shear of thin material
- Accommodate misalignment by elastic bending of element
- No lubrication, minimum maintenance
- Zero backlash
- Should last as long as machinery
- Can be used from lowest to highest powers and speeds
- Medium to high initial cost
- Extra safety features possible
- Torsionally rigid - very low resilience

Types of Coupling

Which Coupling type ?

- Initial Cost
- Torque v Speed Capability
- Shock Loading / Overload Torque
- Vibration effects - balance
  - loads
- Torsional resilience or rigidity
- Backlash
- Environmental Tolerance
- Durability
- Ease of Installation

Types of Coupling



Torque v Speed

Types of Coupling

Torque Loading

- Motor types to consider
- Normal operation - smooth torque
- Direct on line start - > 2 x normal
- Star Delta or soft start - < 1.5 x normal
- Synchronous - high peak values
- Variable speed - usually smooth
- Re-acceleration torque - very high
- Short circuit torque - > 4 x normal

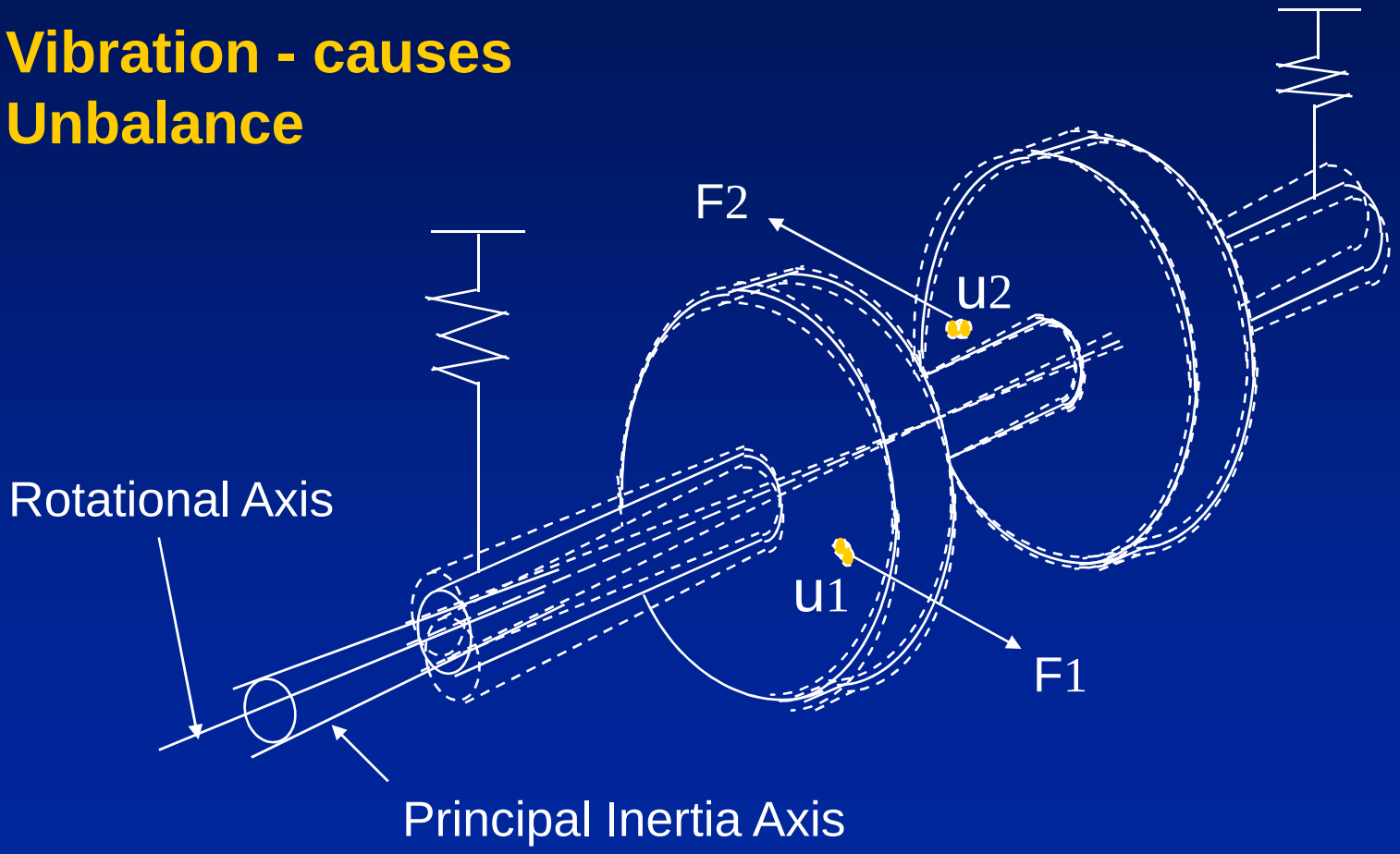
Types of Coupling

Vibration - causes

- Weight
- Mass distribution
- Axial stiffness or frictional forces
- Bending stiffness or friction
- Transmission of torque through angle
- Unbalance effects

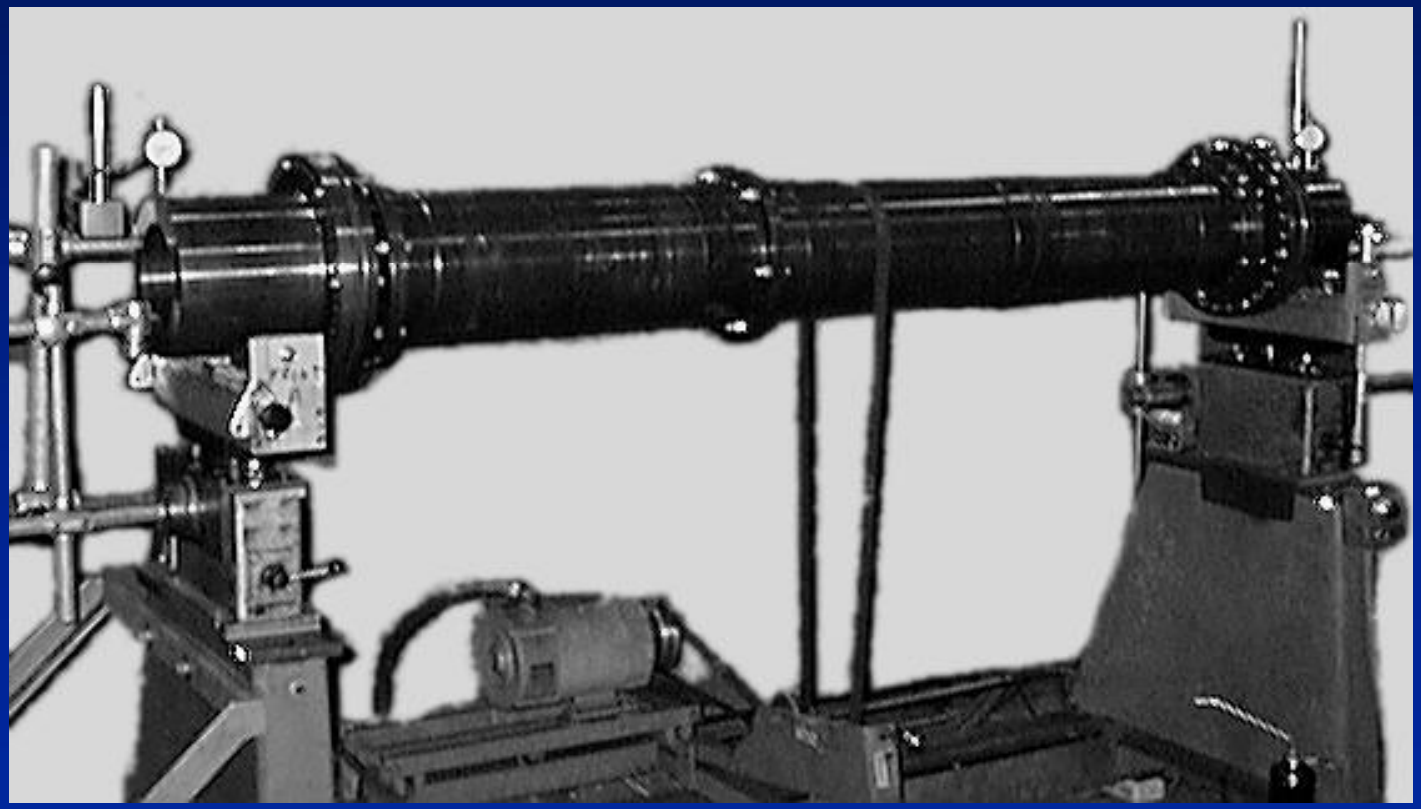
Types of Coupling

Vibration - causes Unbalance



Types of coupling

Balancing (Two Plane)



Types of coupling

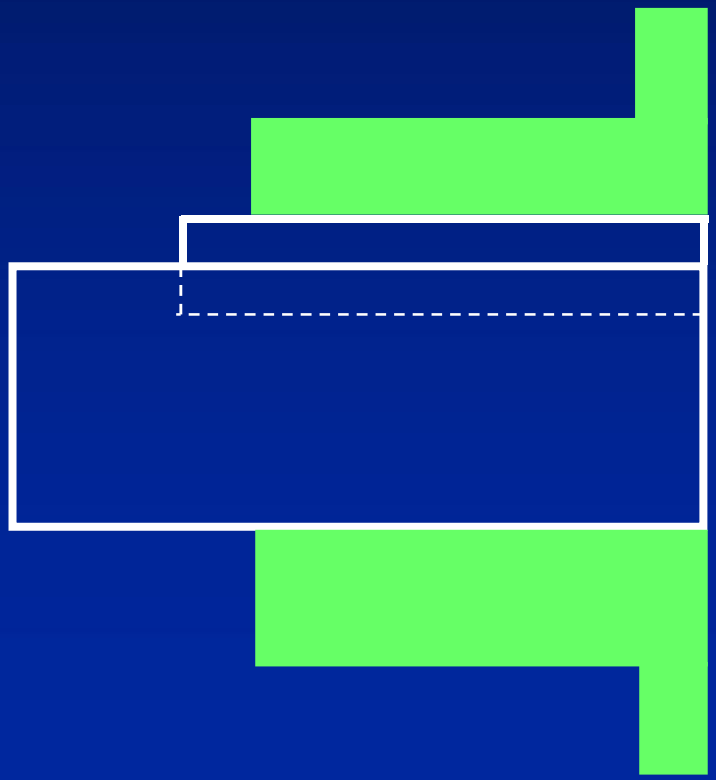
Contributors To Unbalance

- Balance tolerance limits
- Balance fixture/mandrel unbalance
- Balance machine error
- Balance fixture/mandrel eccentricity
- Indicating eccentricity
- Pilot eccentricity
- Pilot clearances
- Hardware unbalance
- Effect of keyways
- Shaft runout

Types of coupling

Balance issues

Cylindrical Shaft with Key

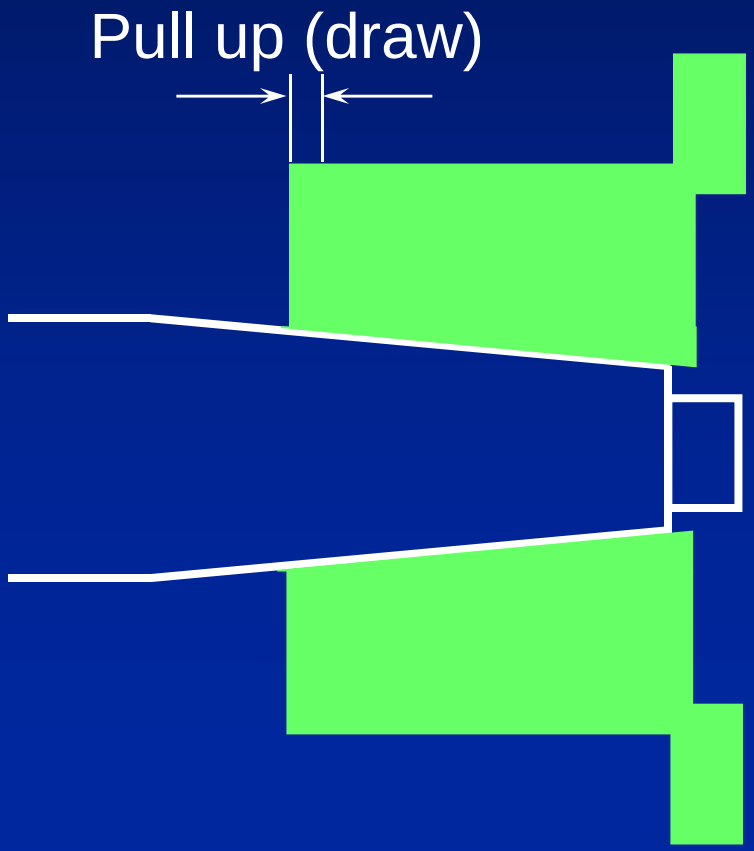


- Clearances around key
- Excess key length
- How to control balance better

Types of coupling

Better balance

Conical Tapered Hydraulic Without Key

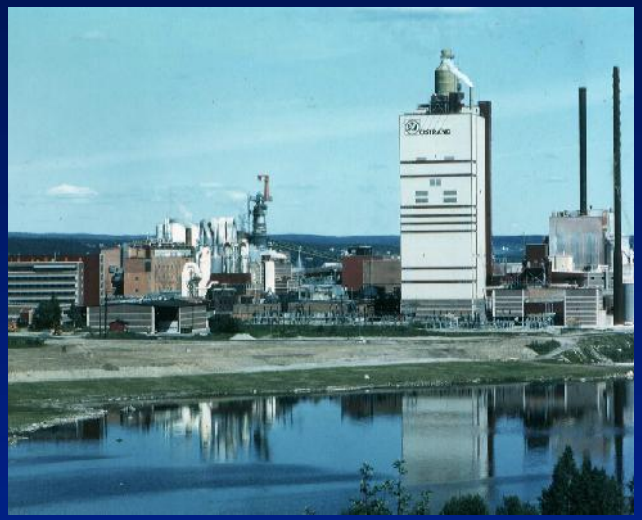


Bore fits

- **Interference 0.002 in/in**
- **Special tools required**
- **Perfect balance repeatability**

Types of Coupling

Backlash
v
Paper making



- **Gear couplings**
  - **have an in built ‘backlash’**
  - **require maintenance causing expensive downtime**
  - **require lubrication - can be dirty**
- **Membrane couplings**
  - **zero backlash - best paper production**
  - **No lubrication and no maintenance**

Types of Coupling

Do you require

- Long life - no lubrication, no maintenance
- Low shaft loads
- High standard of inherent balance
- Easy access - Spacer Between Shaft Ends
- Zero backlash
- Precise rotational location or timing

but

- Torsional damping is not required

Types of Coupling

Then

- Torsionally rigid couplings are probably best
- Membrane / disc couplings are preferred

Types of Coupling

Membrane Couplings
The Solution for

- **Reduced maintenance**
  - Easy to fit
  - No lubrication
  - Low loads on bearings
  - Low induced vibration - better balance
- **Reliability and safety**
  - element type dictates failure mode
- **Freedom from backlash**
- **Spacer types standard**

Contents

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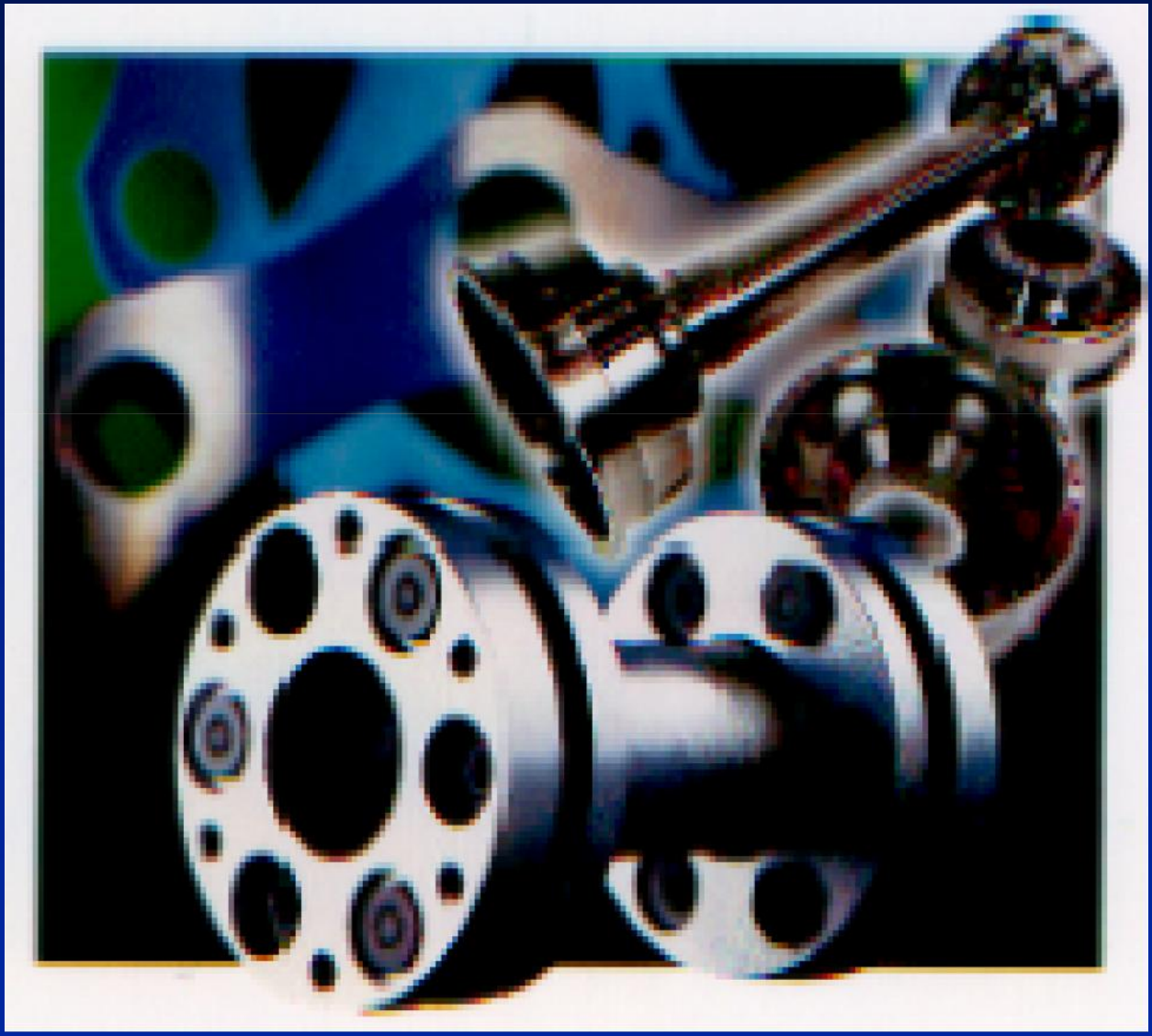
Membrane Couplings

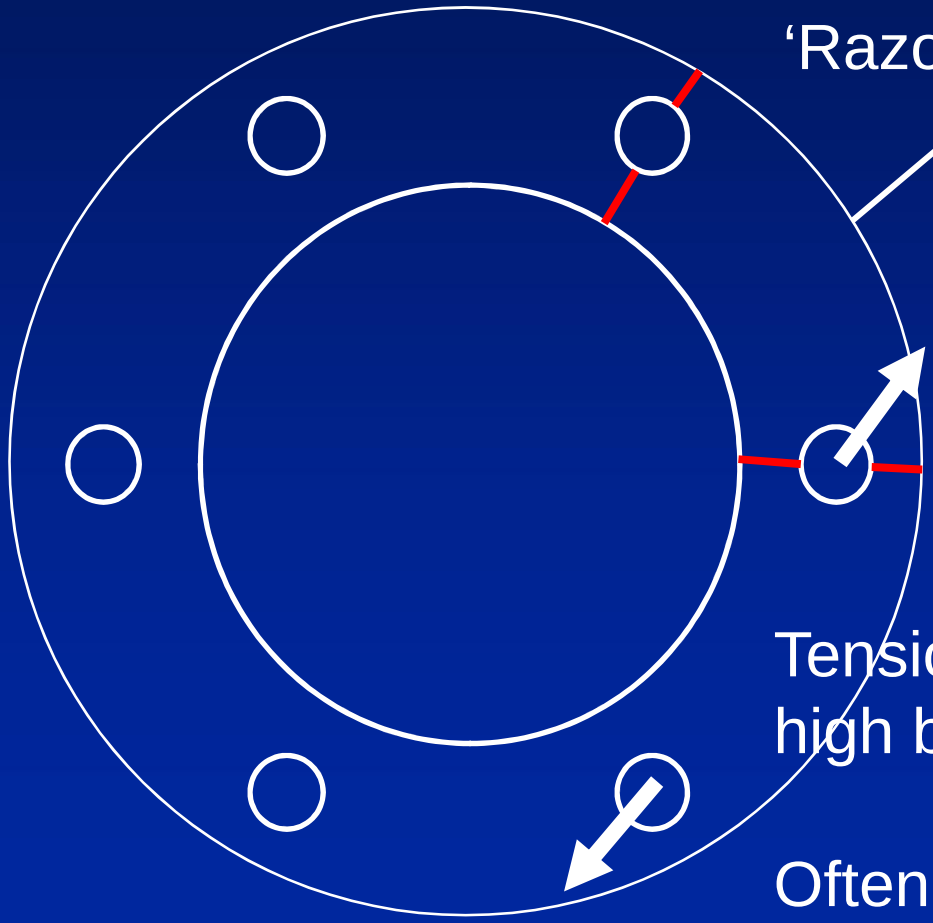


Standard API designs

Highest reliability

Membrane Couplings

Early disc designs



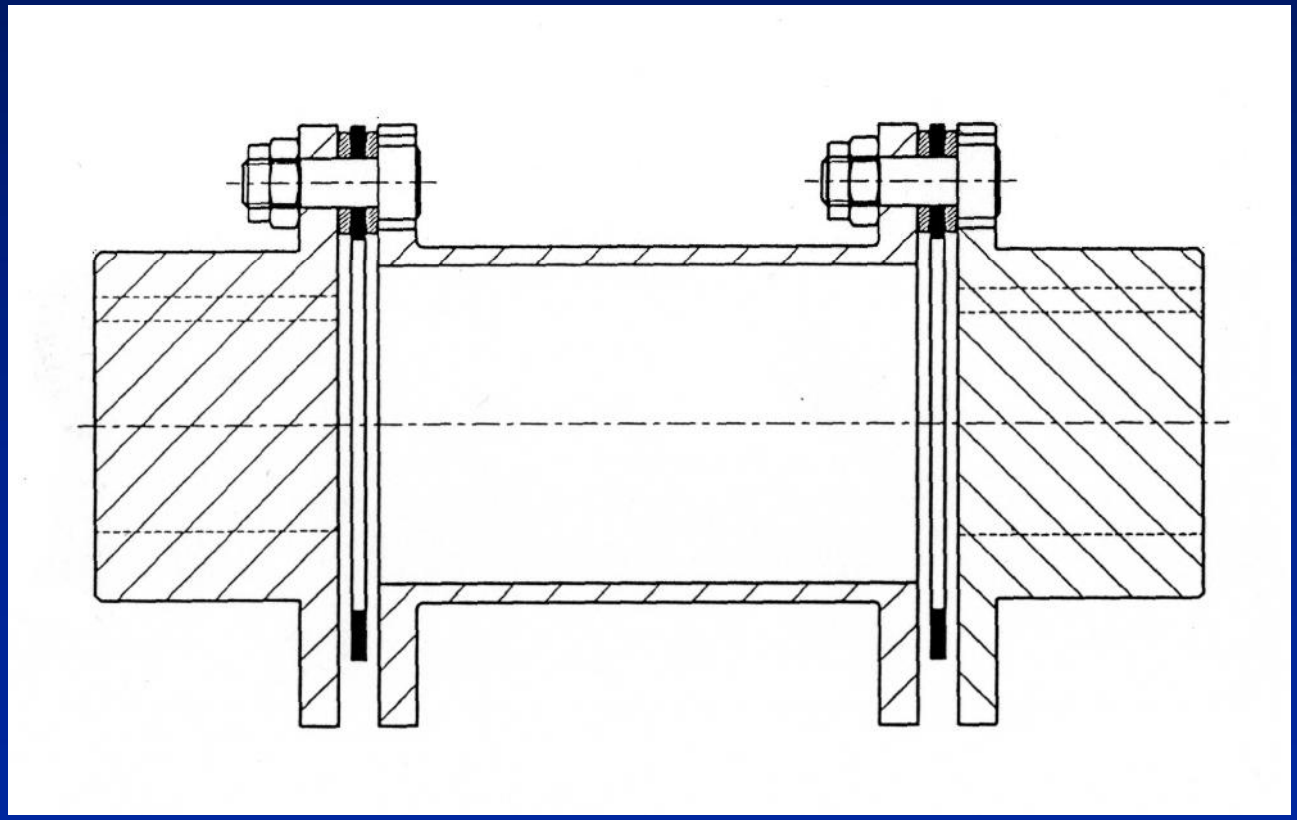
‘Razor blade’ failure

Tension can cause high bending stresses

Often loose discs

Membrane Couplings

Basic early “Disc type” designs



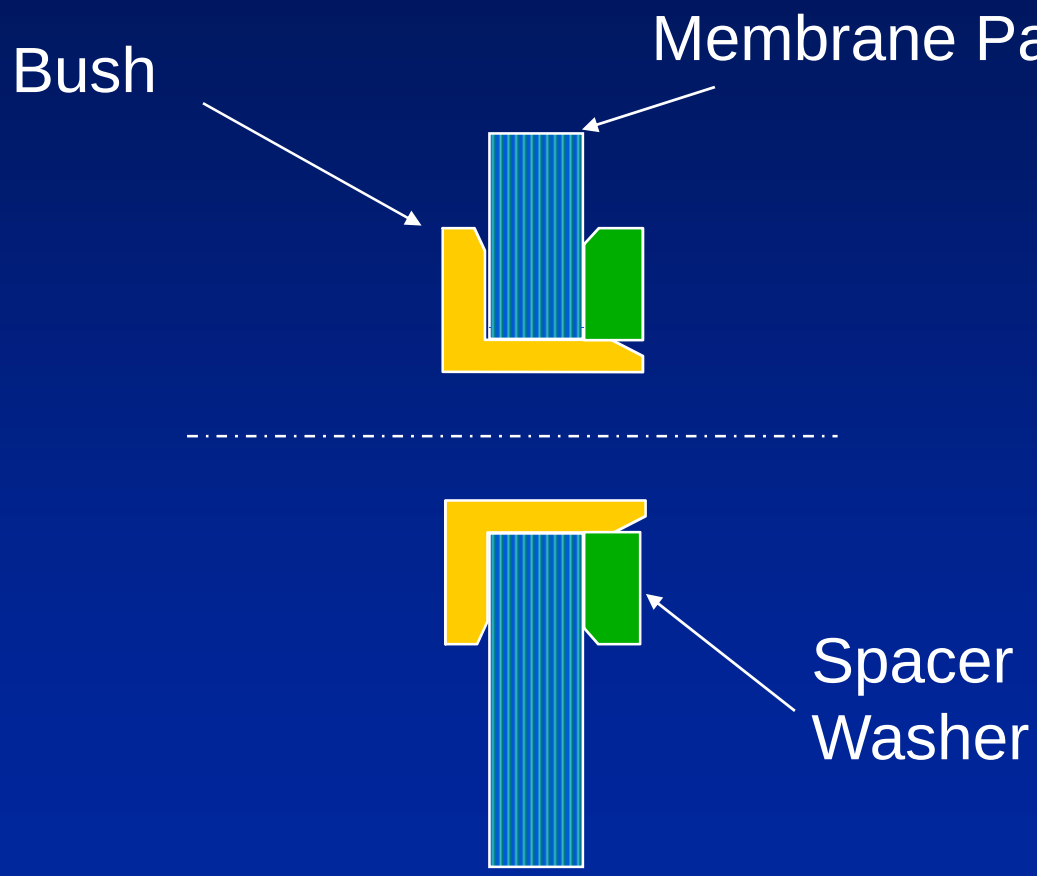
Membrane Couplings

Basic early “Disc type” designs

- Loose components - difficult assembly
  - looser fits
  - early failures
- Carbon steel discs - corrosion
- Solved lubrication problem
  but
- Limited life
- Safety issues

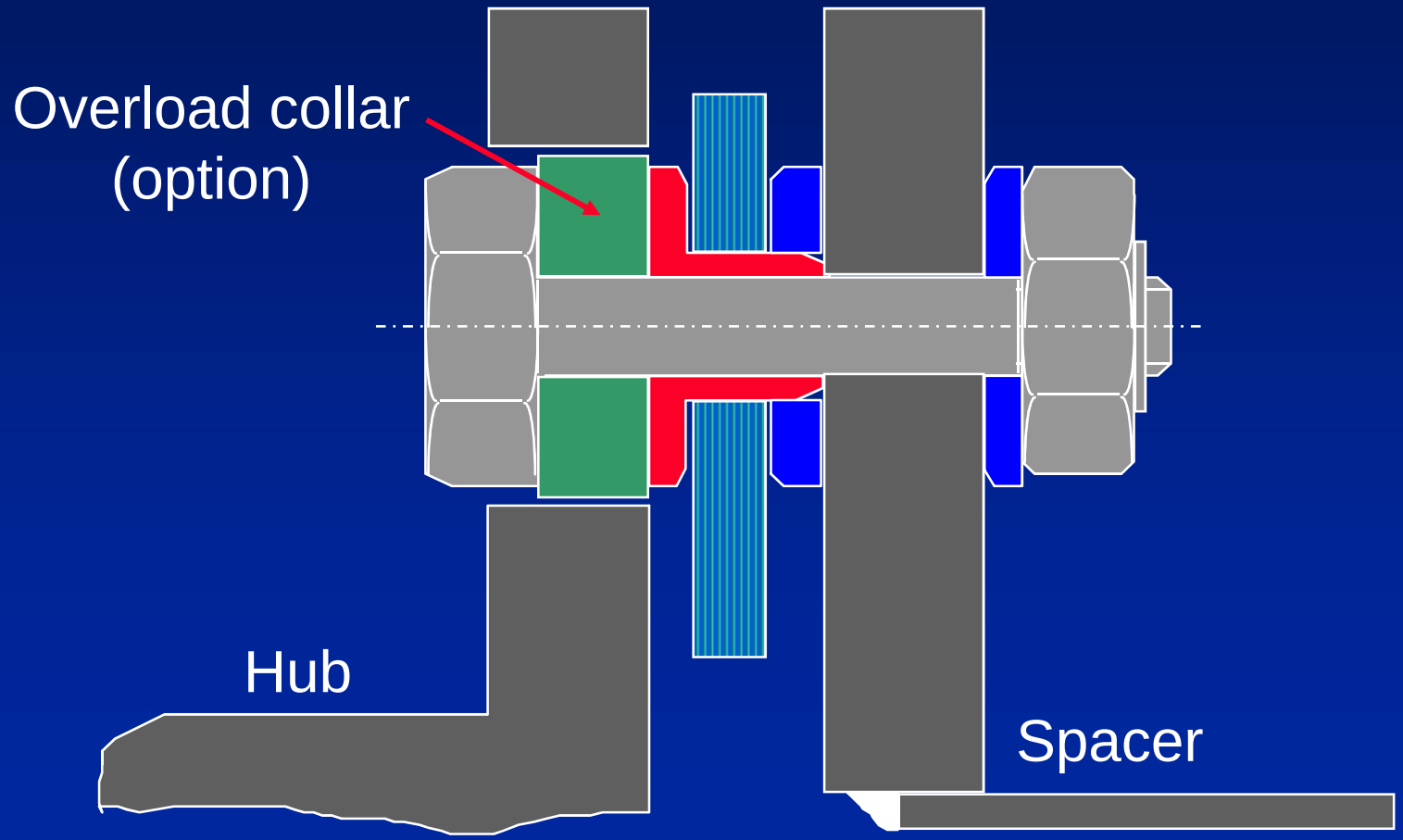
Membrane Couplings

Unitised Disc Pack



Membrane Couplings

Completed Assembly



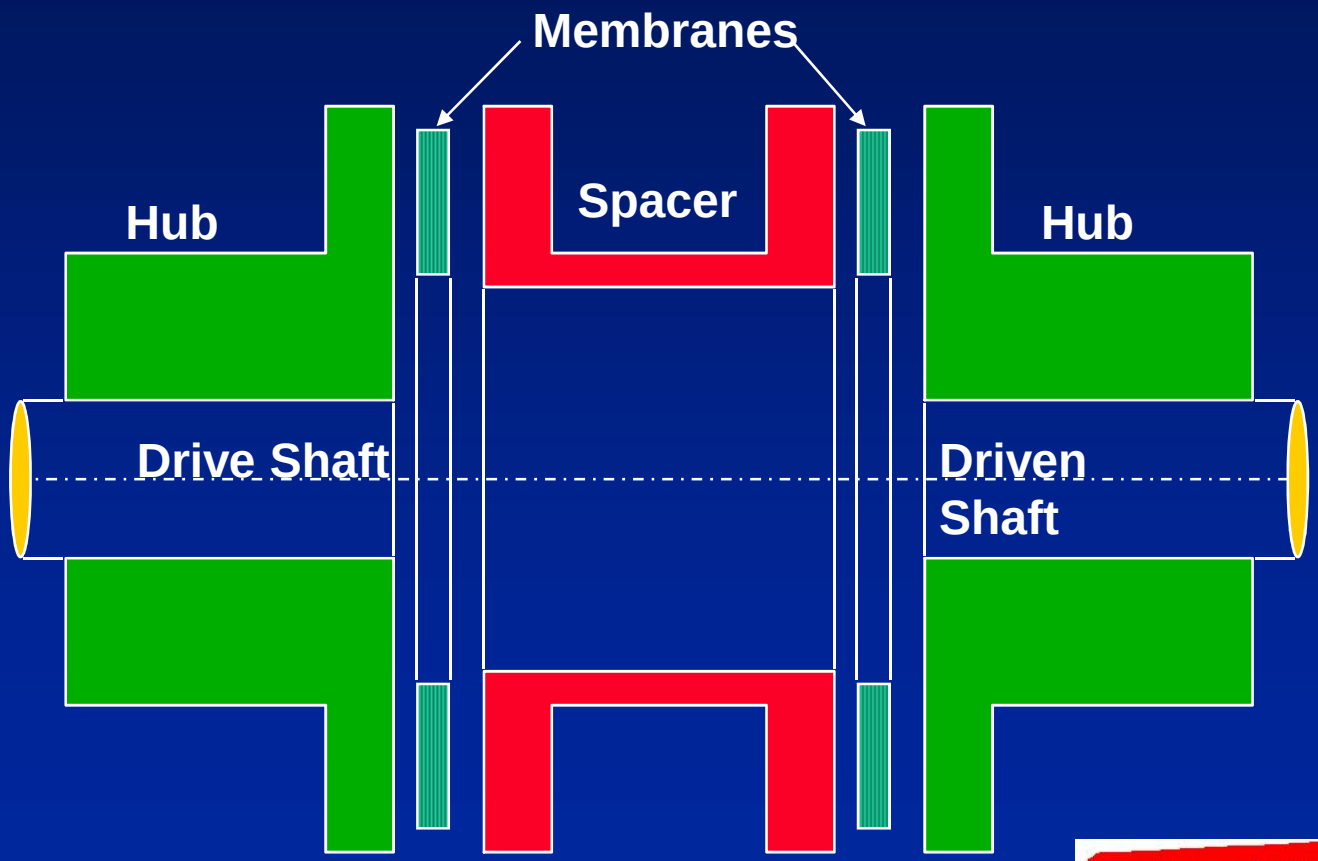
Membrane Couplings

Unitised Disc Pack

- Pre assembled discs - less risk on assembly
- Better control of fit on disc
- Reduces risk of failures
- Still requires careful bolt tightening
- Best suited to lower speeds/lower powers
- Lower balance quality - repeatability poor
  - API demands better
- Fail safe - continues drive
  - bolts can break

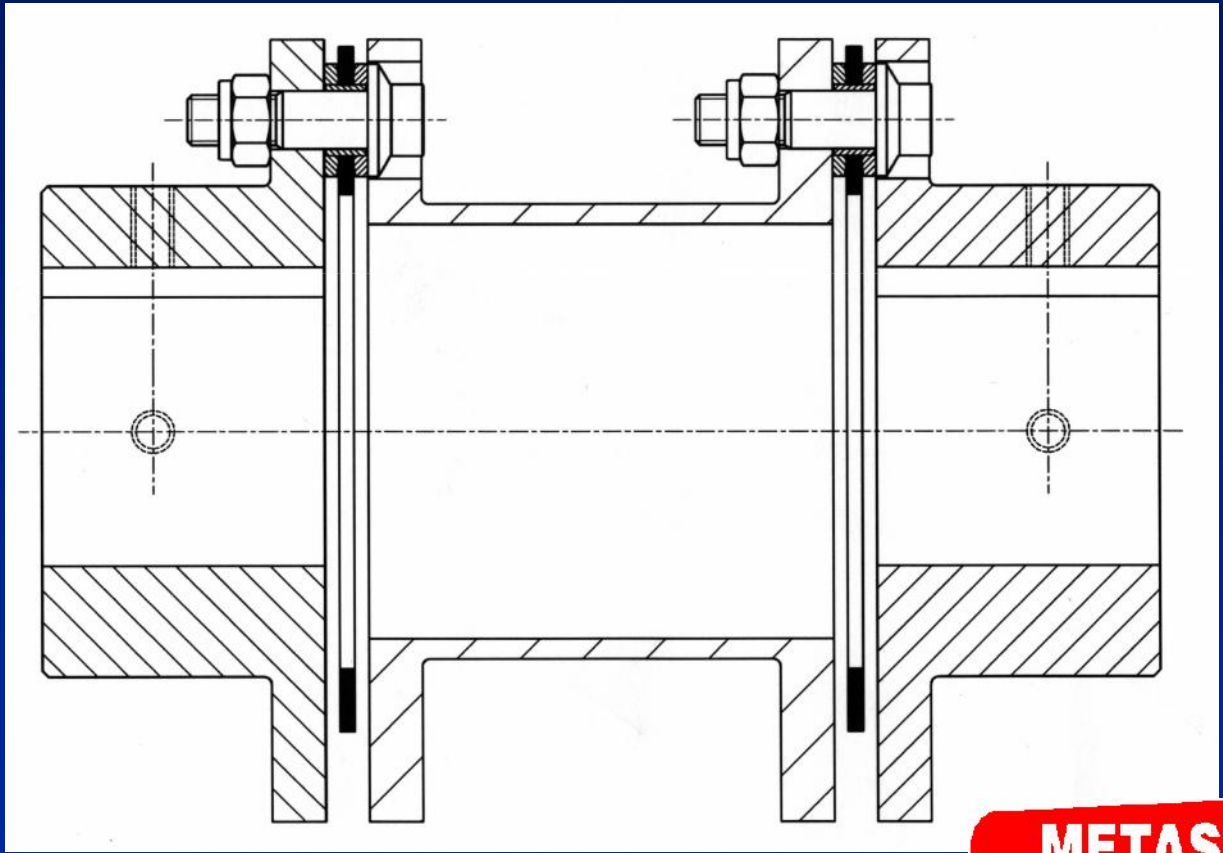
Membrane Couplings

Industrial Coupling



Membrane Couplings

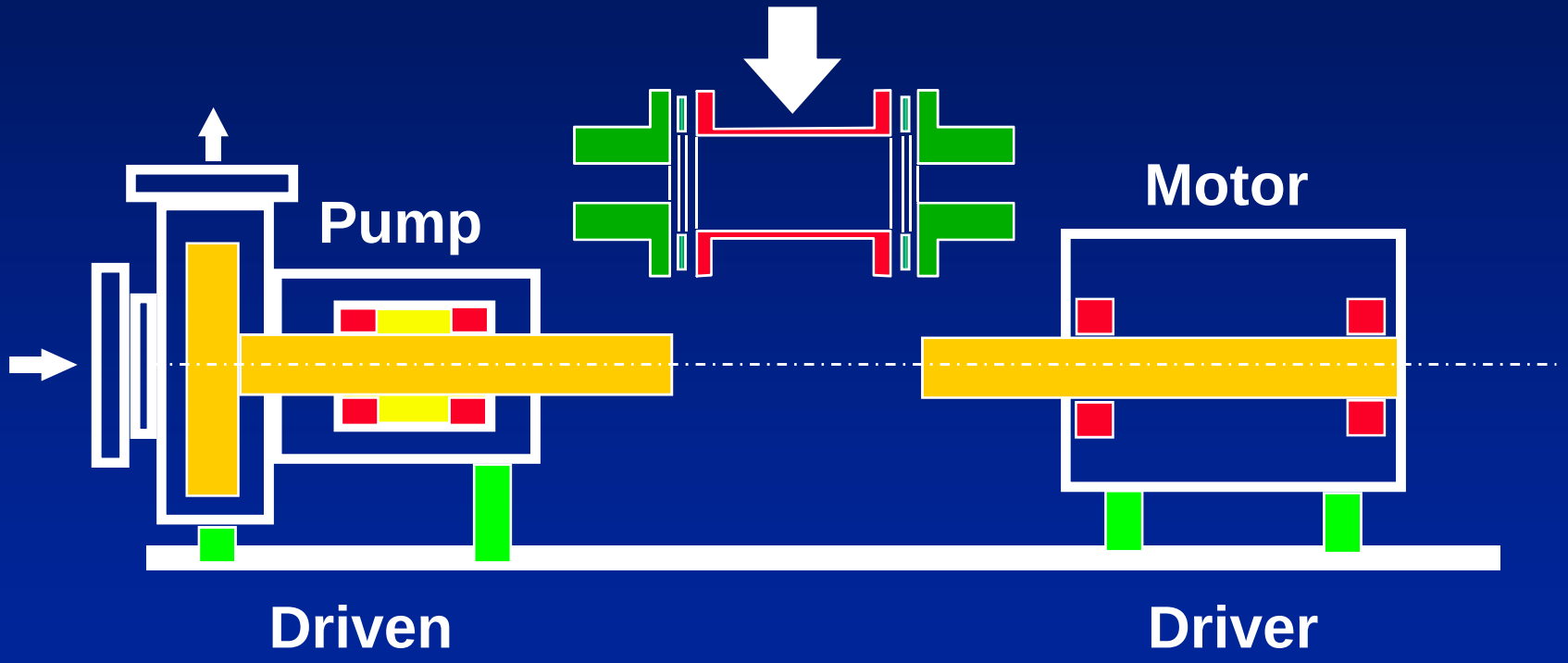
Current basic unitised disc design



METASTREAM

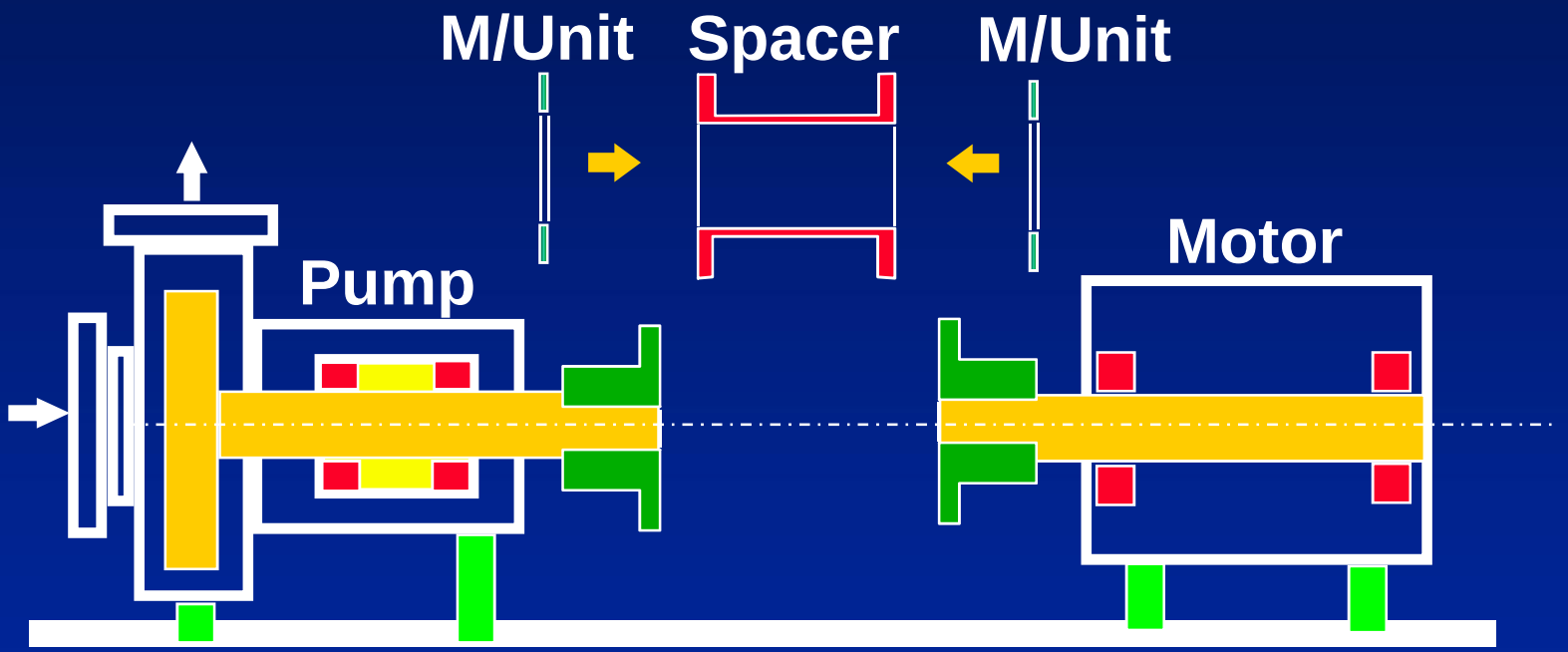
Membrane Couplings

Coupling Required



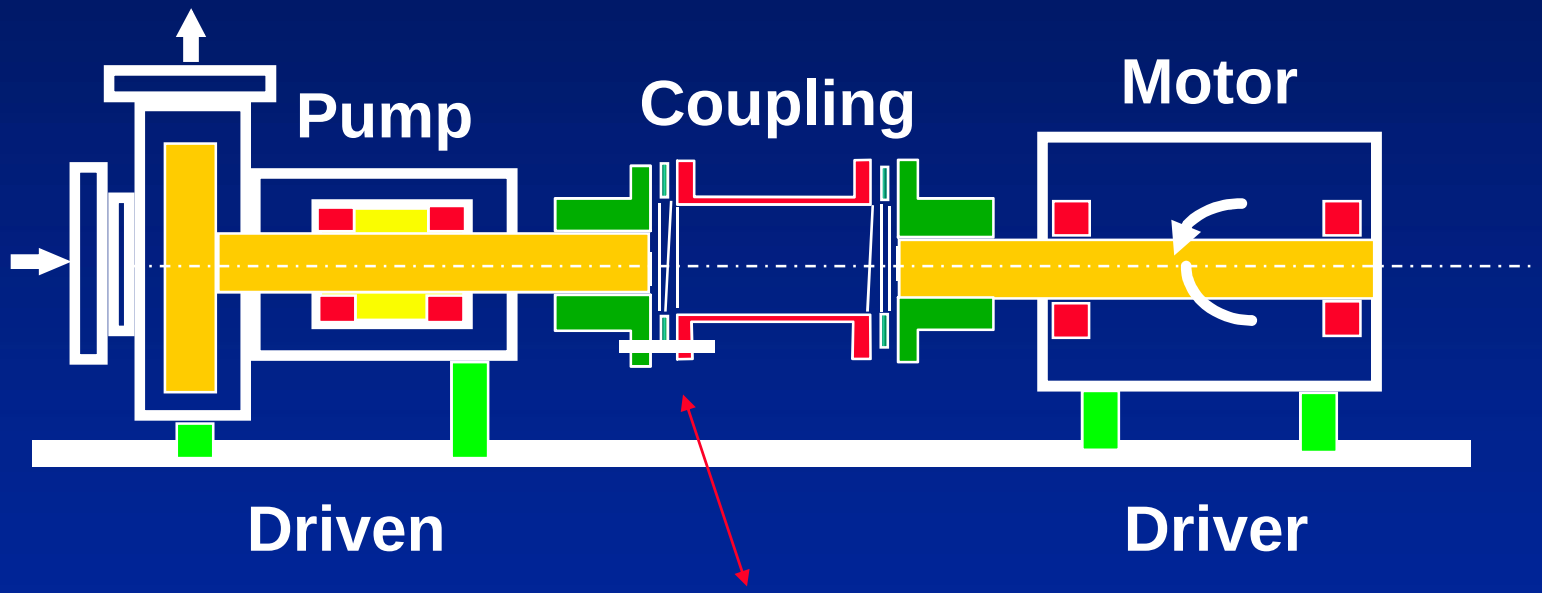
Membrane Couplings

Fit Hubs



Membrane Couplings

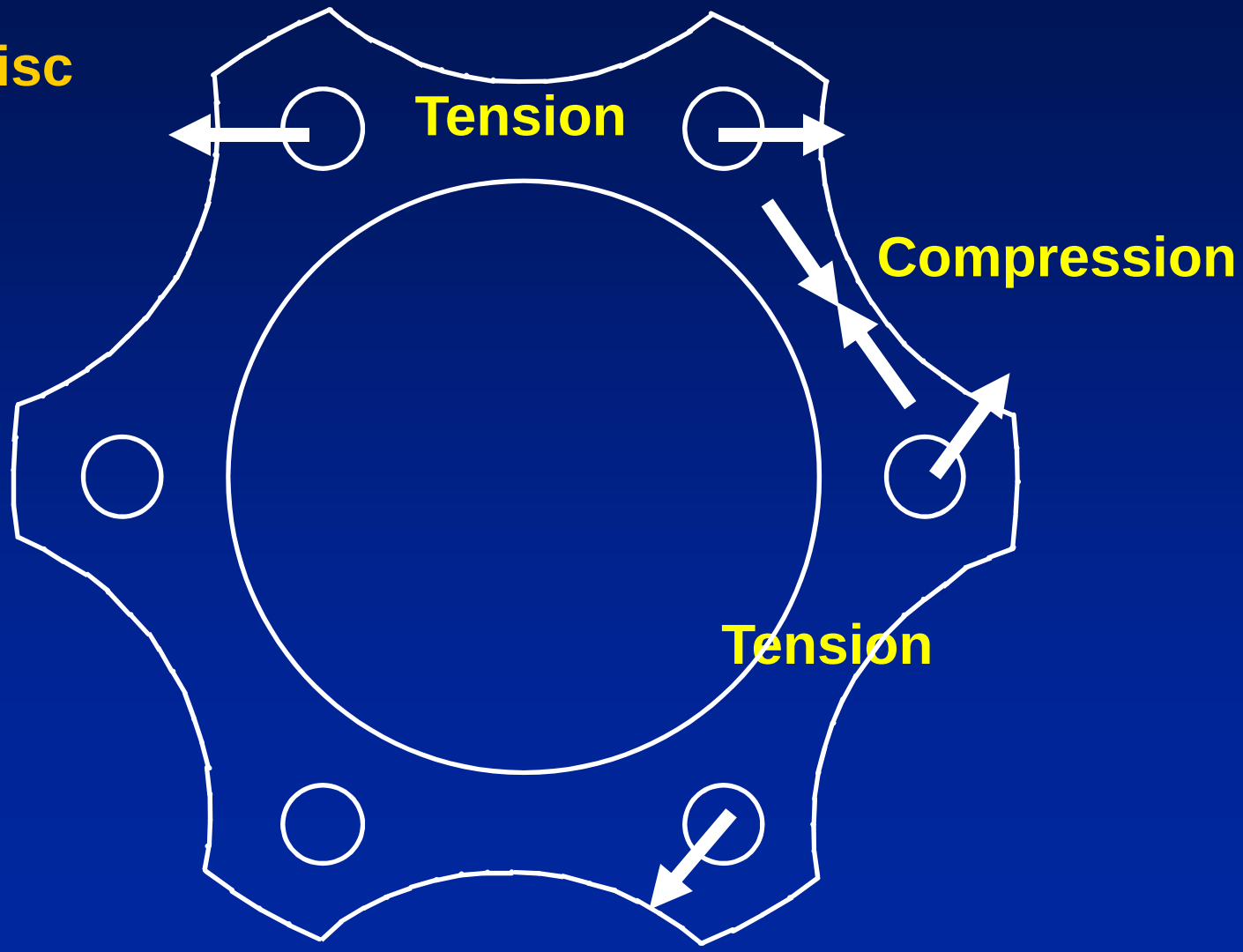
Coupling Fitted

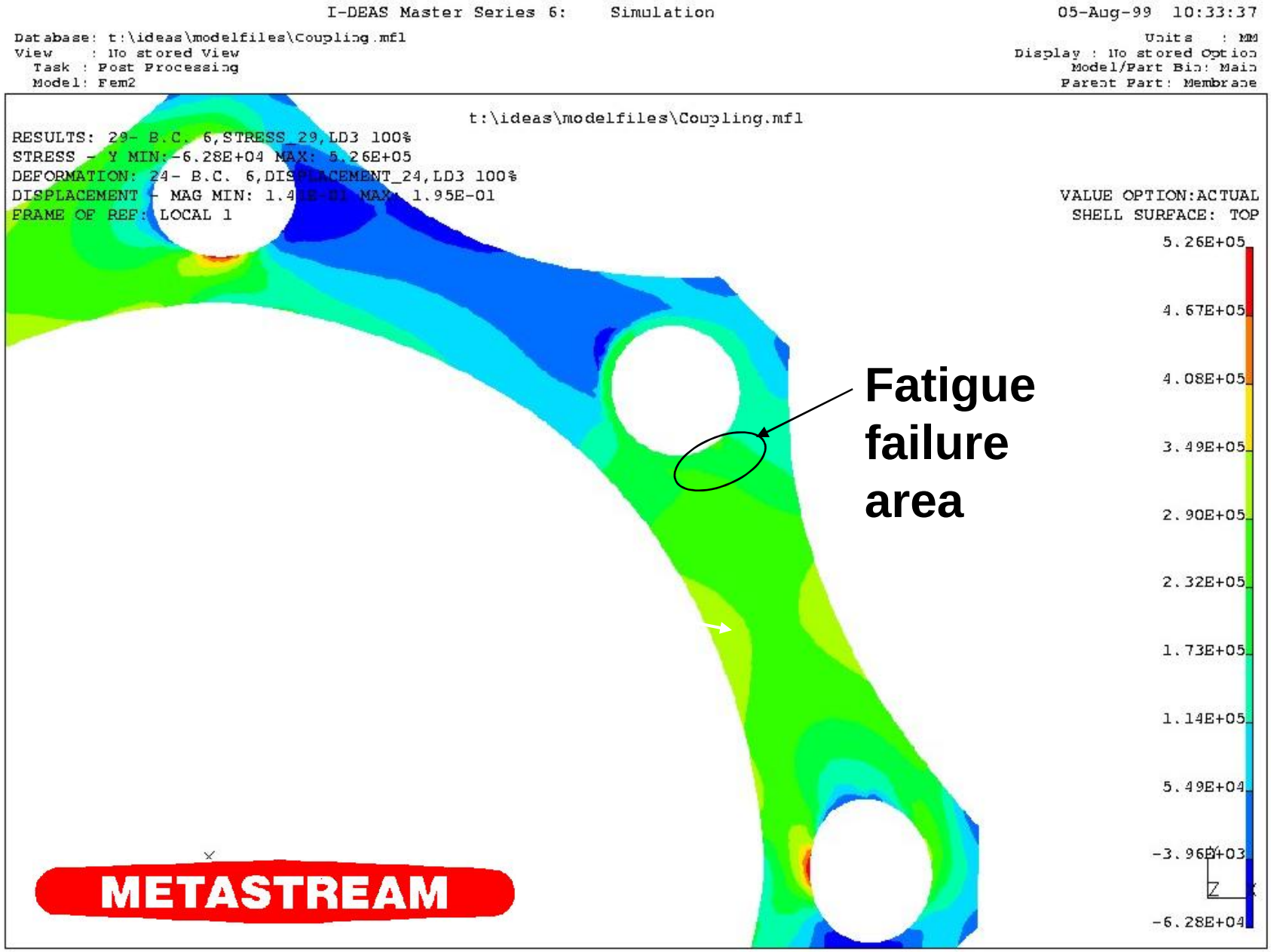


Main drive bolts
must be torque tightened

Membrane Couplings

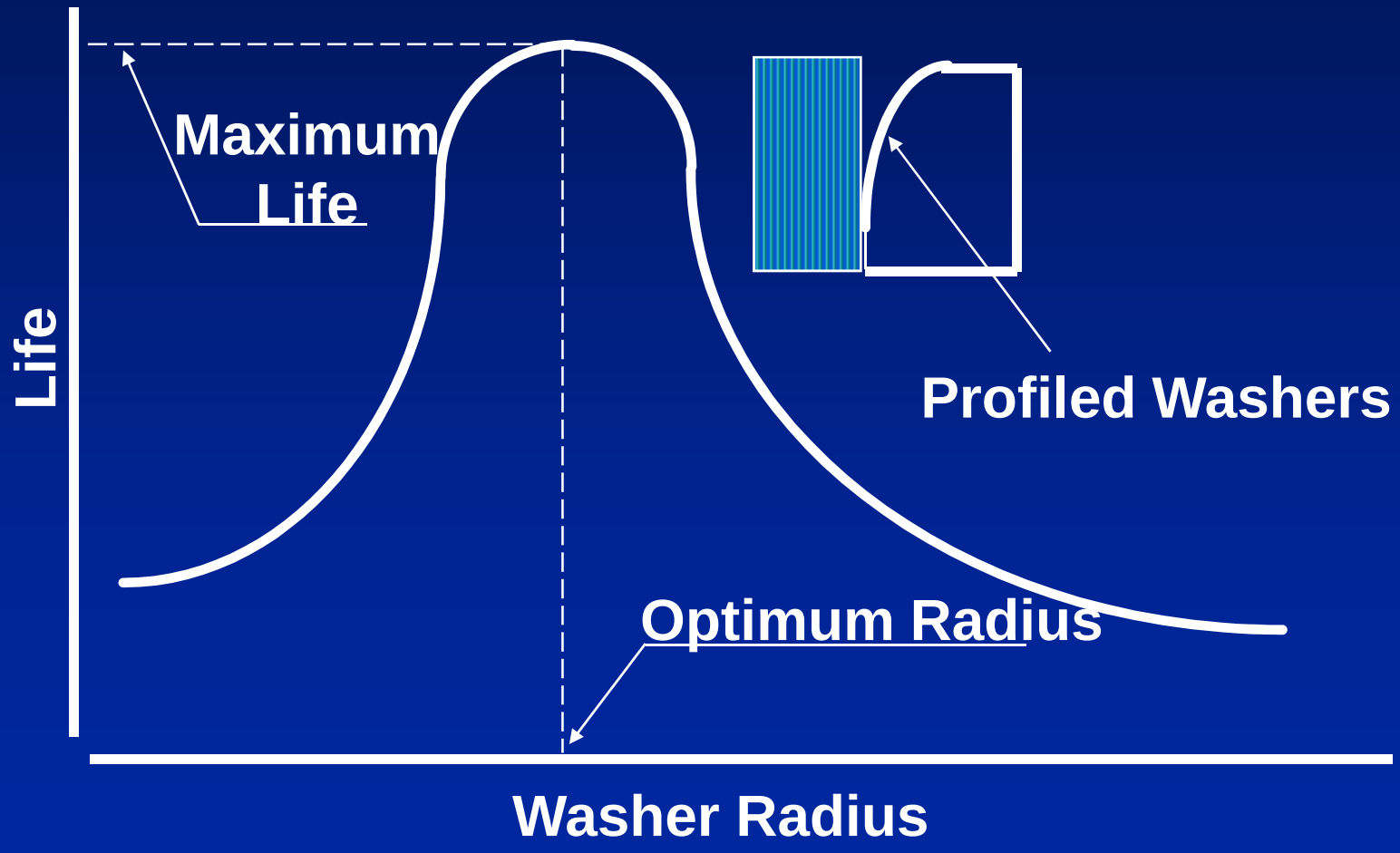
Improved disc design




I-DEAS Master Series 6: Simulation
05-Aug-99 10:33:37
Database: t:\ideas\modelfiles\Coupling.mfl
View : No stored View
Task : Post Processing
Model: Fem2
Units : MM
Display : No stored Option
Model/Part Bin: Main
Parent Part: Membrane
t:\ideas\modelfiles\Coupling.mfl
RESULTS: 29- B.C. 6,STRESS_29,LD3 100%
STRESS - Y MIN:-6.28E+04 MAX: 5.26E+05
DEFORMATION: 24- B.C. 6,DISPLACEMENT_24,LD3 100%
DISPLACEMENT - MAG MIN: 1.4 E-01 MAX: 1.95E-01
FRAME OF REF: LOCAL 1
VALUE OPTION:ACTUAL
SHELL SURFACE: TOP
5.26E+05
4.67E+05
4.08E+05
3.49E+05
2.90E+05
2.32E+05
1.73E+05
1.14E+05
5.49E+04
-3.96E+03
-6.28E+04
Fatigue failure area
METASTREAM

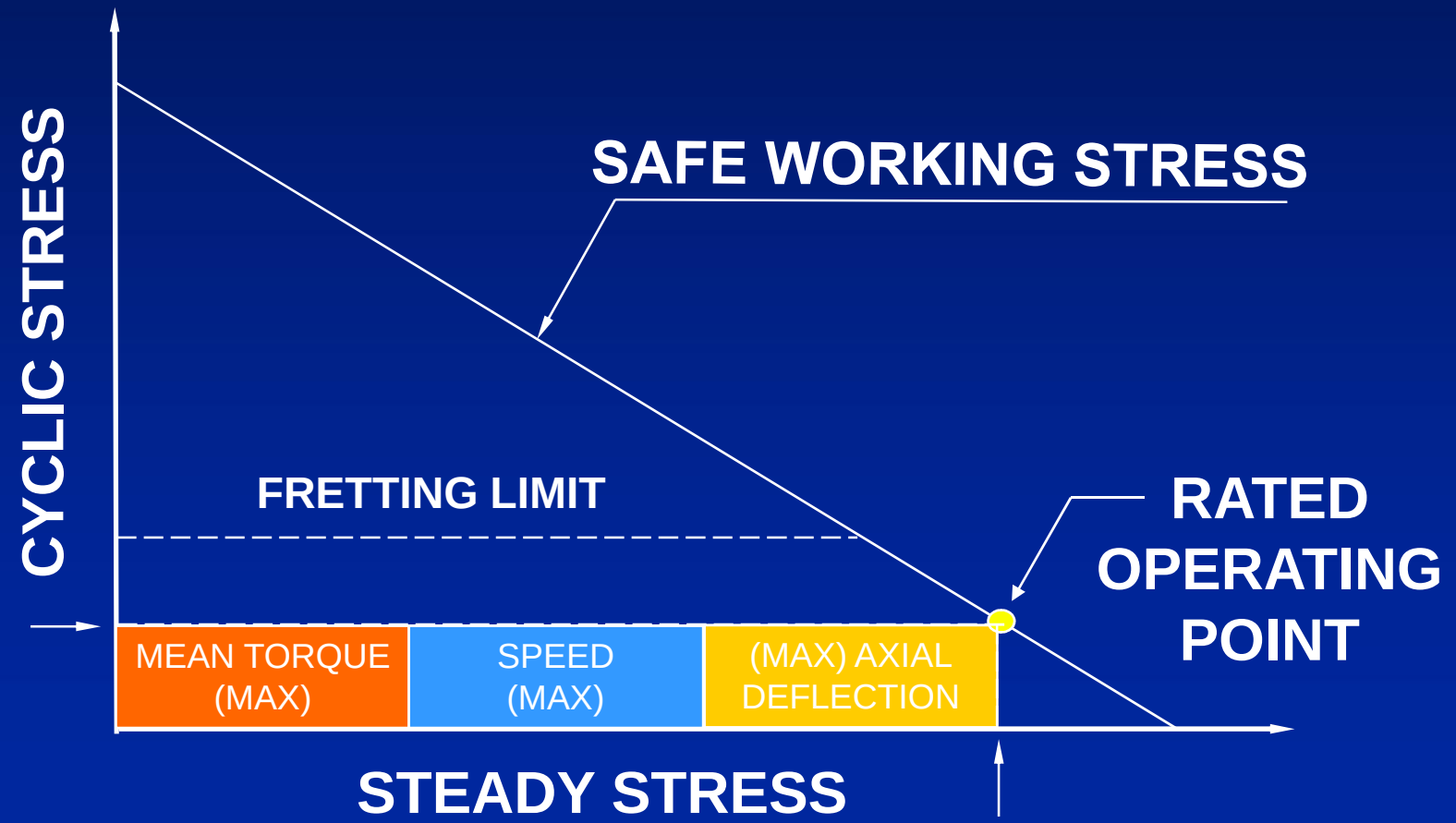
Membrane Couplings

Optimising design

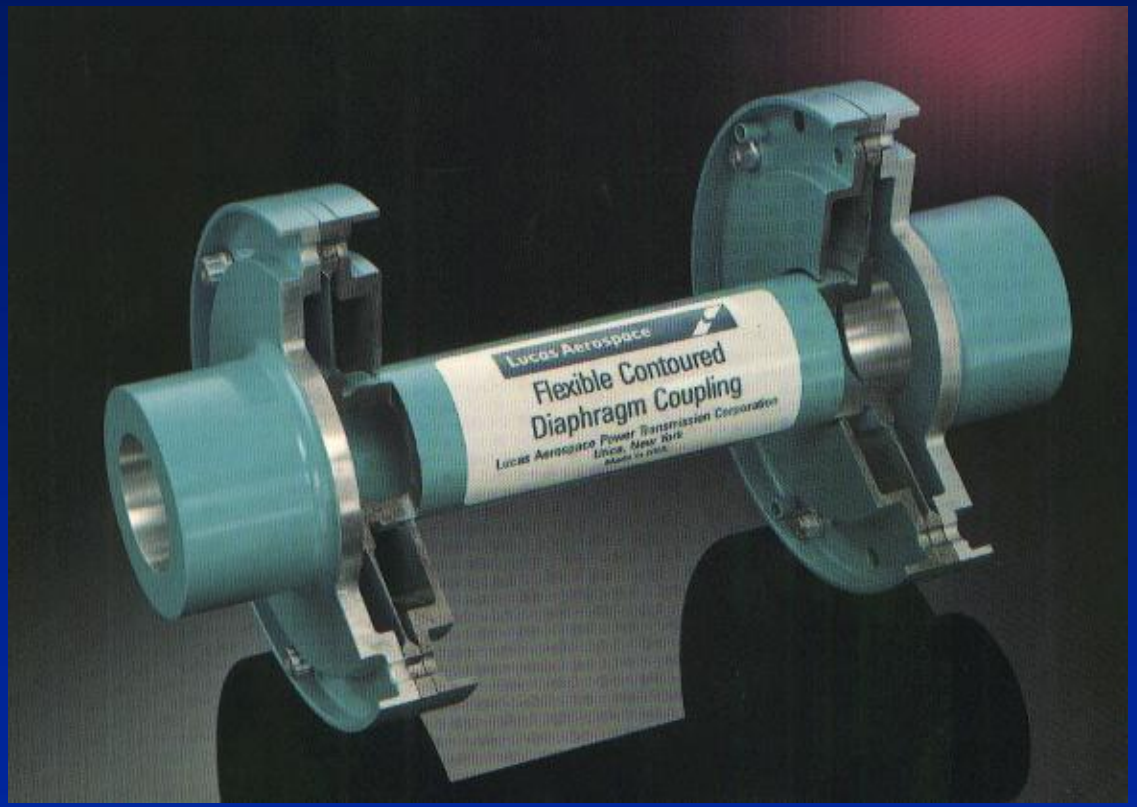


Membrane Couplings

Disc element stresses
Modified Goodman Diagram



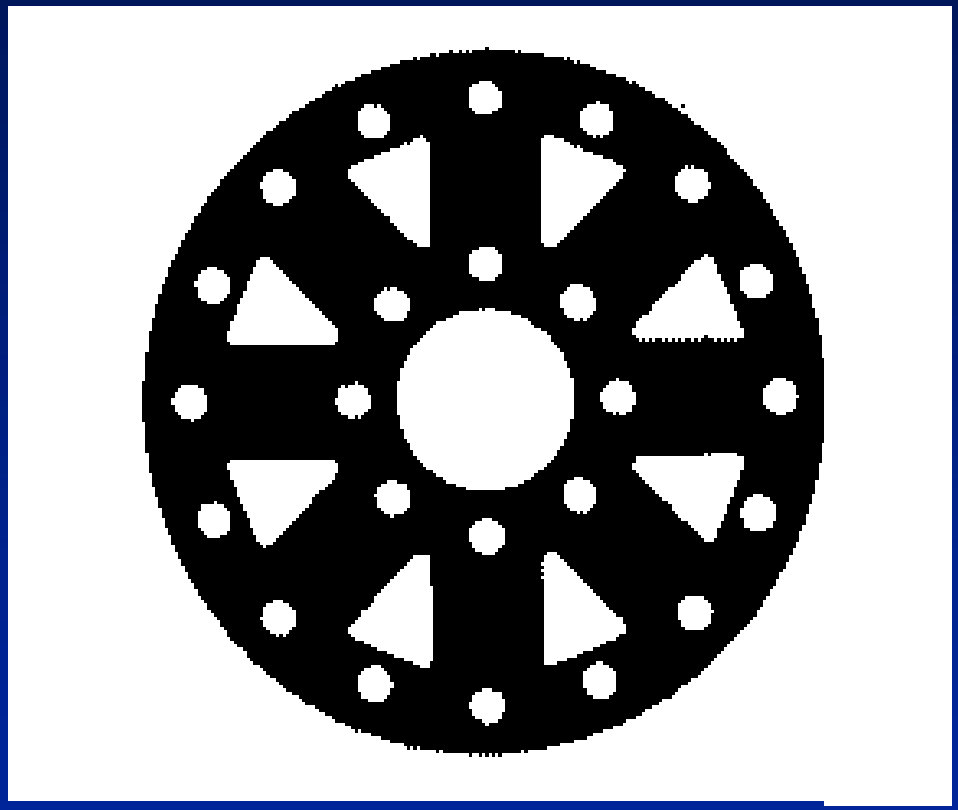
Membrane Couplings



‘Contoured Diaphragm’ type

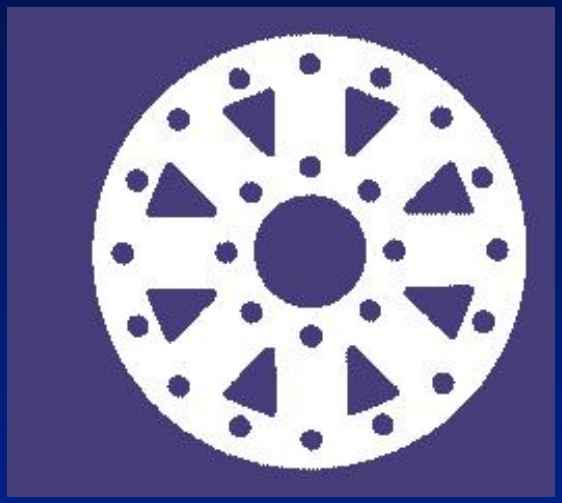
Membrane Couplings

Diaphragm type



Multiple Membrane

Membrane Couplings

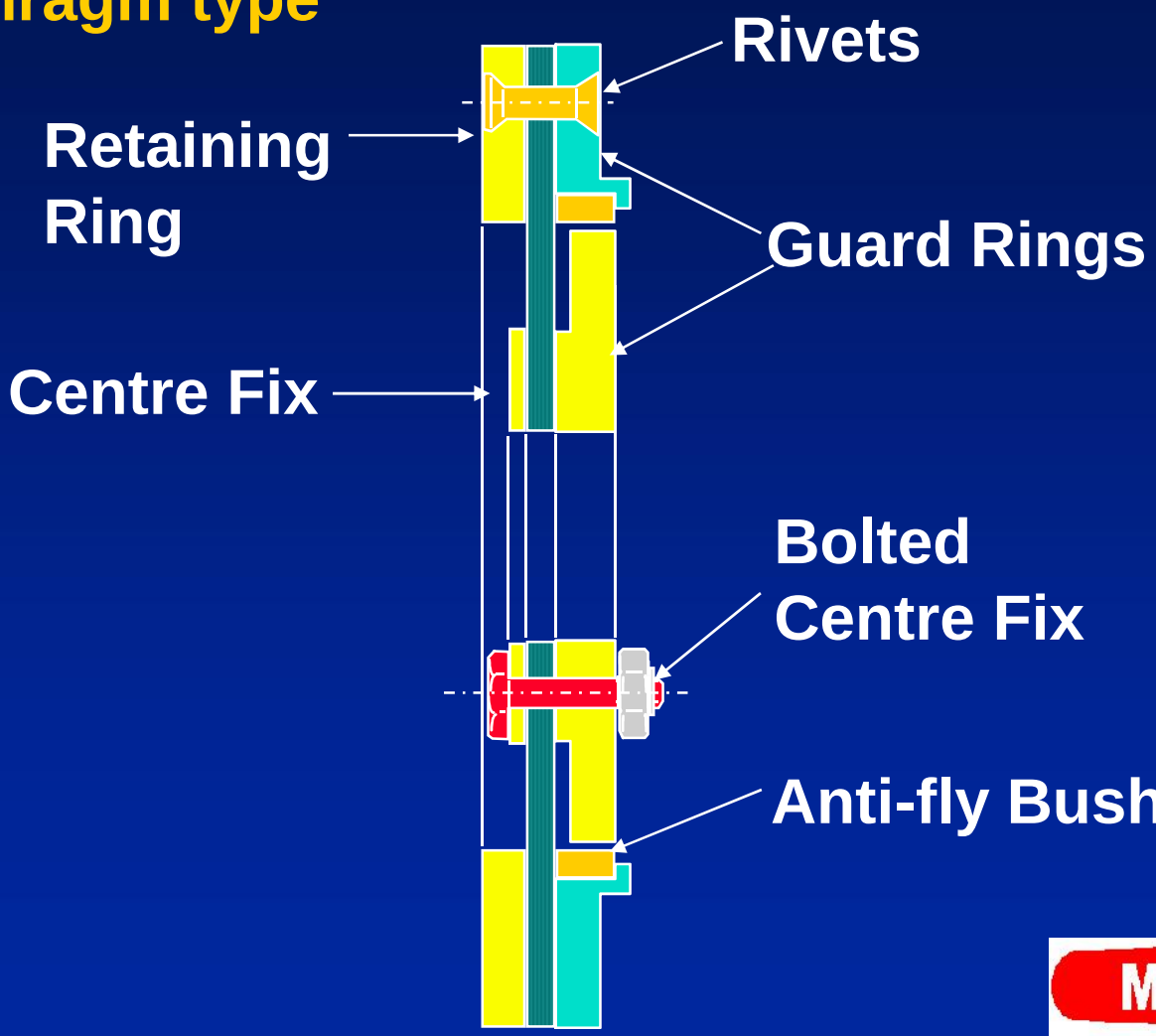


The original Metastream coupling

METASTREAM

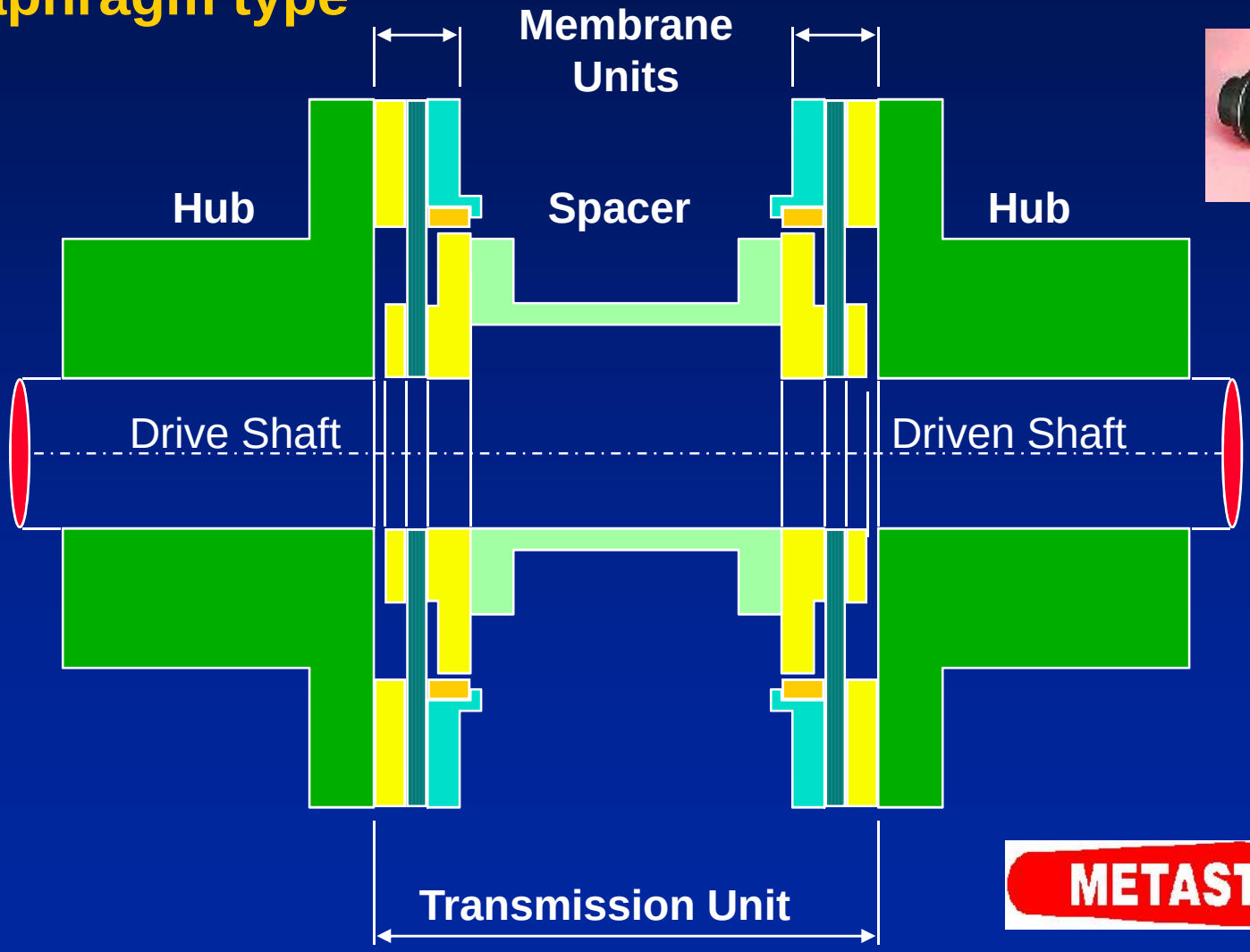
Membrane Couplings

Diaphragm type



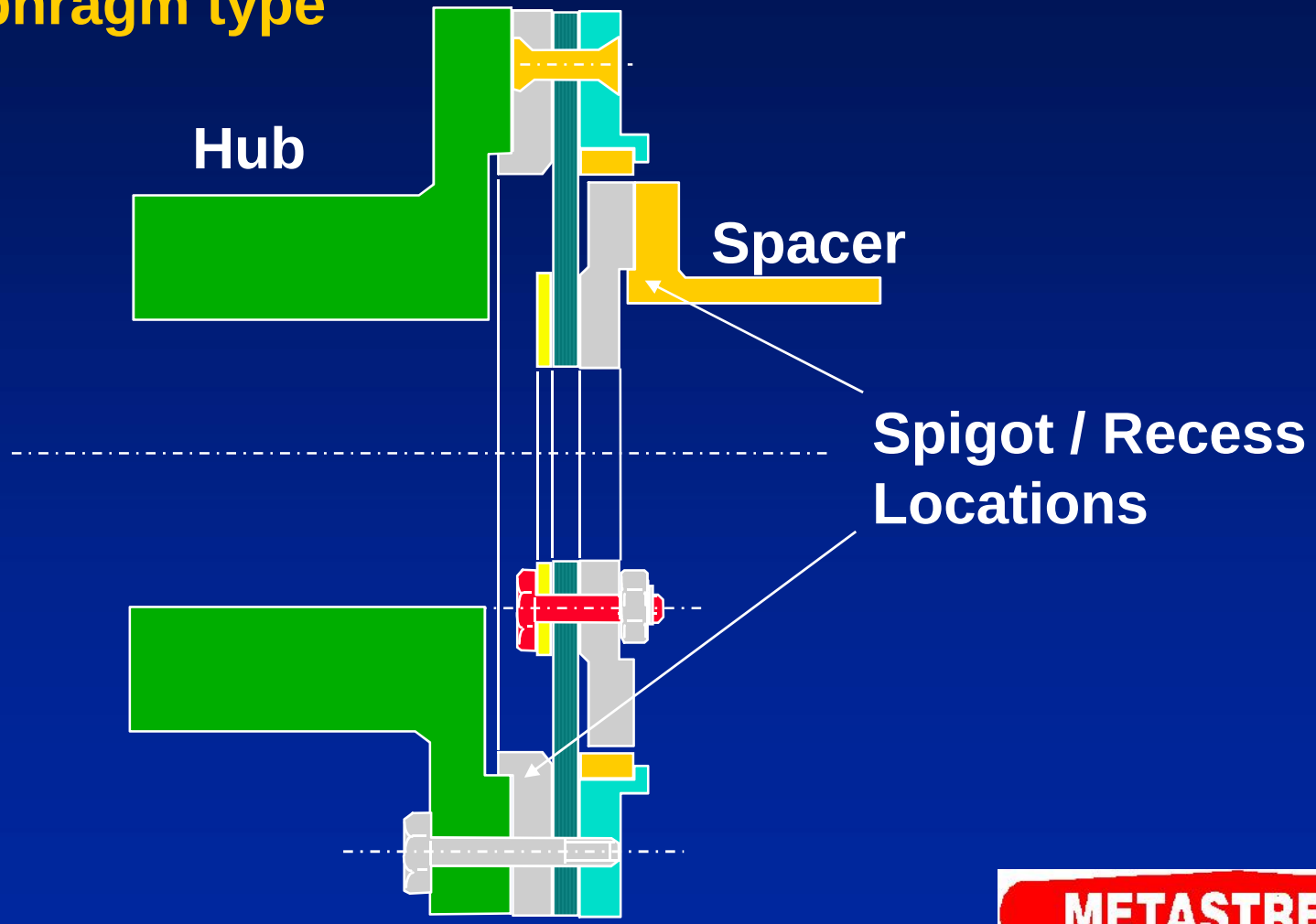
Membrane Couplings

Diaphragm type



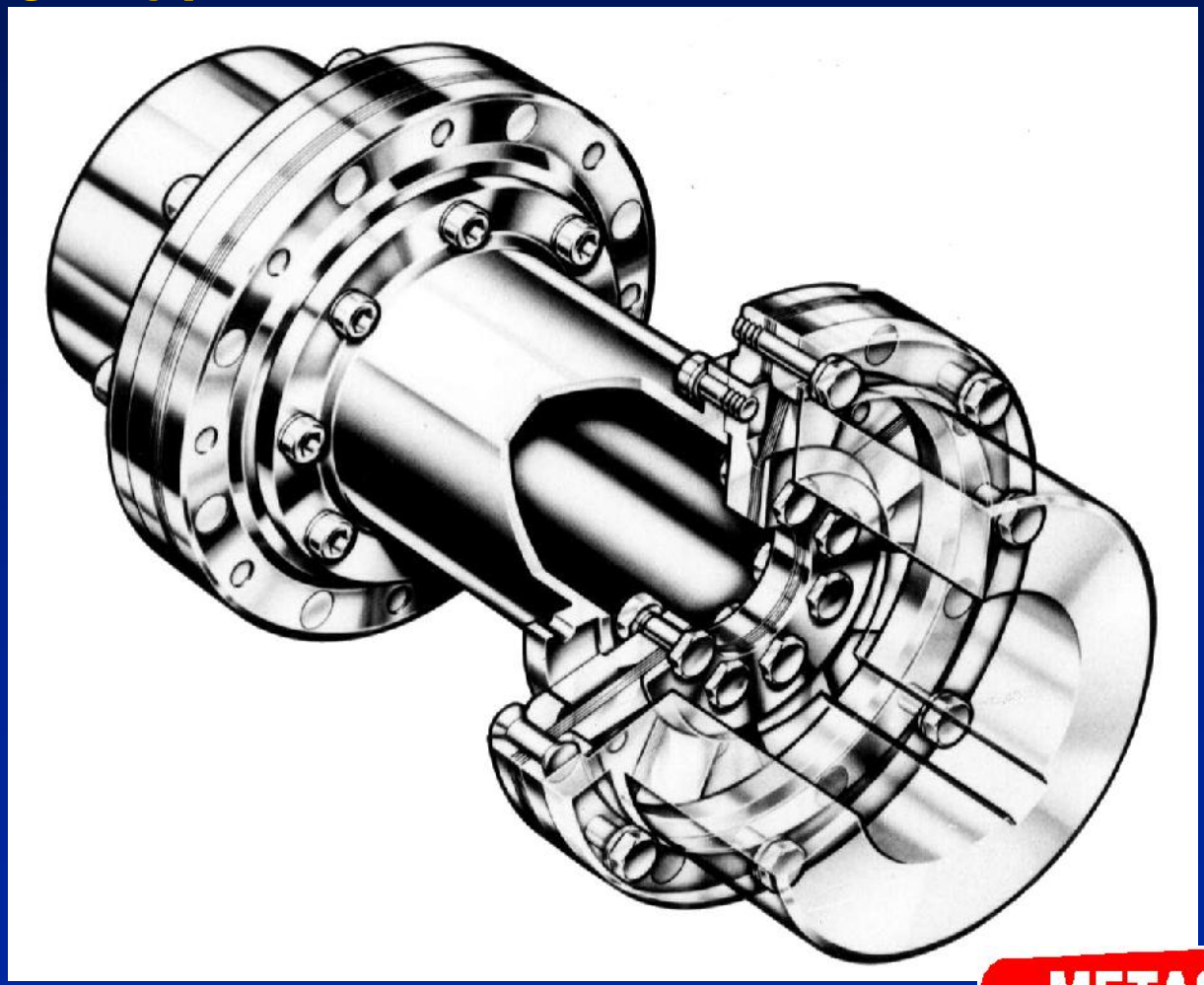
Membrane Couplings

Diaphragm type



Torsionally Rigid Couplings

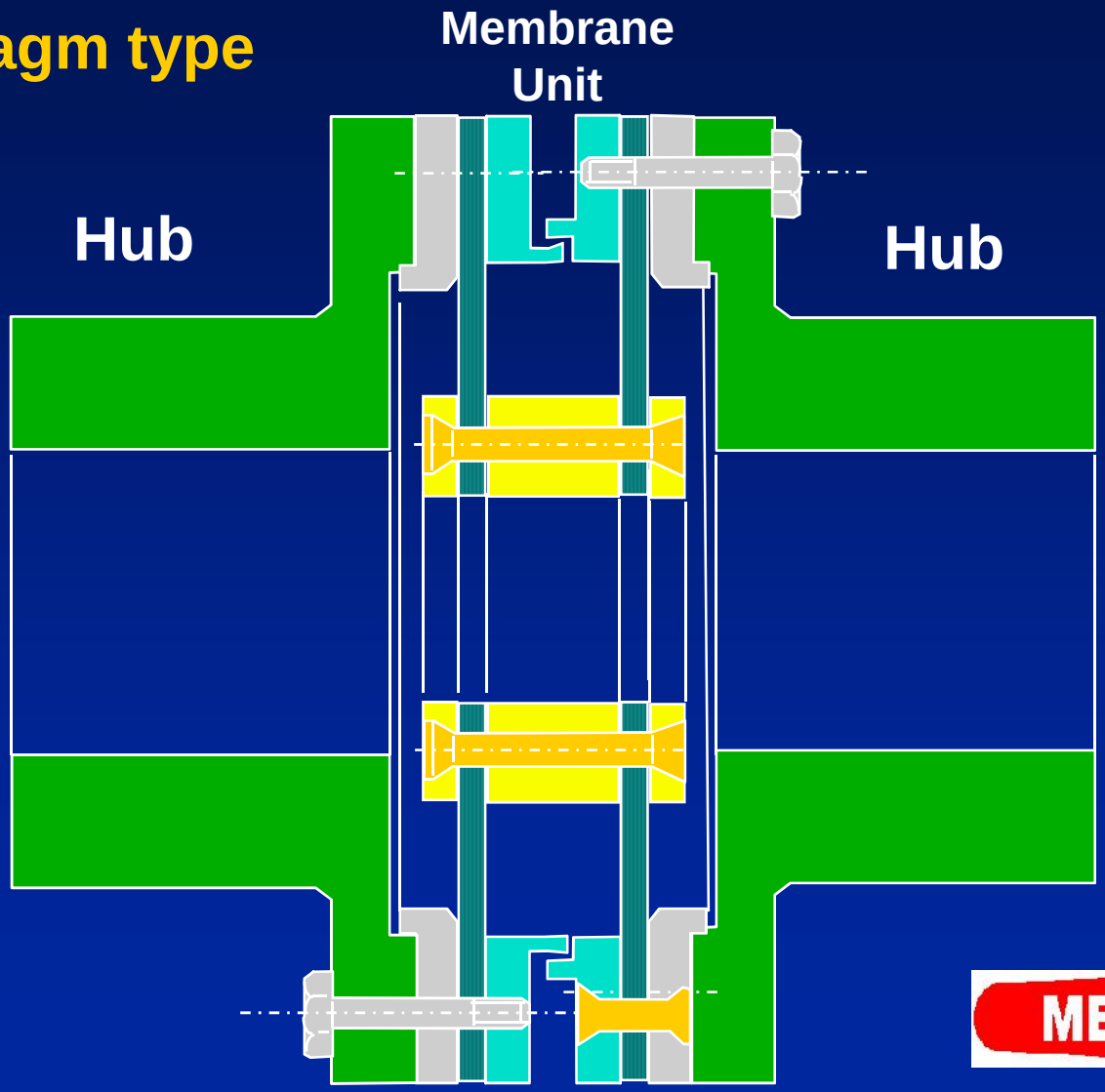
Diaphragm type



METASTREAM

Membrane Couplings

Diaphragm type



Contents

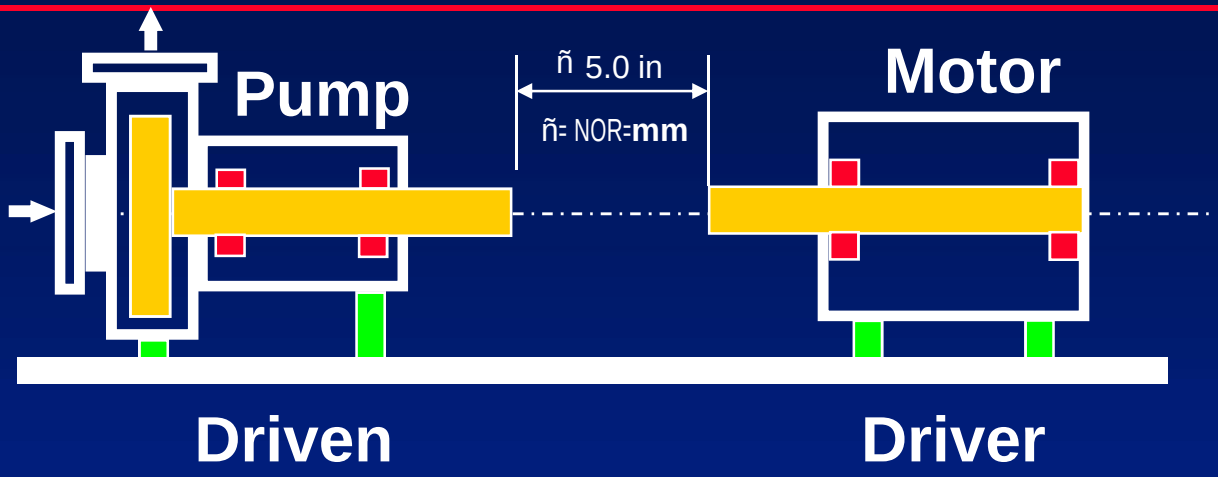
- **Introduction**
- **Types of coupling in use**
- **Membrane couplings**
  - Disc type
  - Diaphragm style
- **API Reliability and Safety issues**
- **Good Alignment practices**
- **Special designs**
- **Conclusion**

Power Transmission Couplings

Key Issues

- Compliance with API 610 (or 671)
- Easy installation - minimal tools and skills
  - spacer types
- Zero maintenance - no lubrication
- Reliability - Fit and Forget / Long life
- Safety - overload capability
  - fail safe design
- Low bearing loads - increased machinery life and performance (seals)

API 610



3.2.2 Unless otherwise specified, couplings shall be flexible element. Coupling hubs shall be steel. Flexible disc types shall have discs of corrosion resistant material. The make, model, materials, service factor, and mounting arrangement of couplings will be specified by the purchaser. A spacer coupling shall be used unless otherwise specified. The spacer shall have a nominal length of at least 125 mm (5 in.) and shall permit removal of the coupling, bearings, seal, and rotor as applicable, without disturbing the driver or the suction and discharge piping.
Note: For flexible element couplings, consideration should be given to designs that will retain the spacer if a flexible element ruptures.

3.2.5 Couplings and coupling to shaft juncture shall be rated for at least the maximum driver power, including any service factor.

API 610

3.2.6 Couplings shall be manufactured to meet the requirements of ANSI/AGMA 9000 Class 9.

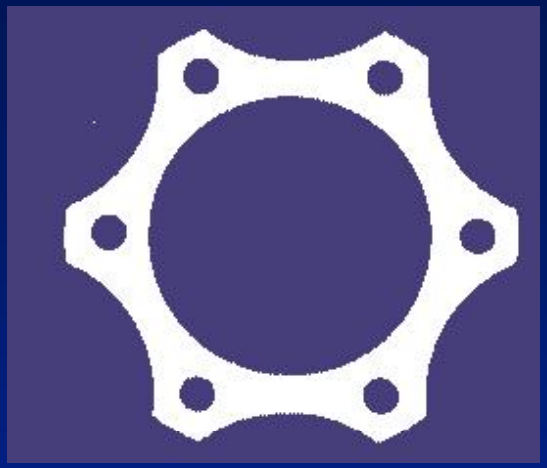
3.2.7 Couplings operating at speeds of 3800 RPM or less shall be component balanced. Each component such as hubs, sleeves, flexible elements, spacers and adapters shall be balanced individually. All machining of components, except keyways of single keyed hubs, shall be completed before balancing. Balancing shall be in accordance with 2.8.4.1. Two-plane balancing is preferred; however, single-plane balancing may be used in accordance with 2.8.4.2 .

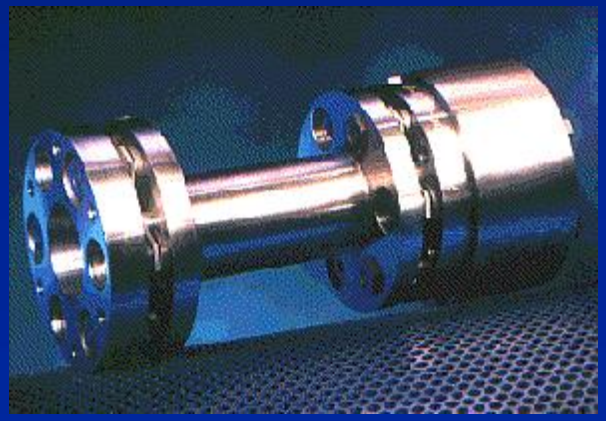
3.2.8 Couplings operating at speeds in excess of 3800 RPM shall meet the requirements of API Standard 67l for component balancing and assembled balance check.

API 610

- couplings shall be flexible element type
  RELIABILITY - LONG LIFE
- Flexible disc types shall have discs of corrosion resistant material
  RELIABILITY - LONG LIFE
- service factor specified by purchaser (torque characteristics ?)
  RELIABILITY & SAFETY
- ….. design will retain the spacer if a flexible element ruptures
  SAFETY
- Couplings shall be manufactured to meet the requirements of ANSI/AGMA 9000 Class 9. (balancing specification)
  RELIABILITY & MACHINE LIFE & INSTALLATION

Reliability



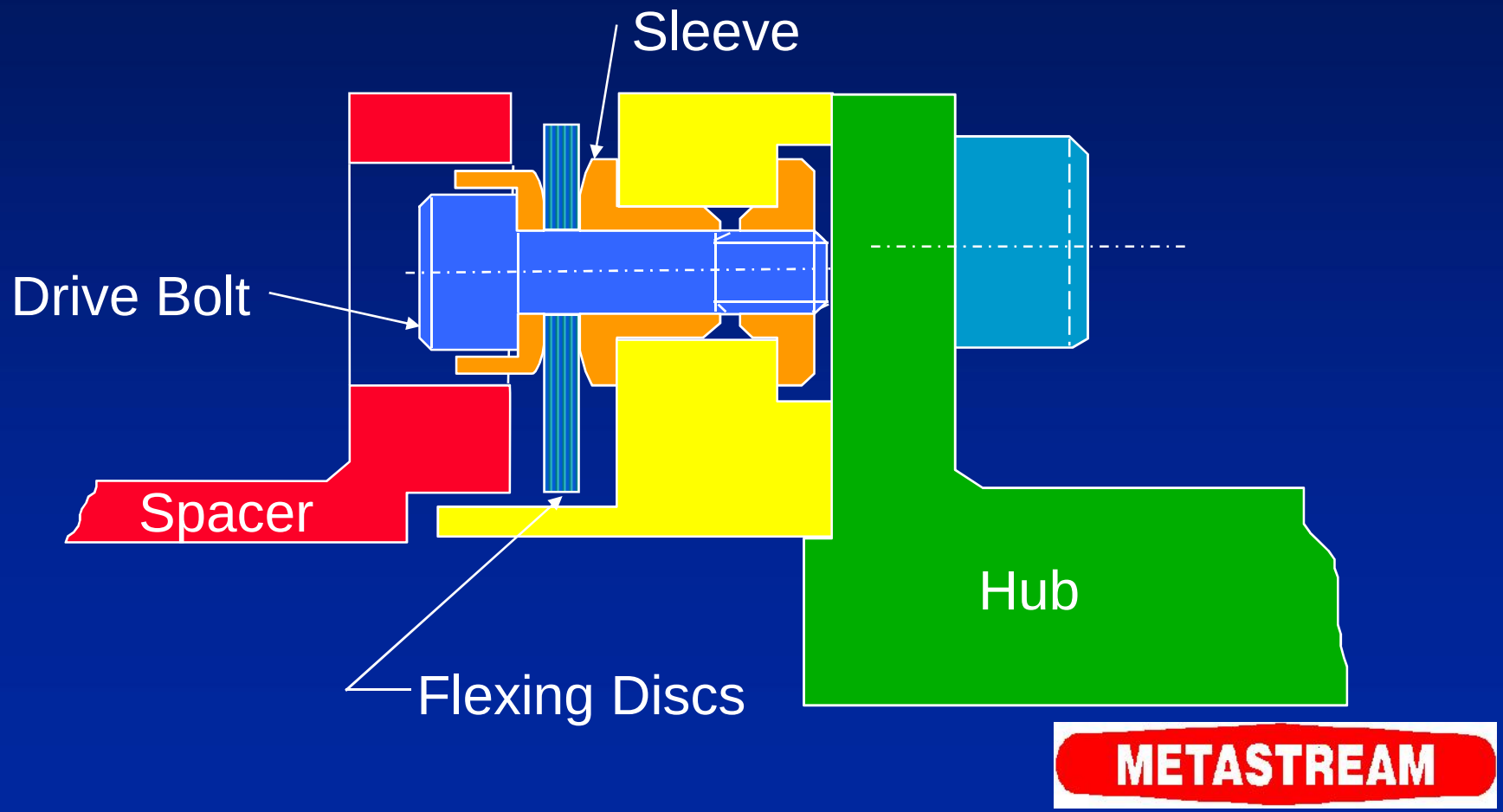


API requirements

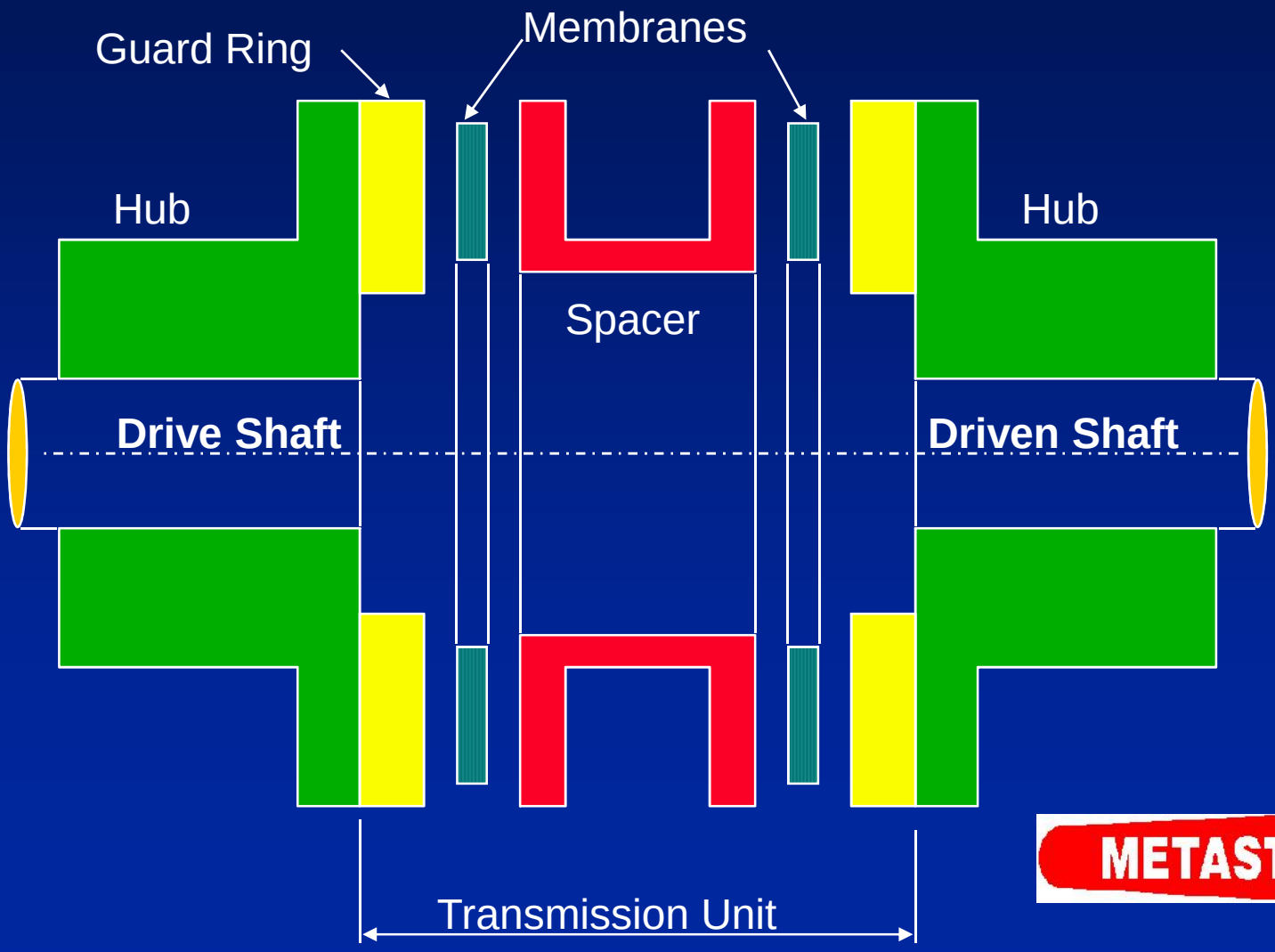
- Reliability/long life
- Ease of maintenance
- Safety
  - containment
  - fail safe

Reliability

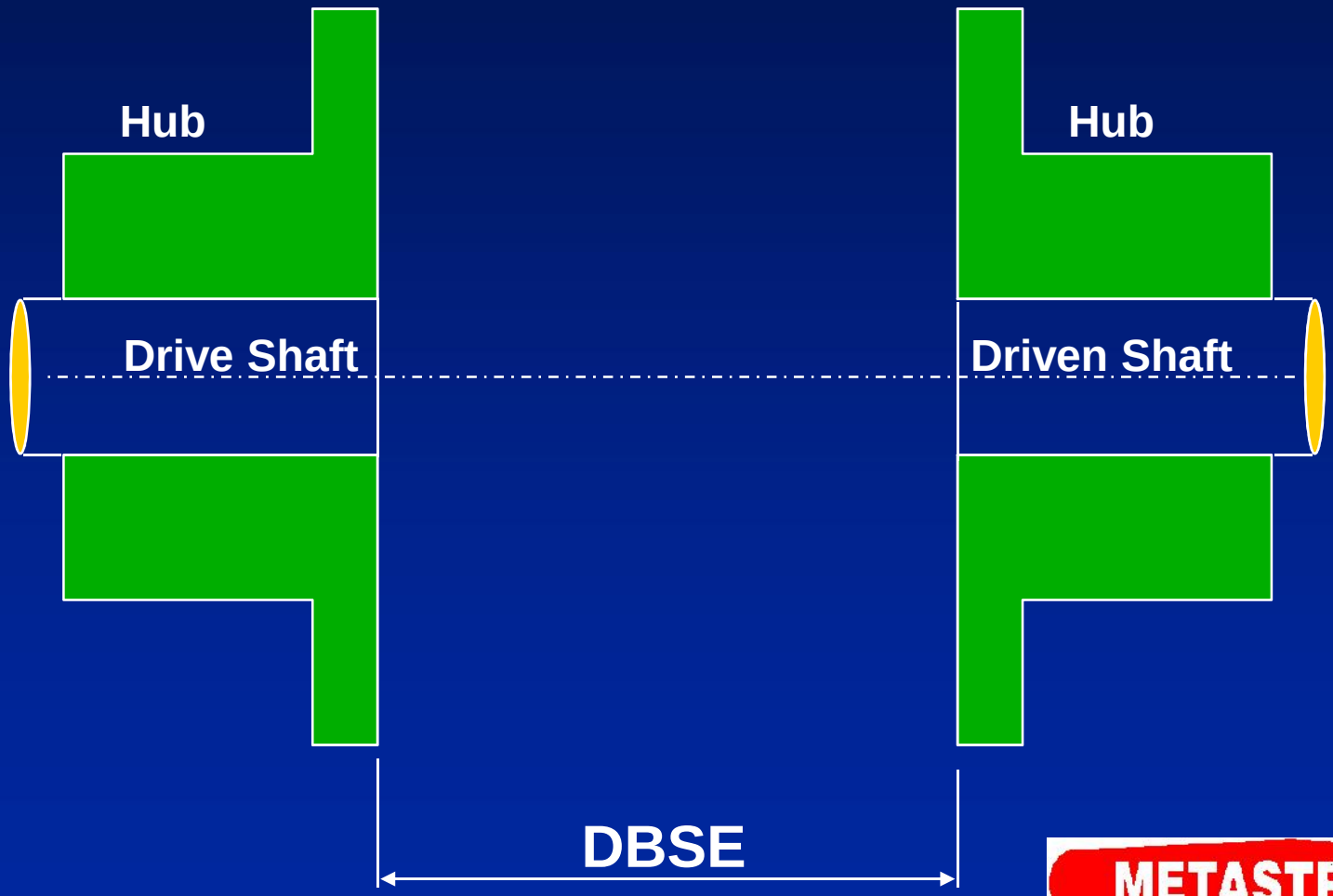
Cartridge assembly



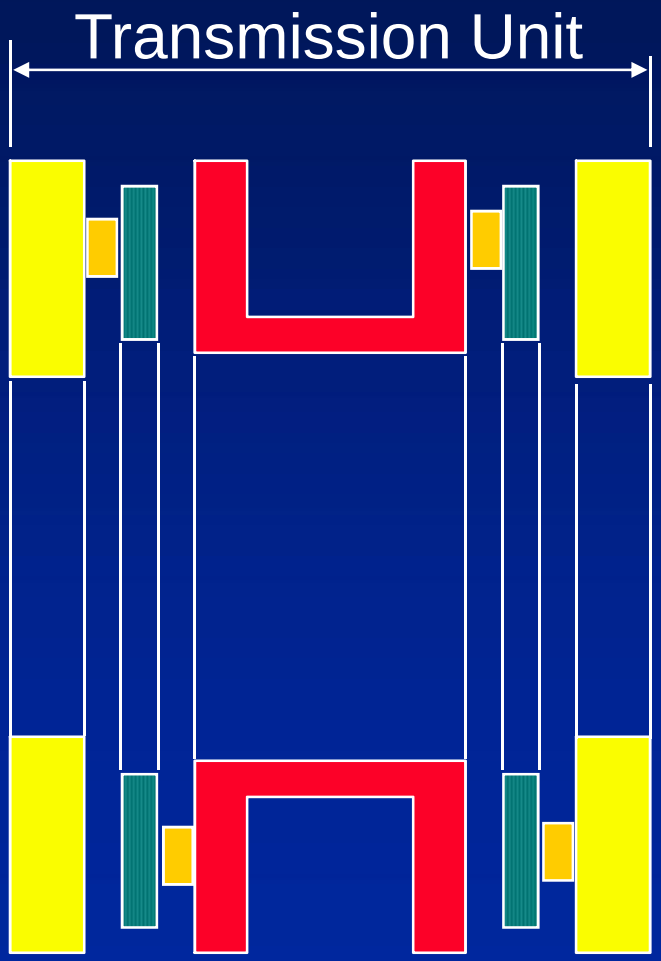
Reliability



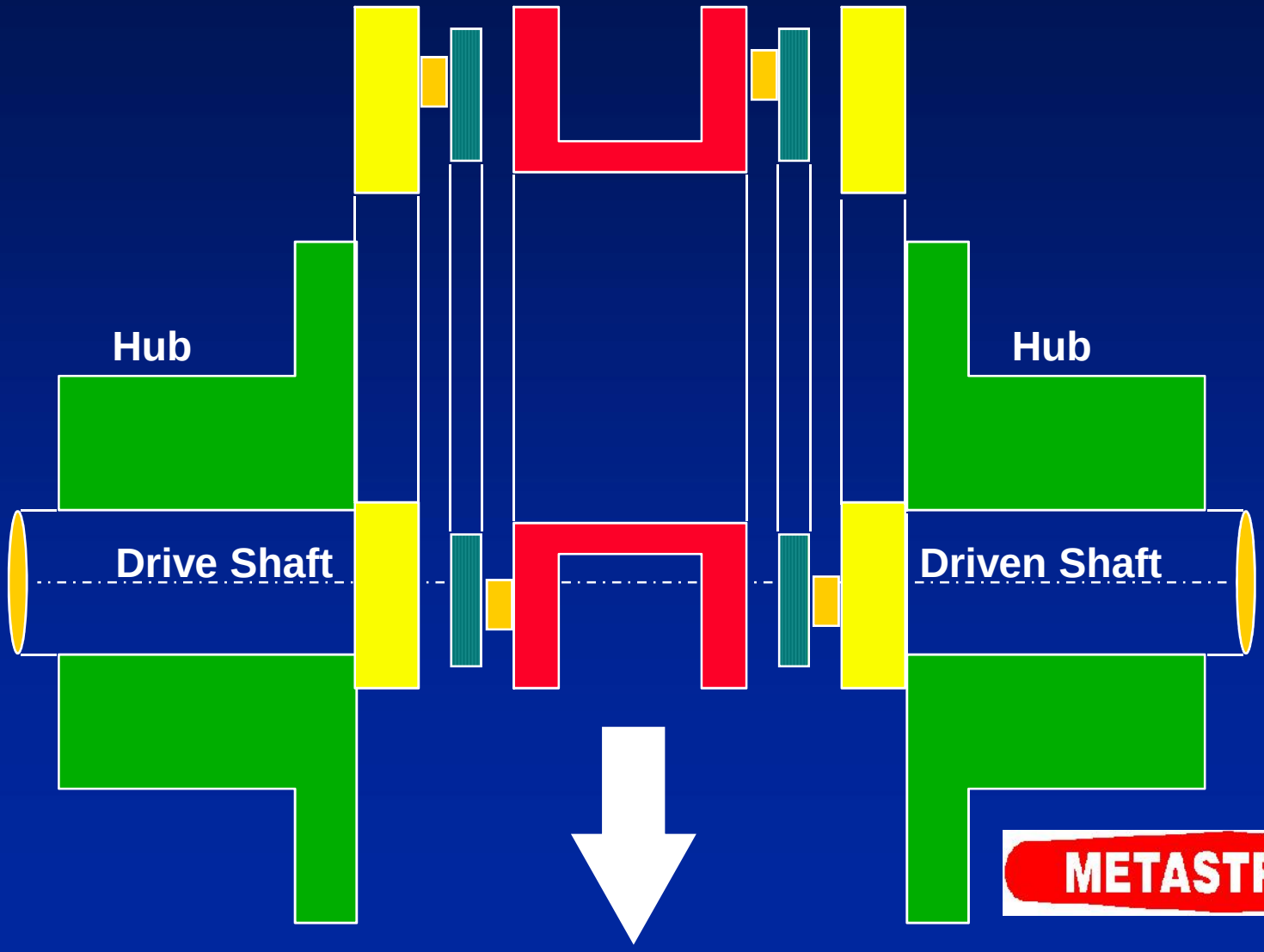
Reliability



Reliability

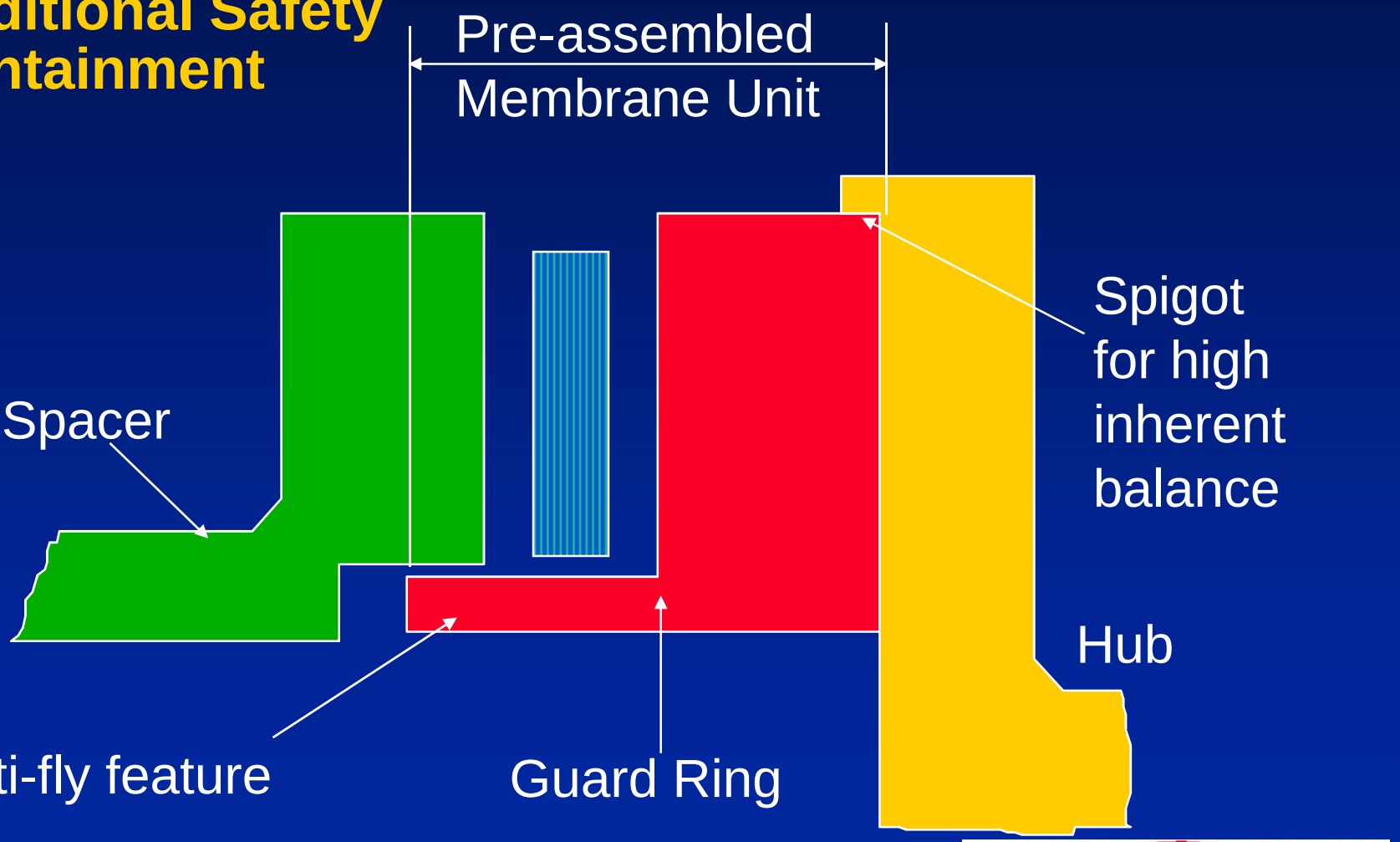


Reliability



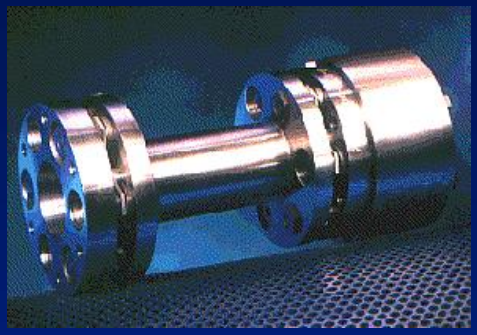
Reliability

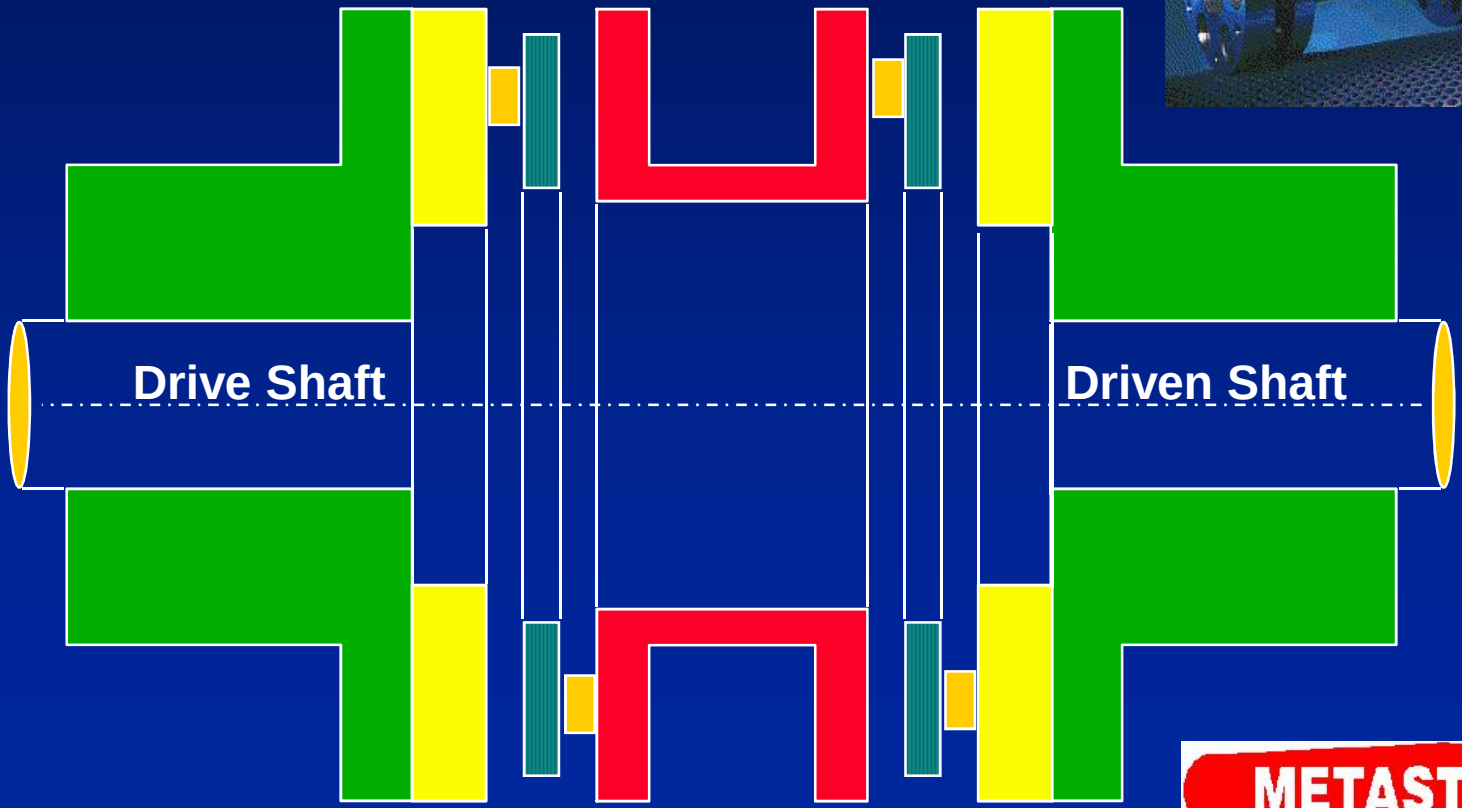
Additional Safety Containment



Safety and Reliability

Metastream T Series type TSK





METASTREAM

Safety and reliability

Fail safe

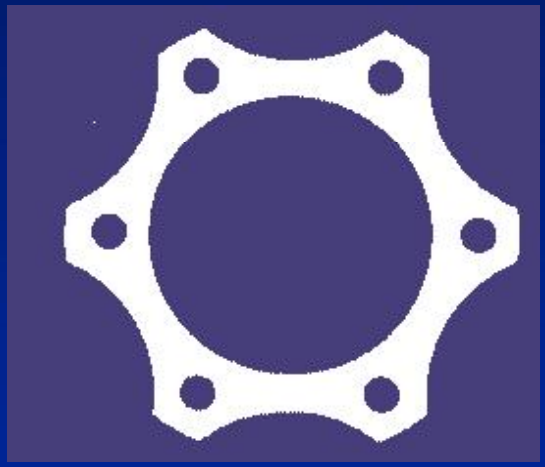
What does it mean

- retains spacer - how long
- continues drive
  - how long to run
  - how to detect
  - total failure
  - non spark
- disconnects drive
  - no flow detection
  - how long to run
  - non spark

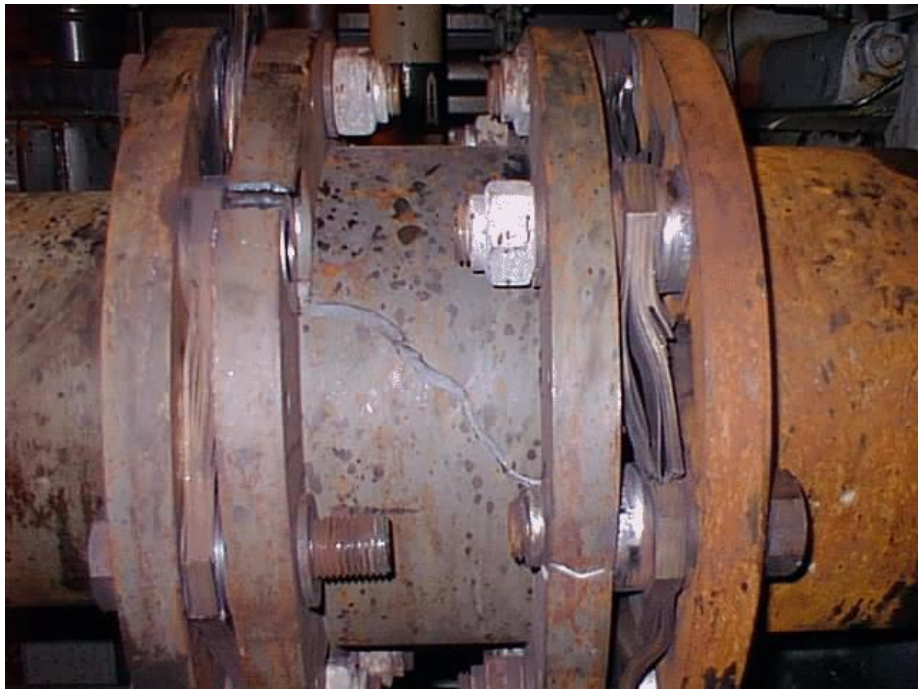
Safety and Reliability

Disc type - fail safe

- Continue drive if failure occurs due to mal-operation
- Drive bolts can eventually break
- Difficult to monitor



Will I Detect Failure?



This failure did not set off the vibration alarm and was found by visual inspection

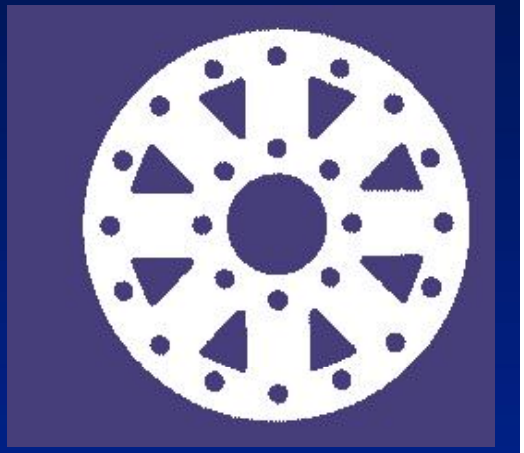
(And could soon have been a catastrophic failure)

Will I Detect Failure?

No apparent vibration until after failure

Safety and Reliability

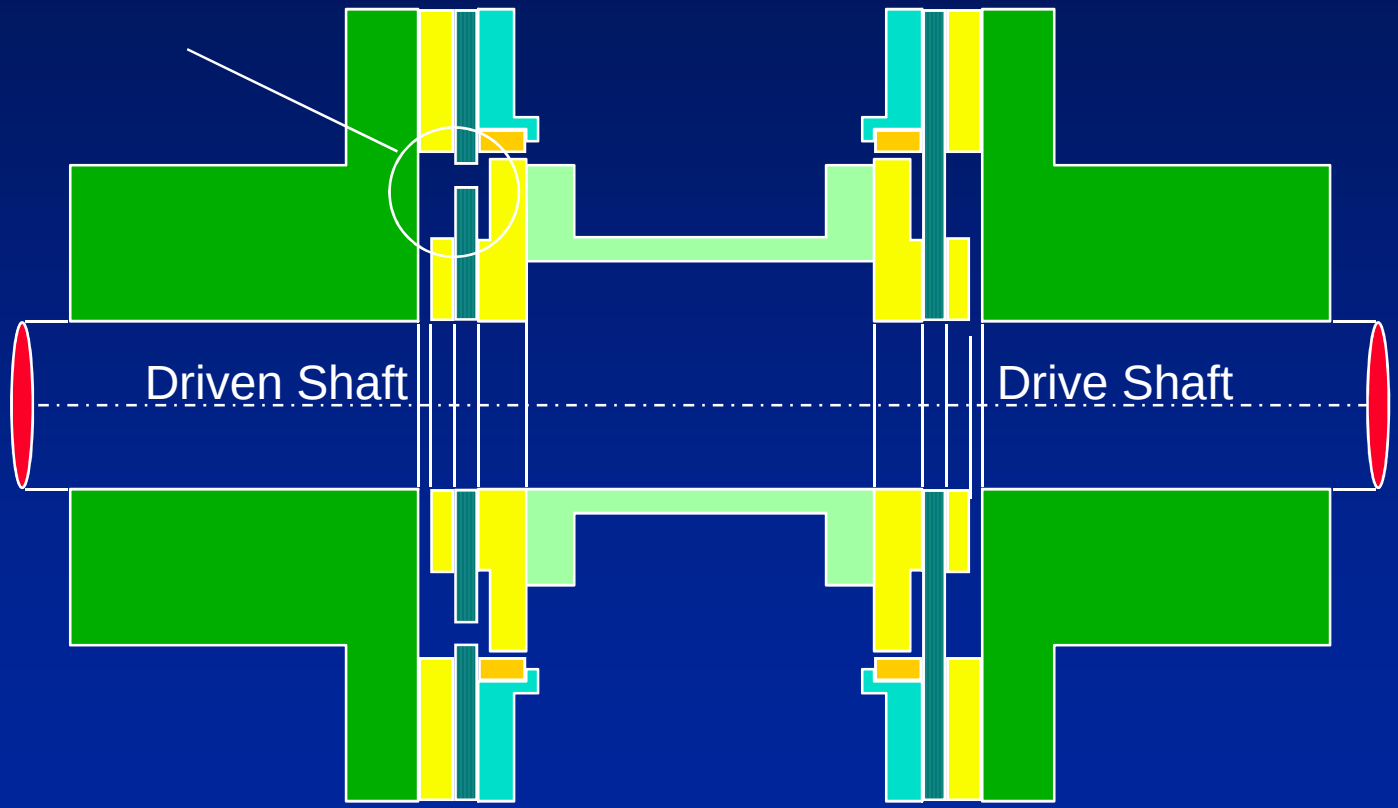
Metastream M Series



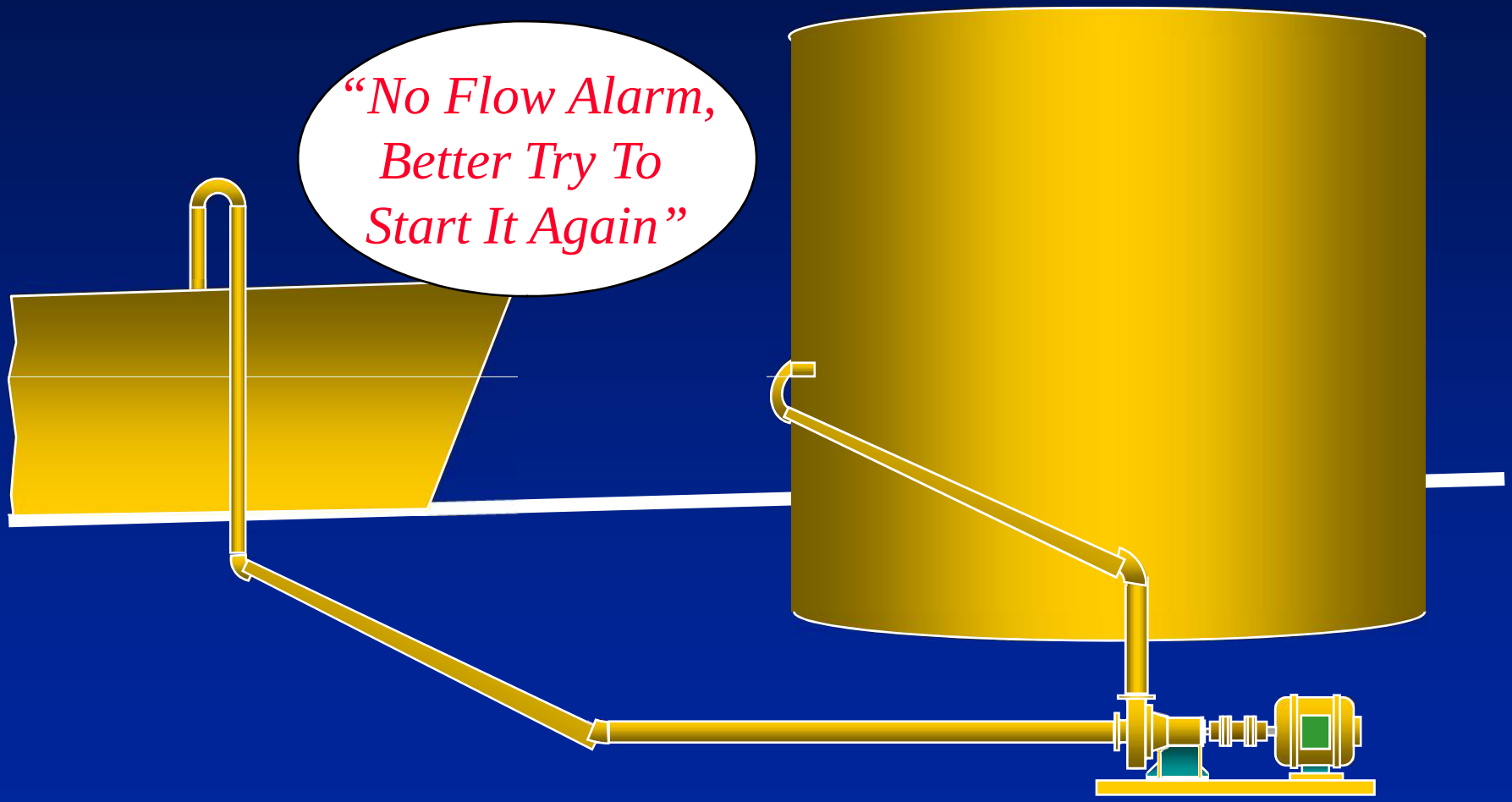
- Unique style flexible element
- Disconnects drive if failure occurs due to mal-operation
- Simple replacement of membrane pack
- Spark resistant option for hazardous areas
- Exceeds API requirements

Safety and Reliability

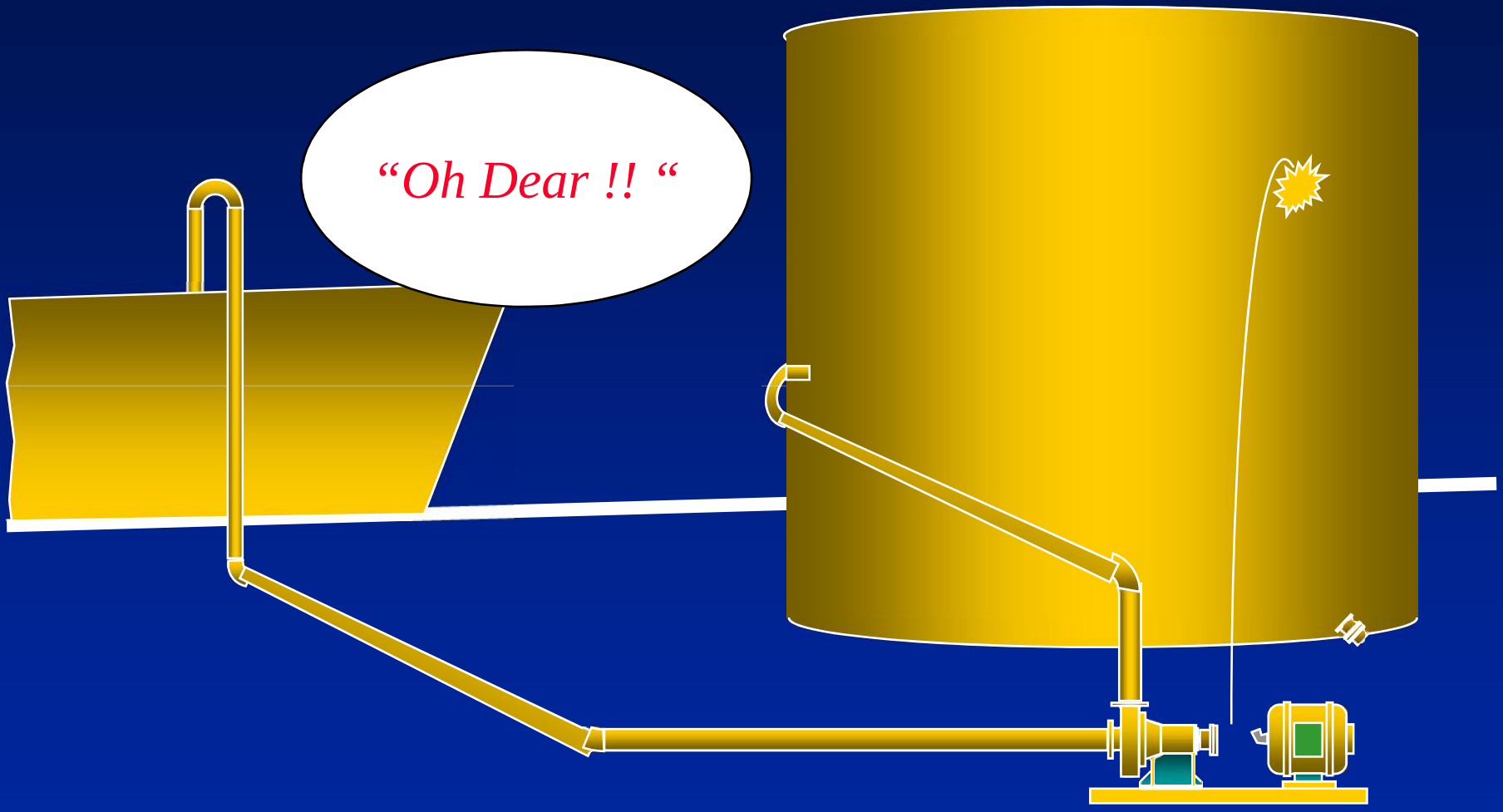
Membrane Shear



Will I Detect Failure?

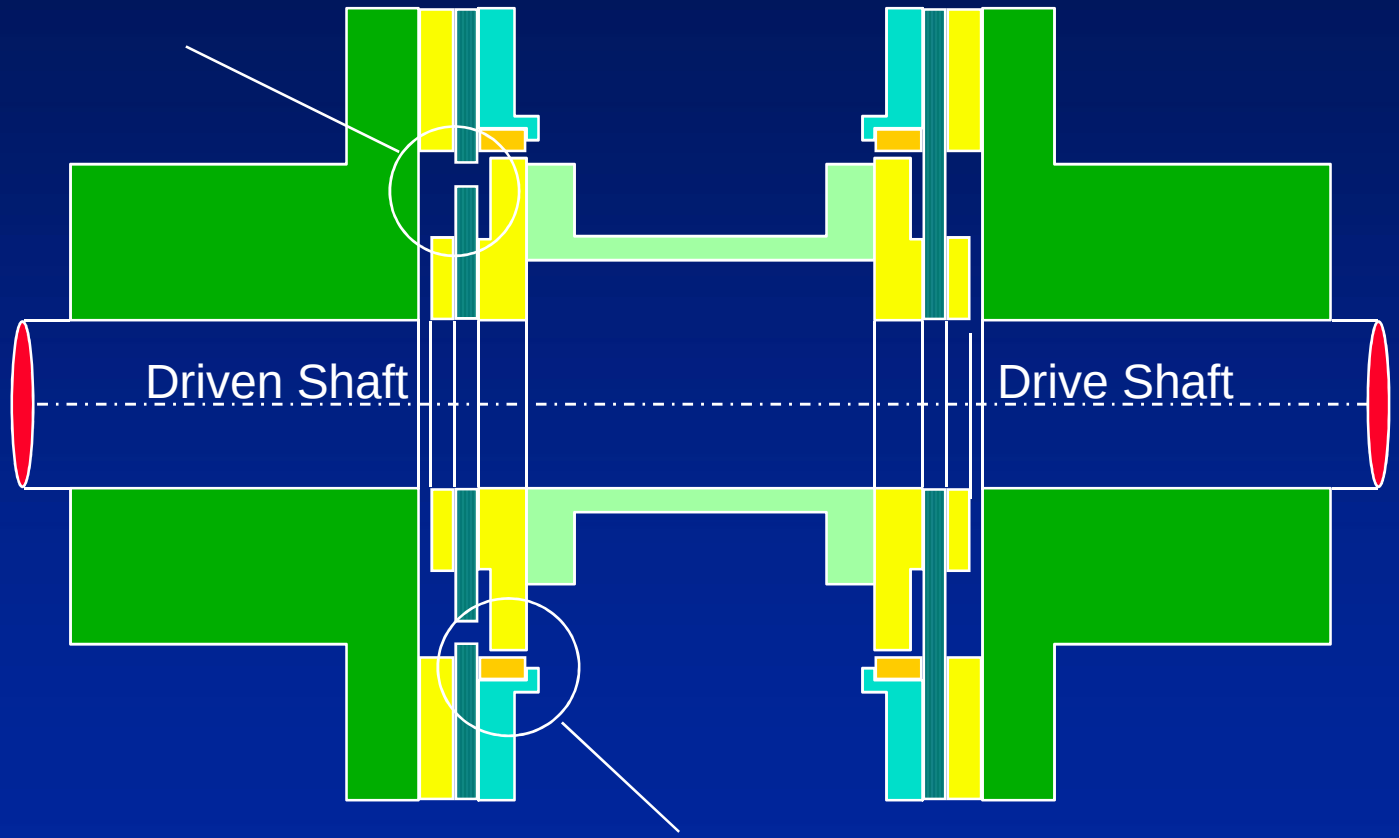


Will I Detect Failure?



Safety and Reliability

Membrane Failure



METASTREAM

Safety Bush Retains the Spacer - fail safe

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- **Conclusion**

Reliability

Membrane couplings

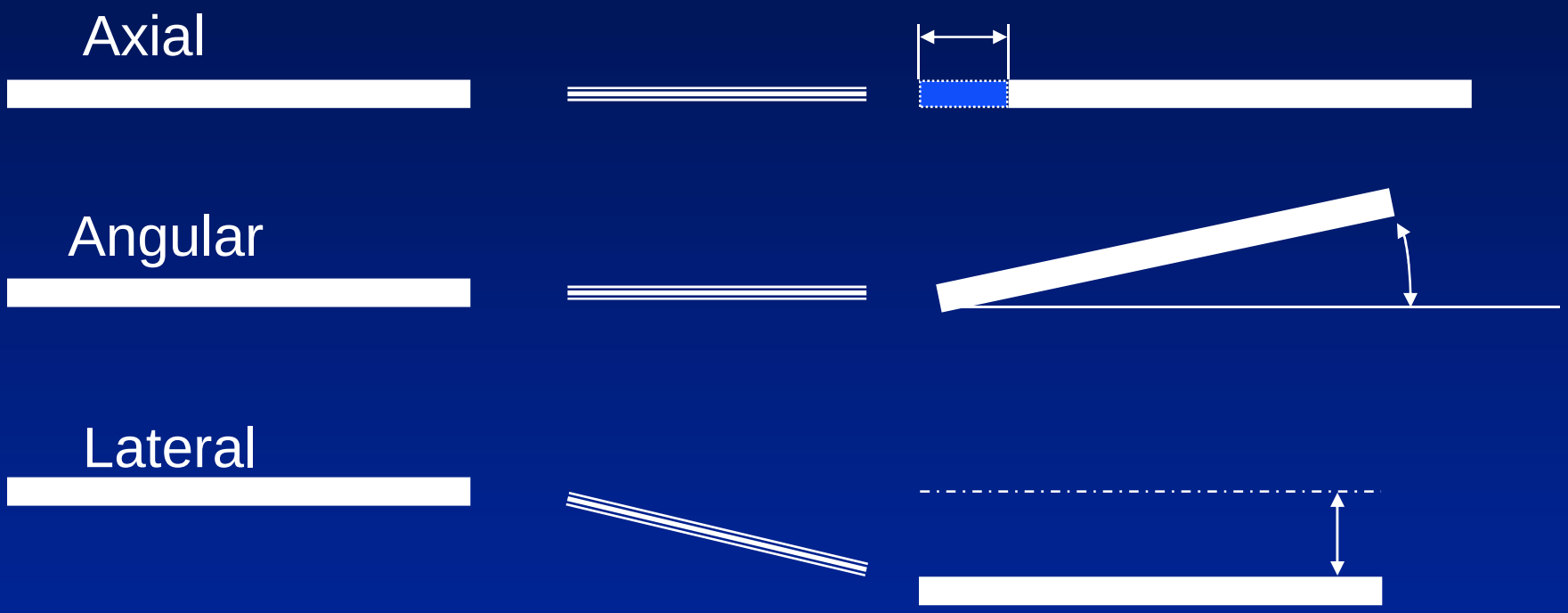
- Long or Infinite life
- No routine maintenance required

- Why do they sometimes fail ?

Reliability

- **Excessive misalignment**
- **Contamination**
- **Upset conditions**
  - Overtorque
  - Cyclic torque
  - Machinery movement
  - Excessive temperature

Reliability

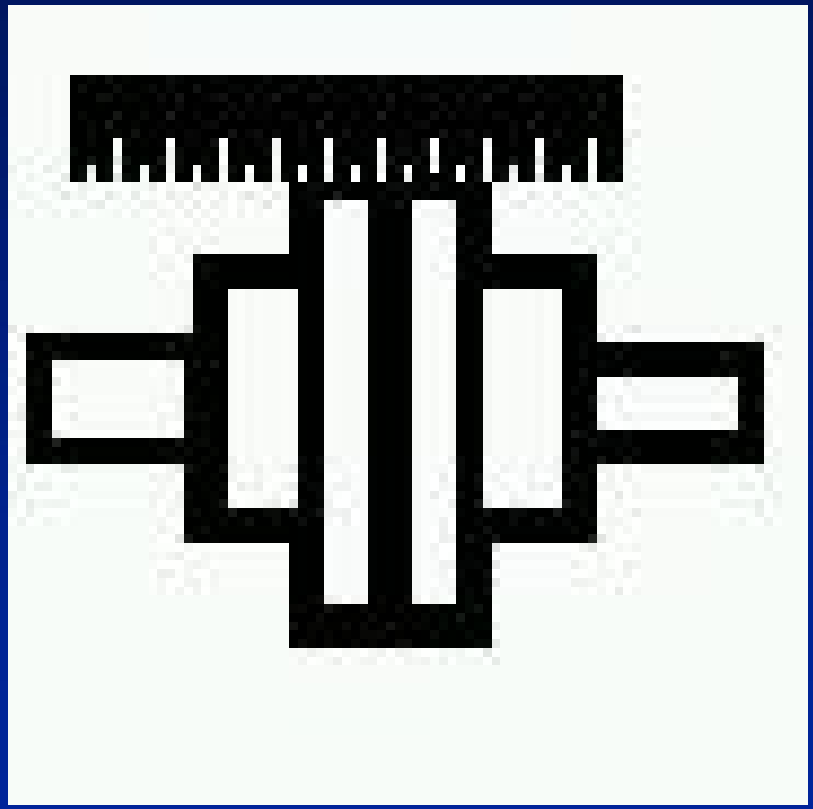


- **Poor alignment is a frequent cause of rotating machinery outage**

Shaft Alignment

- **Ruler or straight edge**

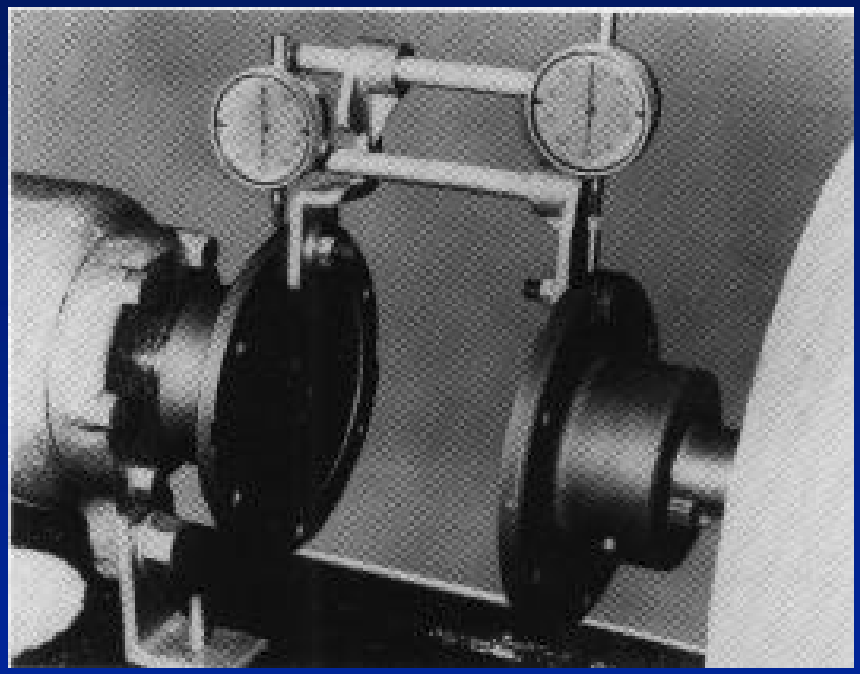
- **Not accurate**
- **Lateral check only**
- **No data recorded**



Shaft Alignment

- **Dial Indicators(DTI's)**

- **Skill & experience required**
- **Best results with reverse periphery method**
- **Time consuming for calculation and accuracy**

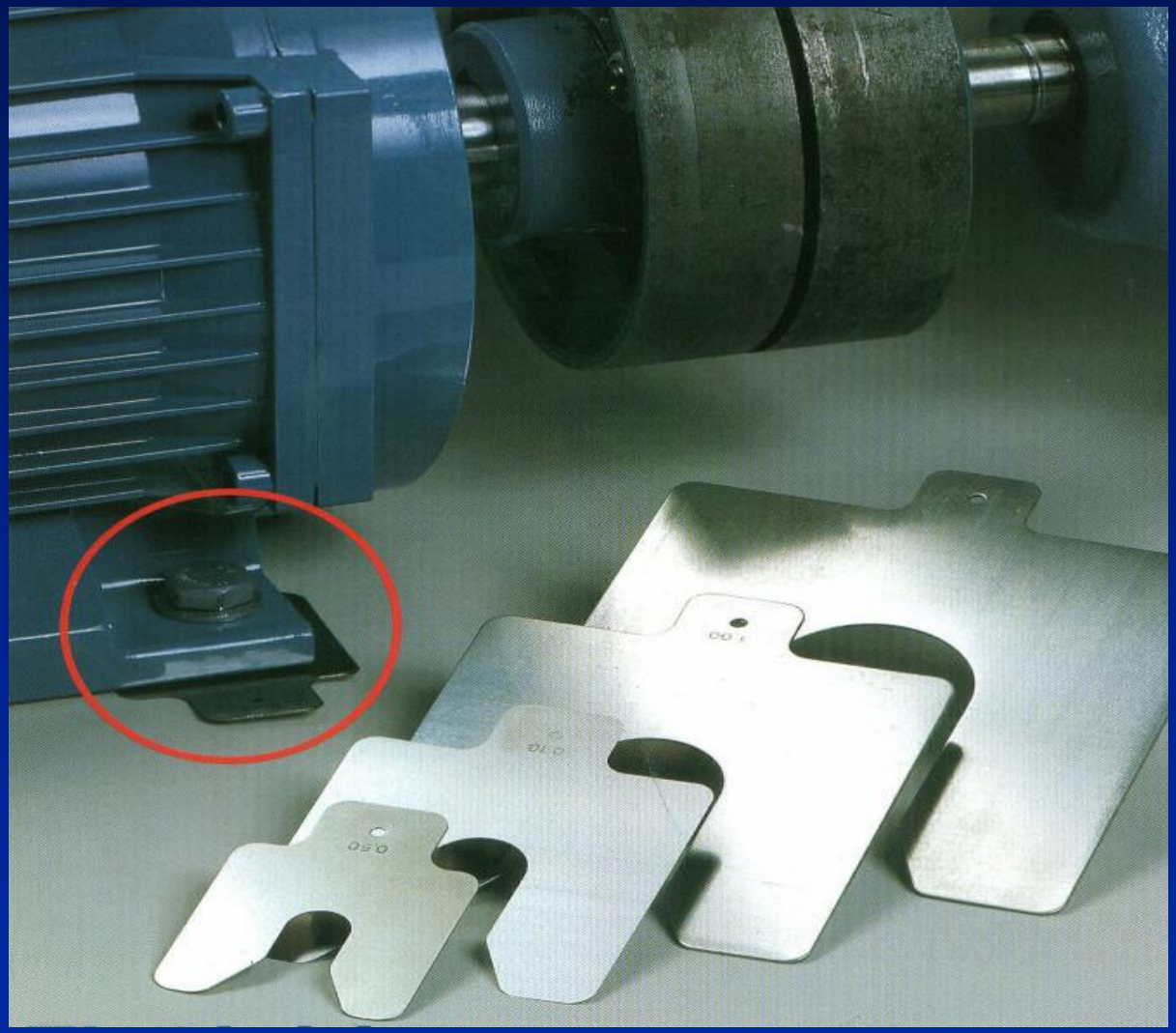


Shaft Alignment

- **Laser based system**

- **Significant reduction in alignment time**
- **Significant reduction in downtime**
- **Very high degree of accuracy**
- **Very high degree of repeatability**
- **Printed record with some systems**

Shaft Alignment



Use good shims

Safety

"Oh By The Way,
If You Do Have A Failure"

Don't Try This !!

Safety

Rope Trick

Contents

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Special designs

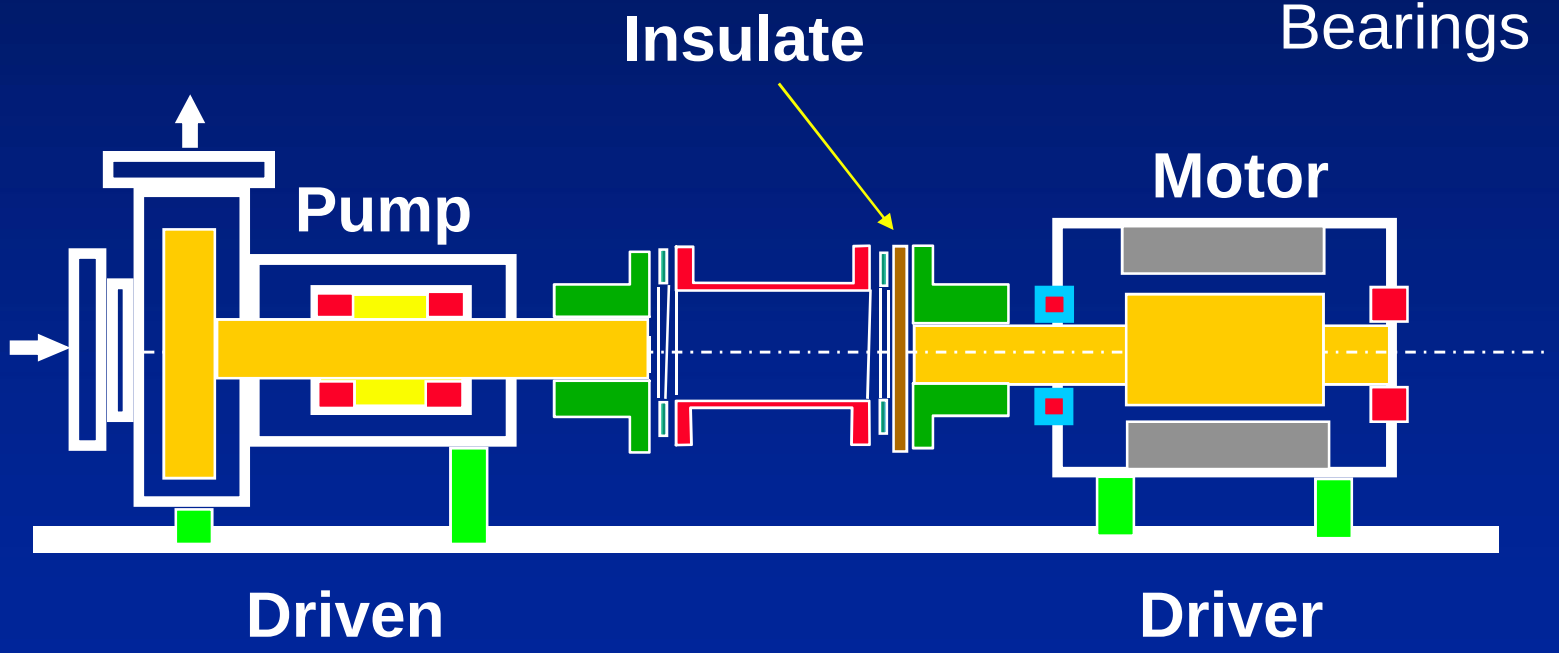
Other features

- Electrical Insulation
- Vertical Applications
- Rigid Couplings
- Large Axial Movements
- Shear Devices
- Limited End Float
- Close Coupled
- Long spacers
- High Powers and Speeds
- Torque Monitoring

Special designs

Electrical Insulation

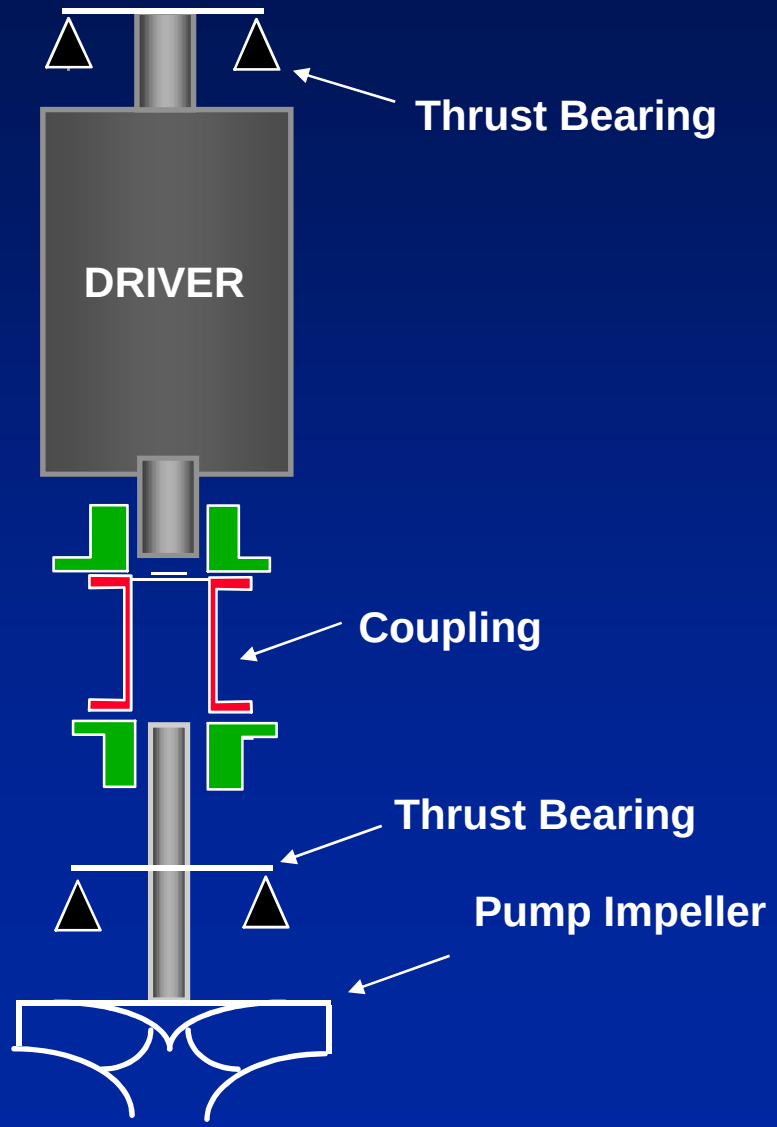
- Bearings
- Insulated Bearings



Special designs

Vertical applications

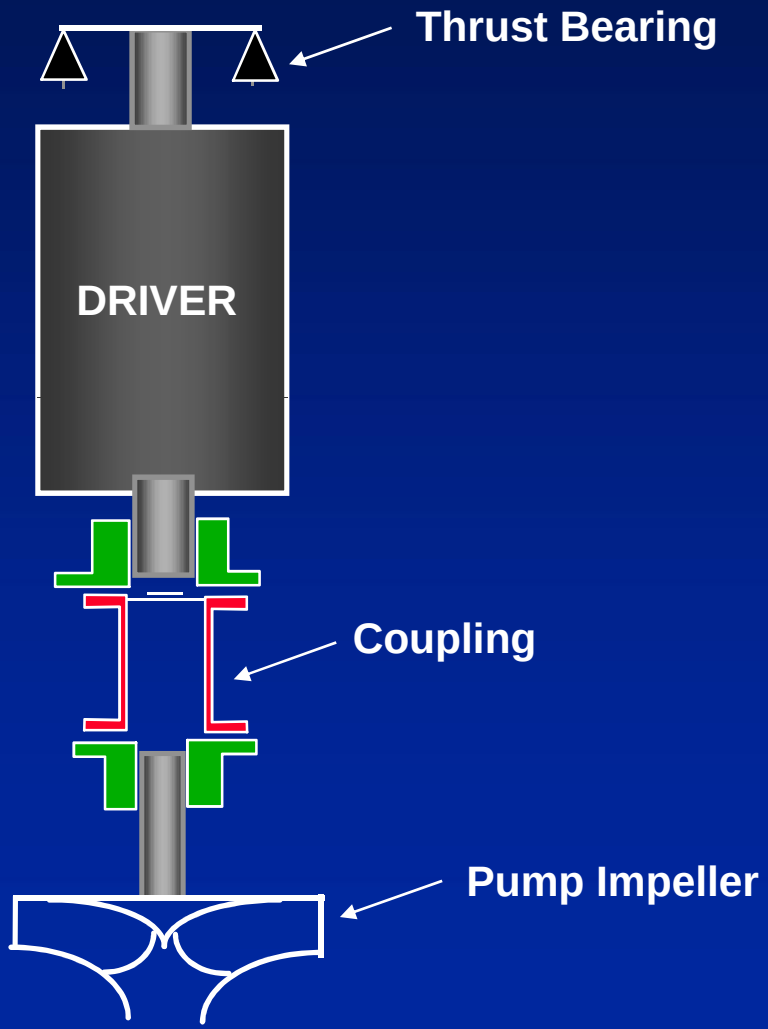
- Coupling bears the weight of its own spacer only



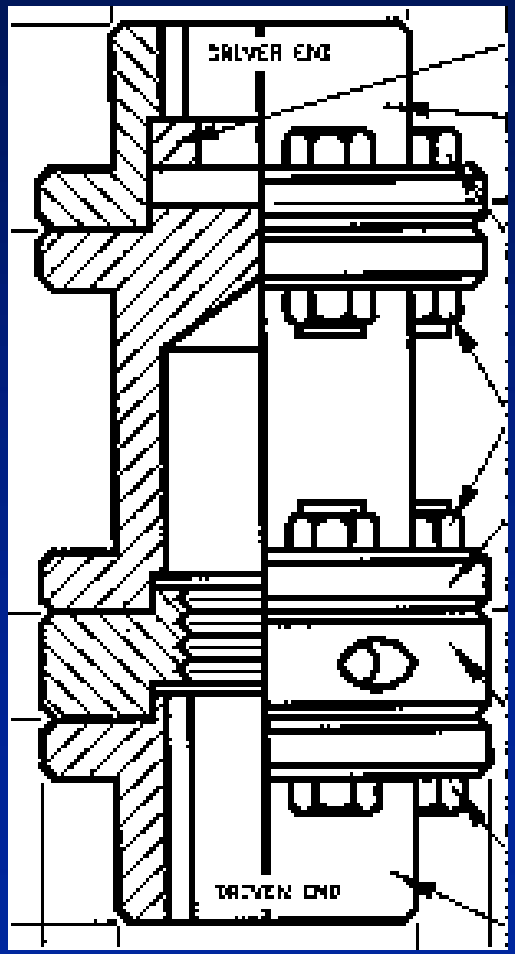
Special designs

Rigid Coupling

- Coupling bears the weight of the pump impeller, shaft and spacer



Special designs



Rigid Adjustable Coupling

- Vertical applications
- Supports pump shaft
- Allows for axial setting of pump

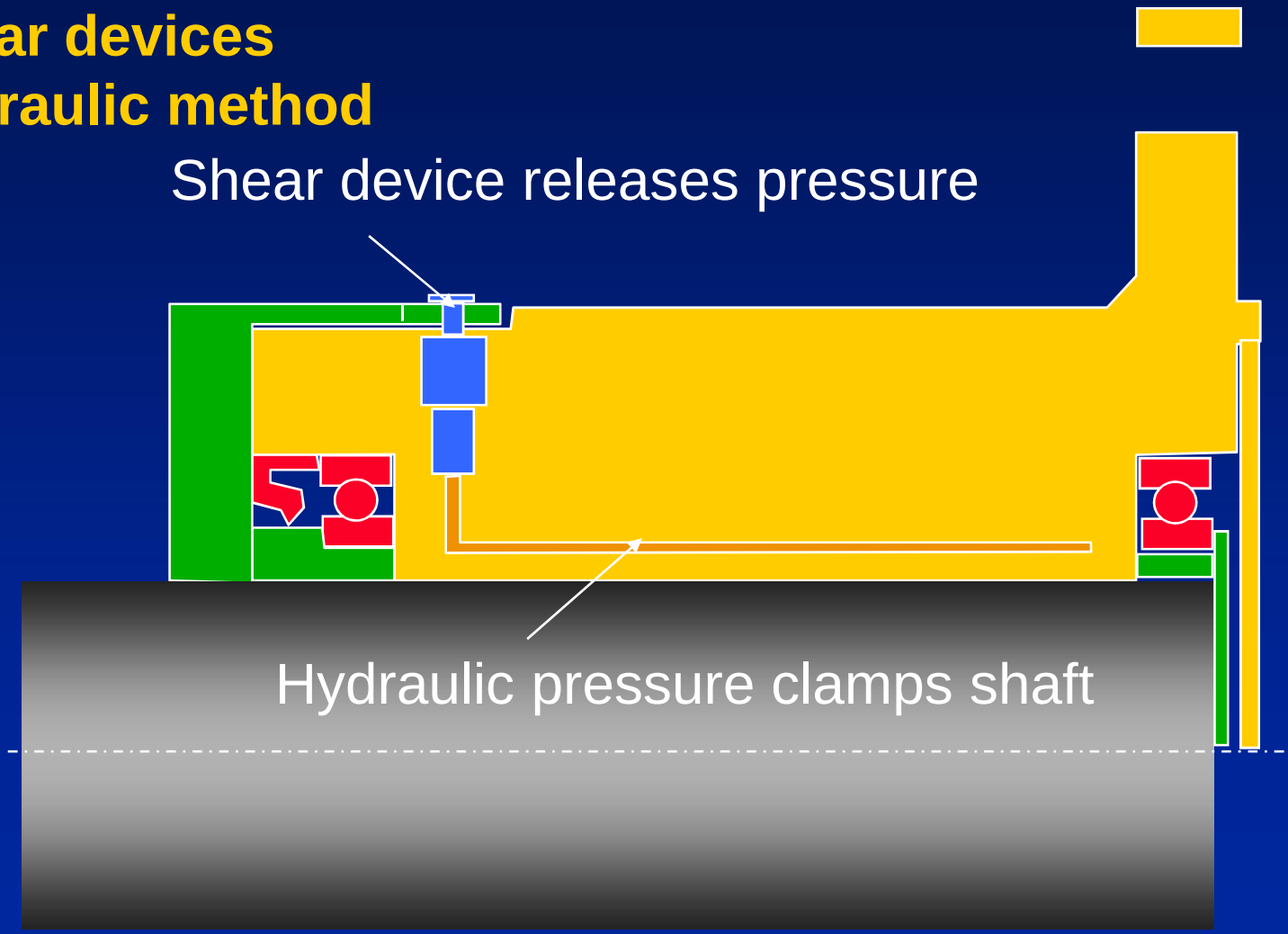
Special designs

Shear Devices

- Protects equipment from damage due to torque overload
- Shear device disconnects the drive
- Controlled disconnection (preset torque)

Special designs

Shear devices
Hydraulic method



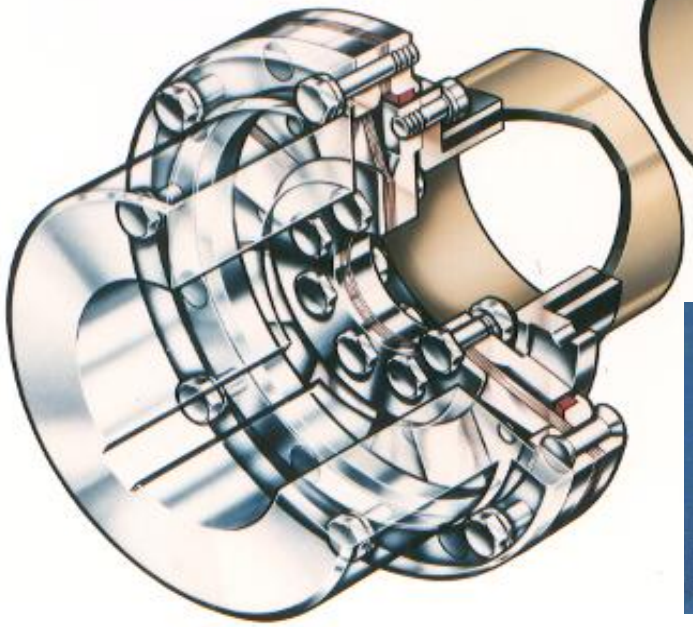
Special designs

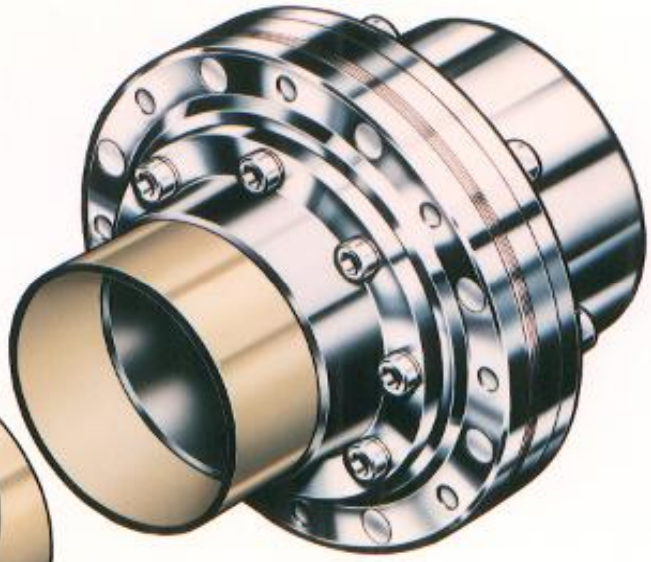
Limited End Float

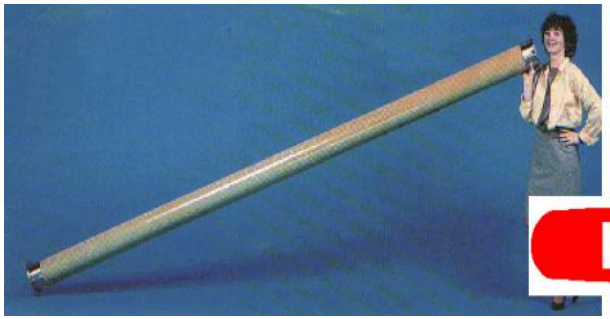
- Arises from use of “sleeve” or plain journal bearings with no thrust bearing
- Allows motor rotor to float at it’s magnetic centre position
- Protects prevent high axial/thrust forces
- Metal membrane couplings are usually inherently limited end float

Special designs

Long spacer Couplings - Cooling Towers







Composite

Spacer

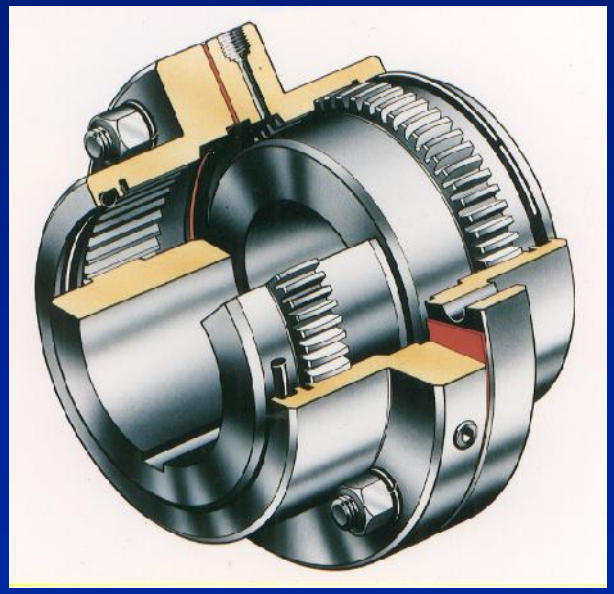
Light weight

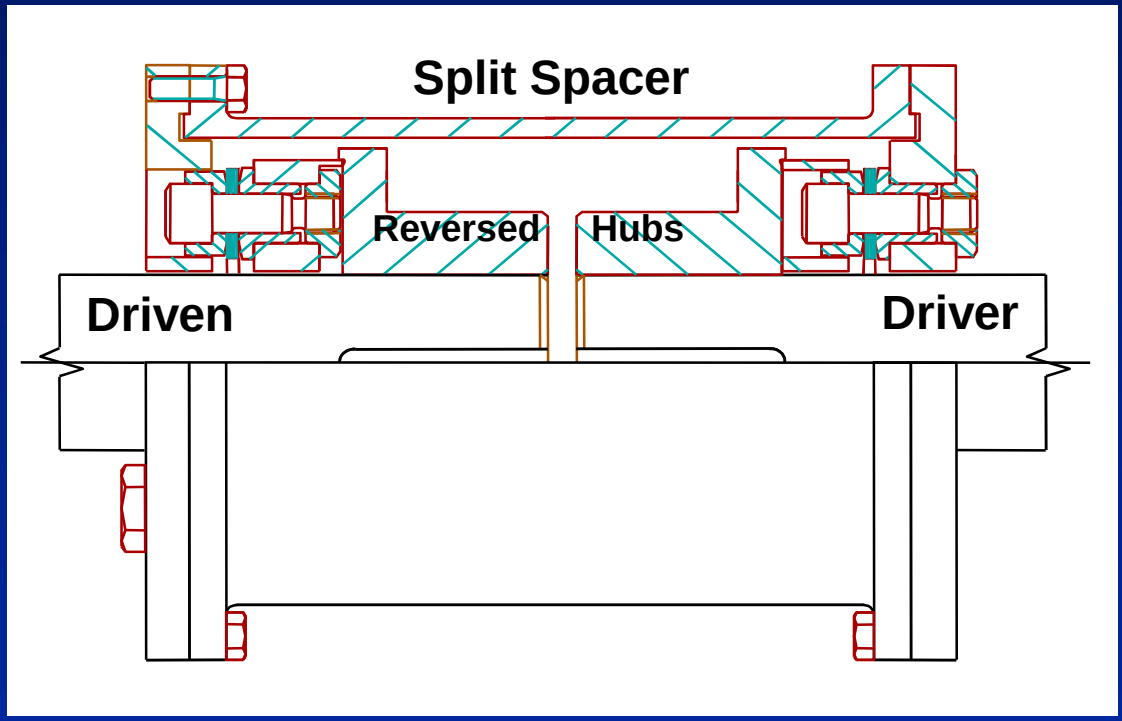
METASTREAM

Special designs

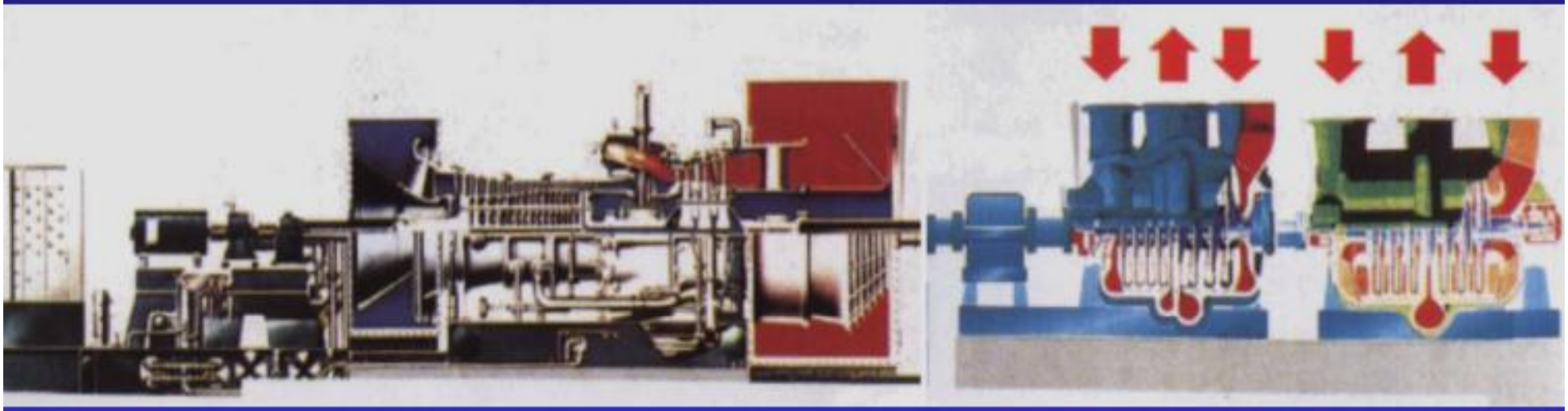
Close Coupled - short DBSE

Replacement of gear coupling on API pump





Special designs



High Performance Couplings

Turbo Compressor drives
Powers to 100 MW
Speeds to 40,000 rpm
API 671 required

Special designs

API 671

- **Special Purpose Machinery**
- **Critical unspared machines**
  - Turbine drives
  - Compressor drives
  - High Power/High Speed critical pumps
  - typically > 2000kW and/or 5000 rev/min
- **More detailed technical specifications**
- **Now at 3rd Edition**

Special designs

ISO 10441

- **Special Purpose Machinery**
- **Critical unspared machines**
  - 1st Edition released
  - similar to API 671
  - balancing specification more practical and relates more to installed repeatability
  - API 671 3rd Edition gets closer to ISO
- **not widely utilised**

Special designs

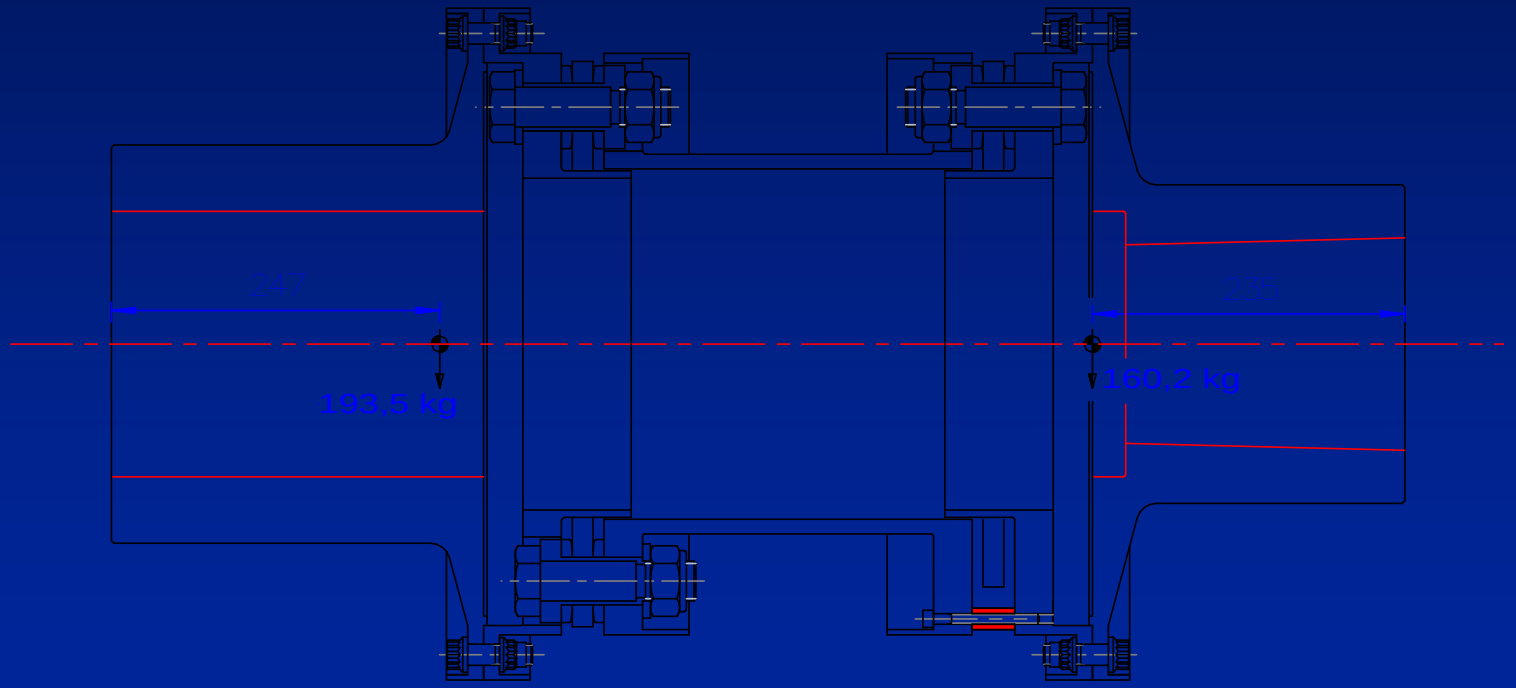
Factors affecting design for Turbo-machinery

- **Rotor- dynamic behavior / natural vibration frequencies (coupling & machine)**
  - Lateral
  - Axial
  - Torsional
- **High speeds - dynamic balance is critical**
  - windage effects
- **Shaft interface requirements/assembly**
- **Peak torque - short circuit effects**
- **Electrical insulation etc.**

Special designs

High Performance Couplings

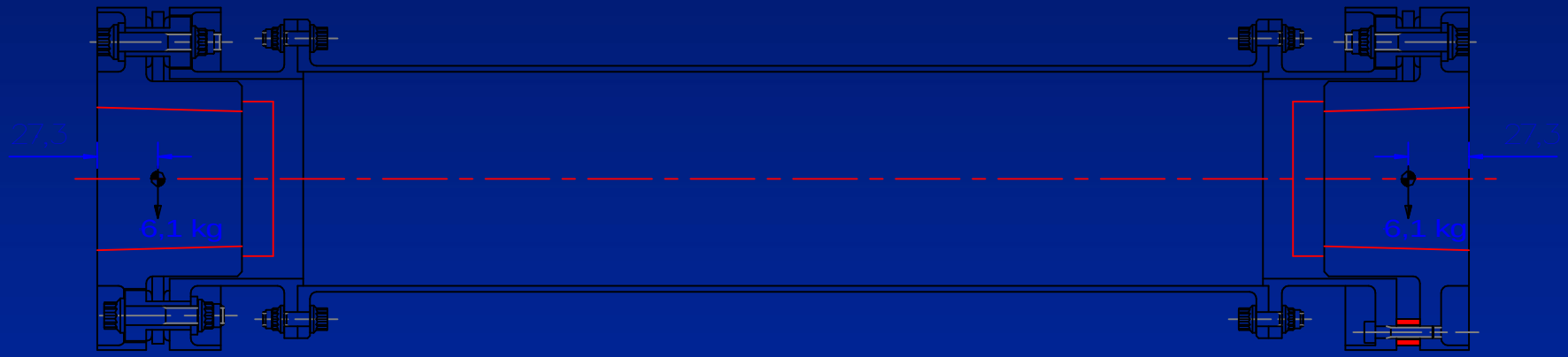
Standard Marine-type Construction



Special designs

High Performance couplings

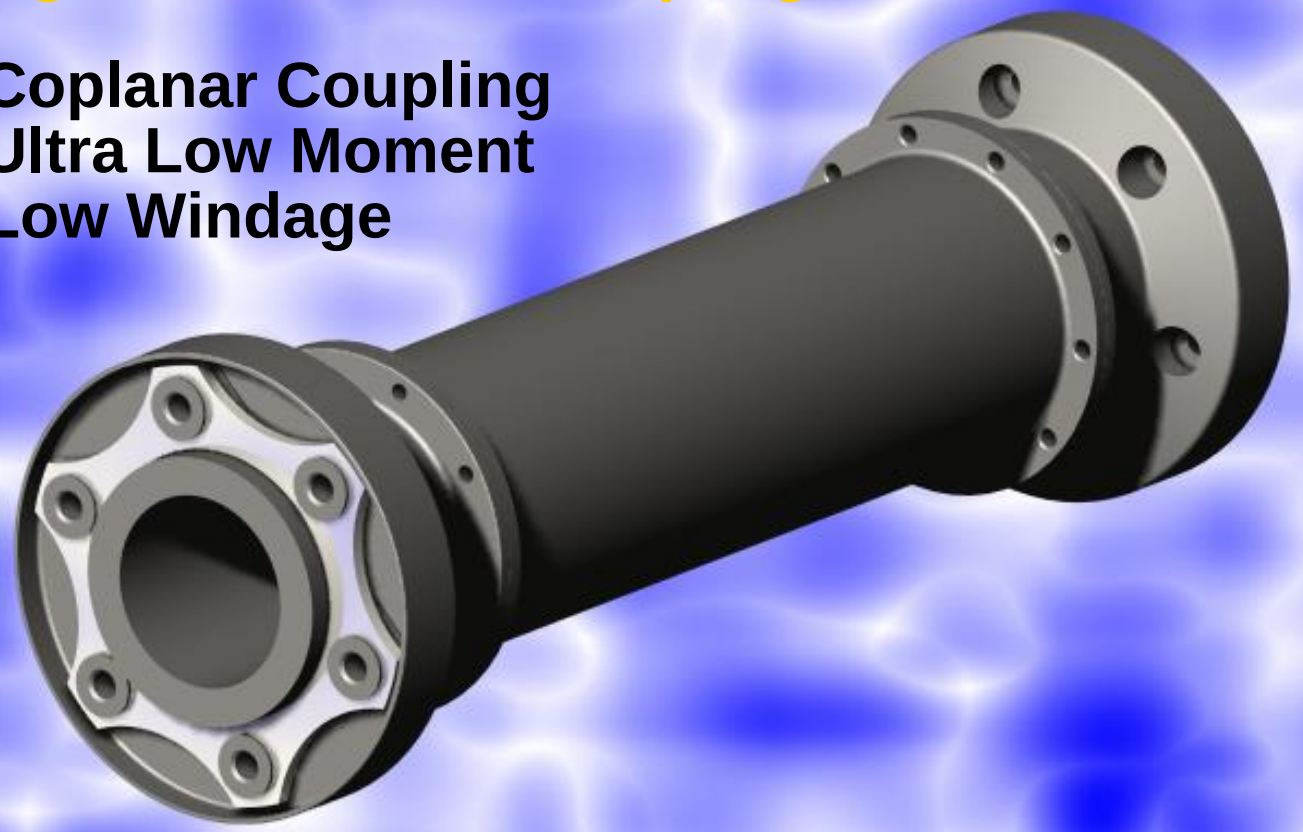
Reduced moment design



Special designs

High Performance Couplings

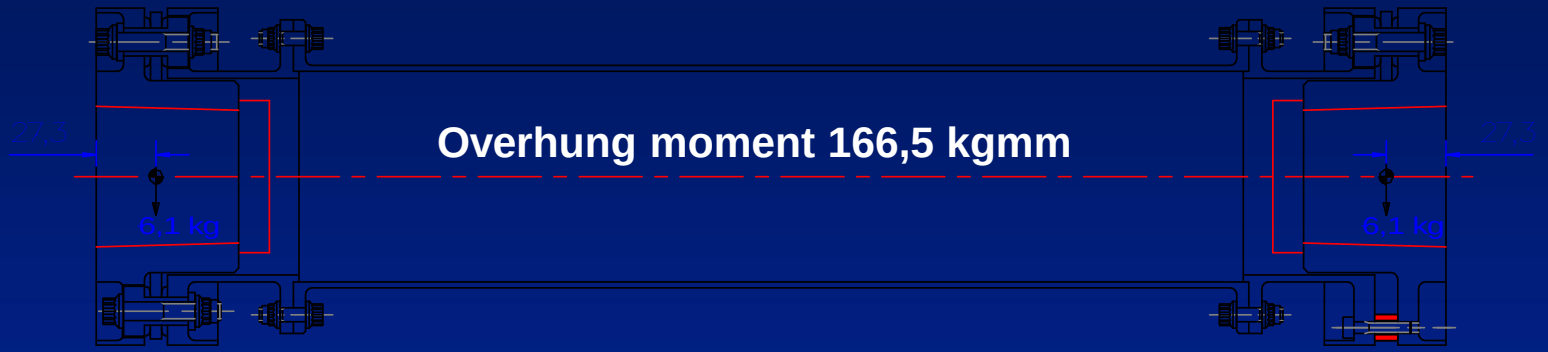
Coplanar Coupling
Ultra Low Moment
Low Windage



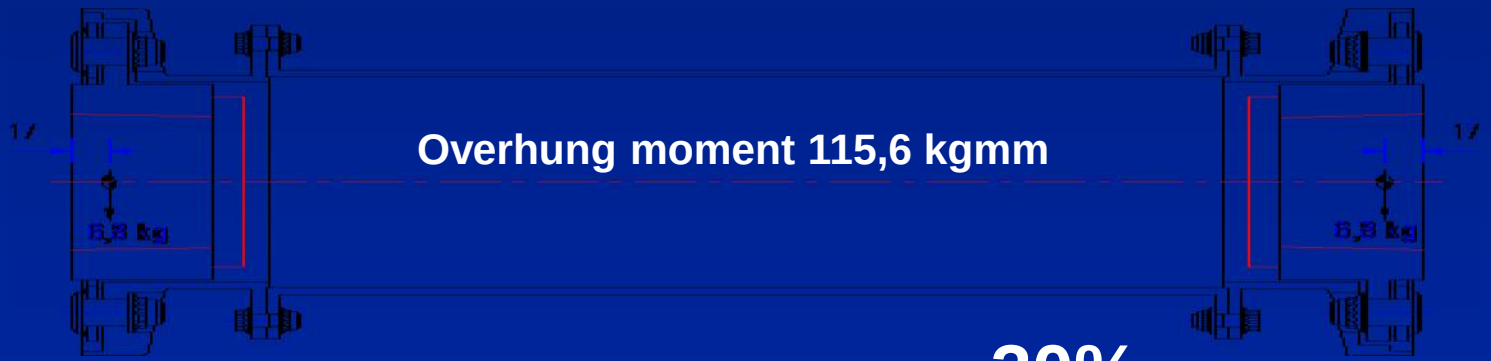
METASTREAM

Special designs

High Performance couplings



Overhung moment 166,5 kgmm



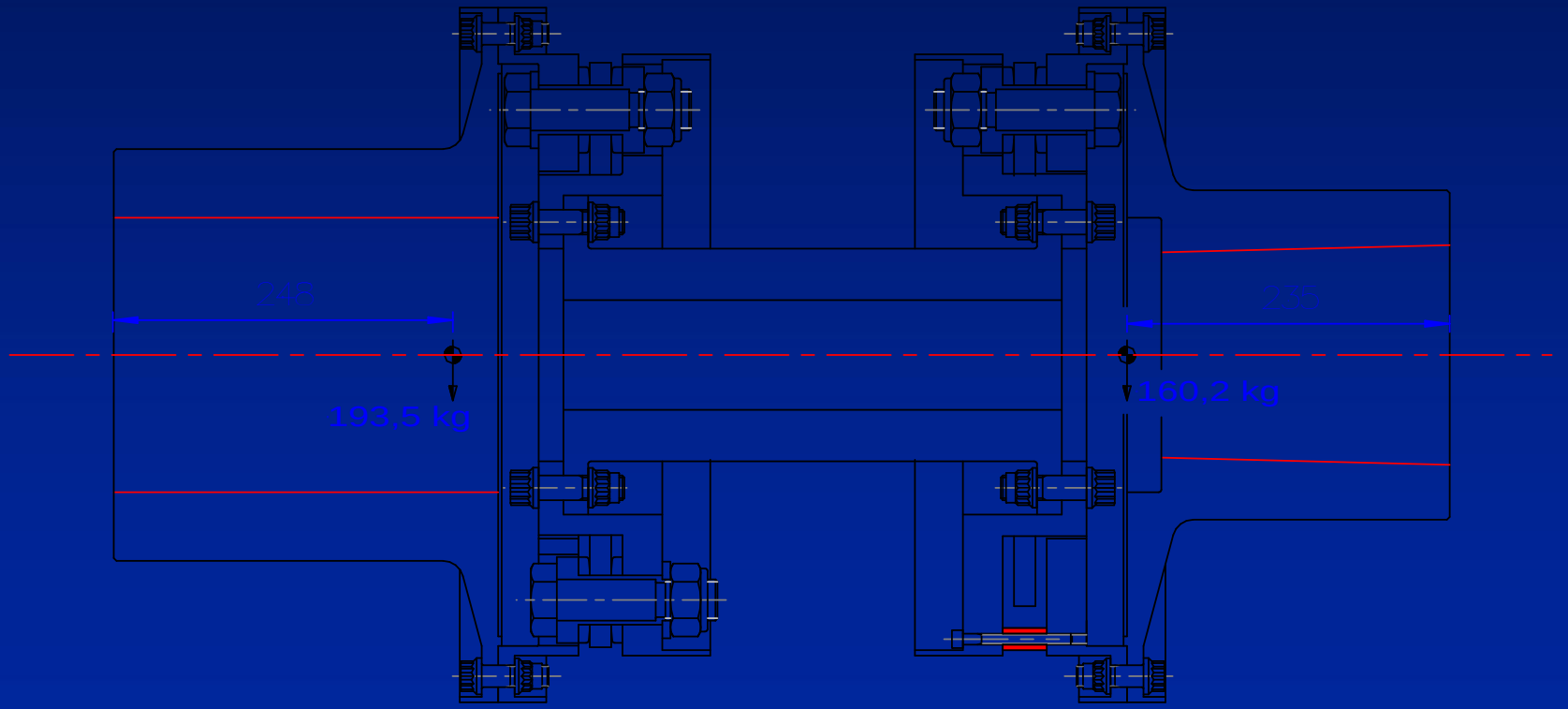
Overhung moment 115,6 kgmm

-30%

METASTREAM

Special designs

Reduced Torsional stiffness



Special designs

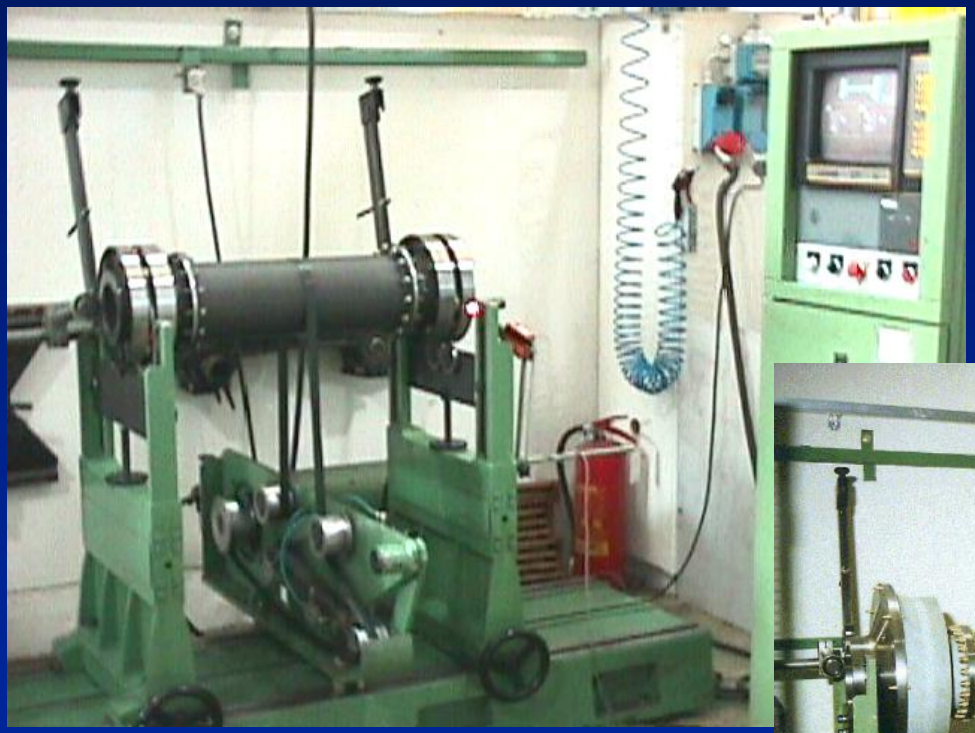
High Performance Couplings

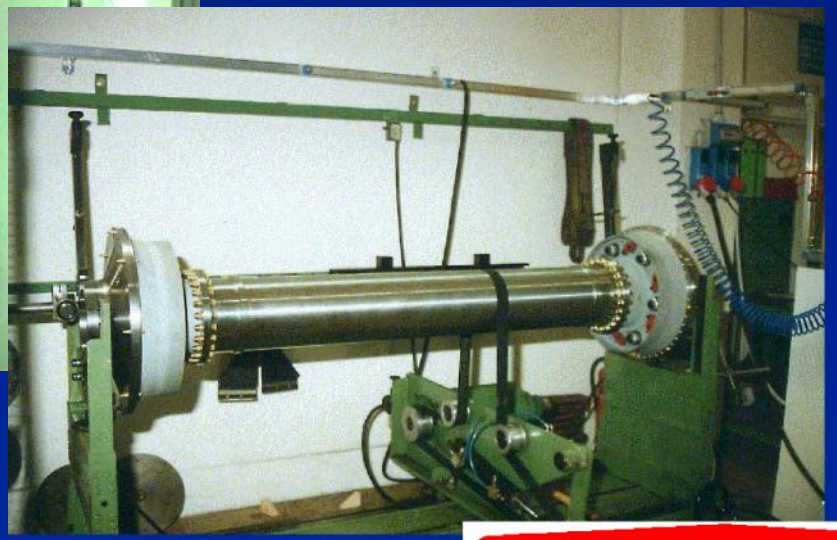
Dynamic Balance to API 671

- **Formula proportional to** $\frac{\text{Weight}}{\text{Speed}}$
- **At 10,000rpm eccentricity of mass < 0.001mm**
- **Repeatability is critical**
- **Dynamic balancing techniques are critical**

Special designs

Special Balancing Requirement

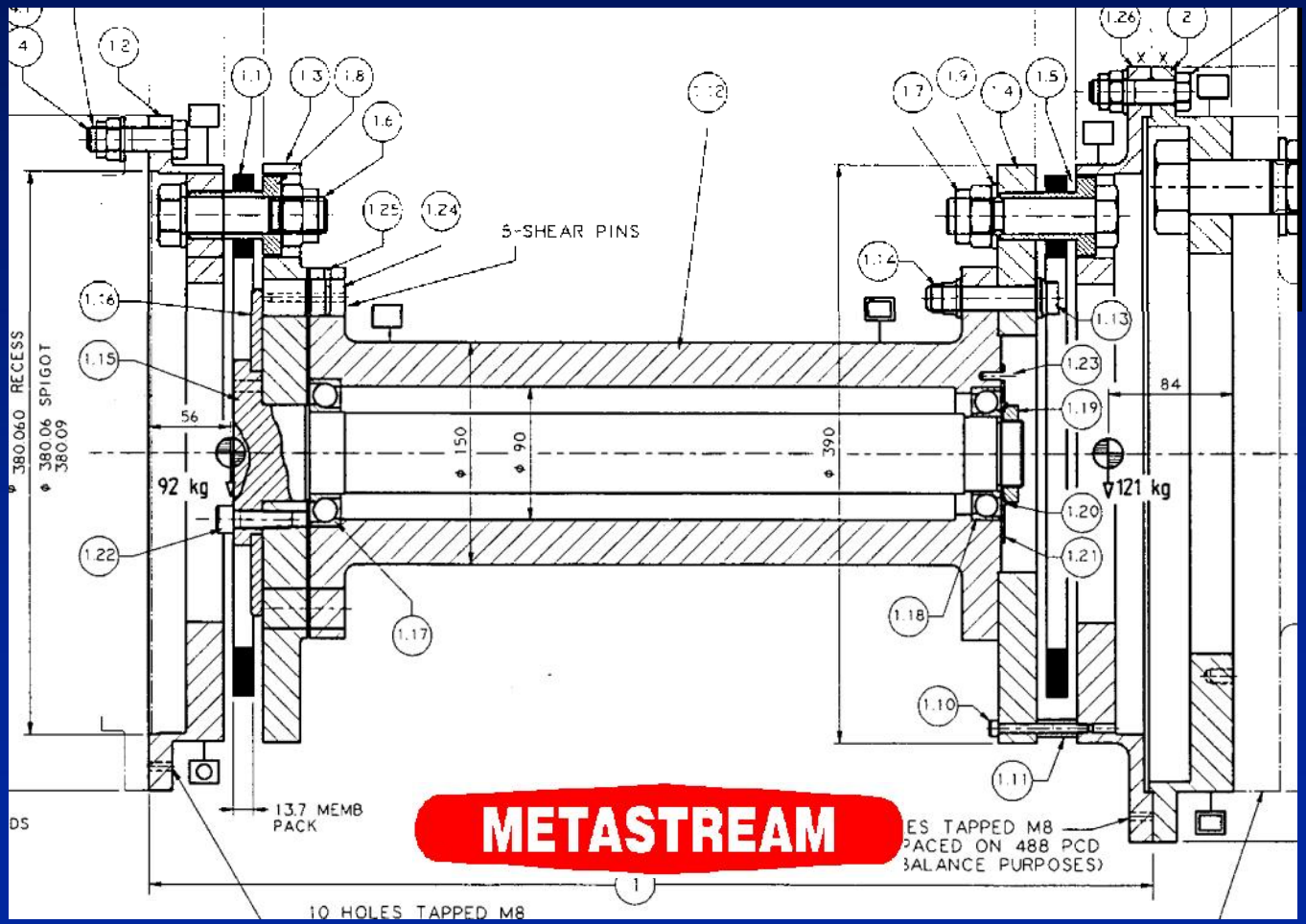




METASTREAM

Special designs

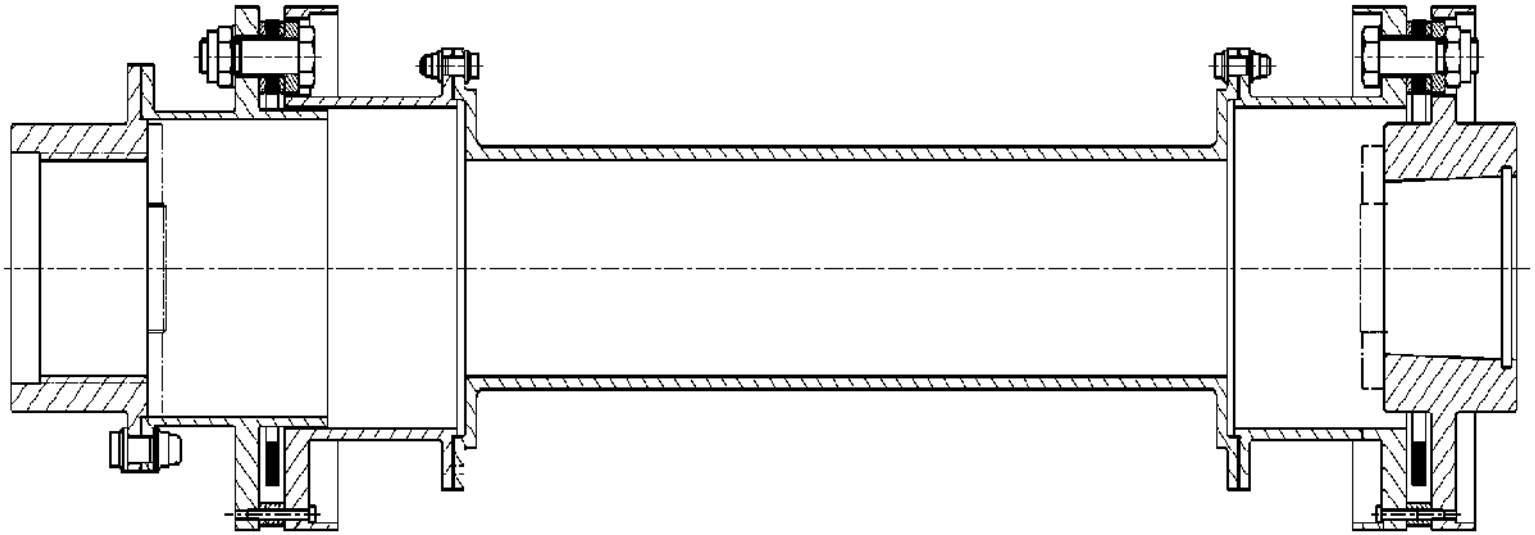
Design Option: Shear Pin



Special designs

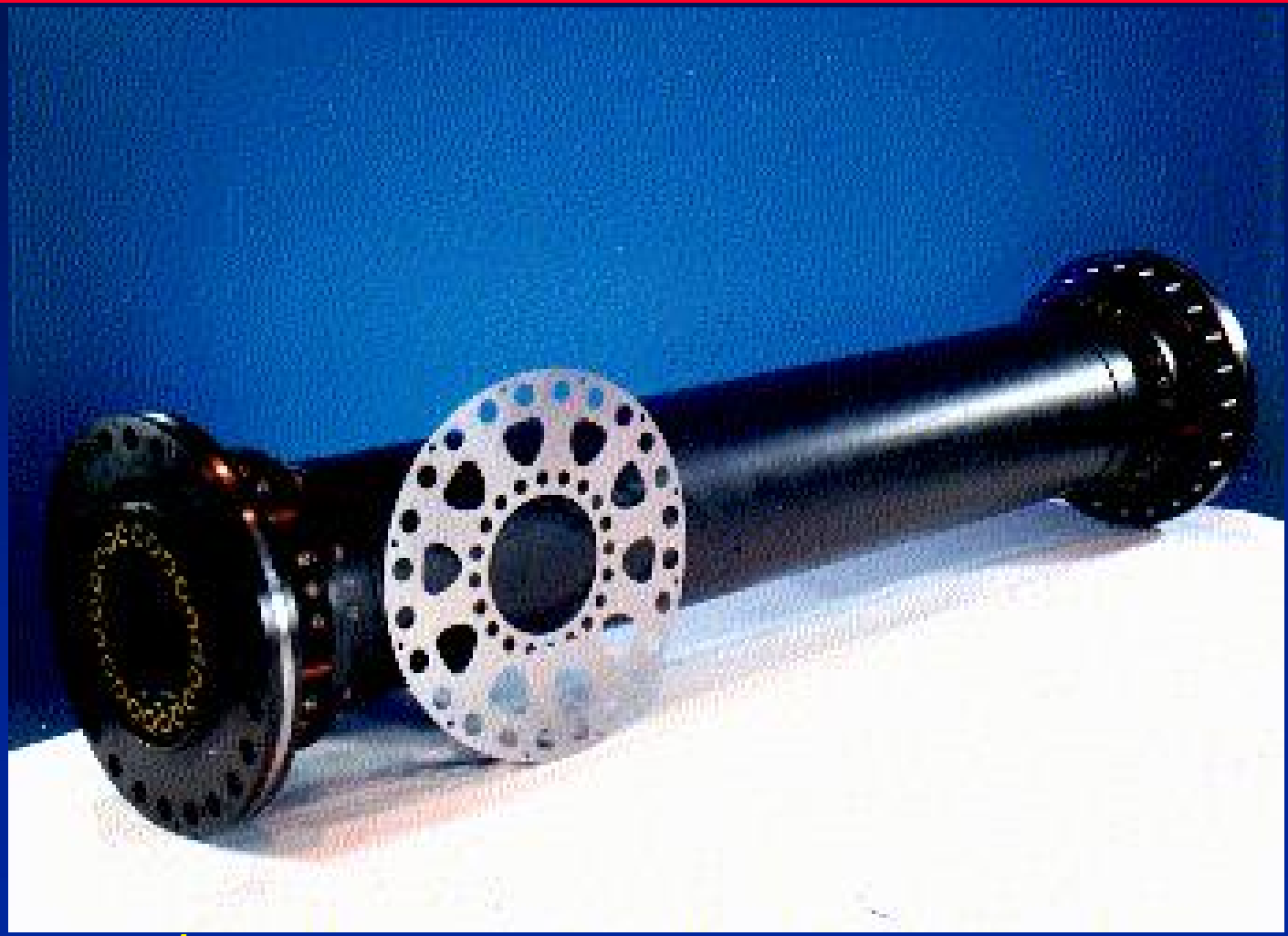
High Performance couplings

Retrofit coupling for Turbine Compressor Drive
To replace existing gear type



METASTREAM

Special designs



Diaphragm type
GE Frame 6 Generator drive - 50 MW

Special designs

Duty 10 MW at 200 rpm
Dia = 1385 mm
W = 3.1 tons
for LDPE Hypercritical Recip.

METASTREAM

Special designs

Torque Measuring Couplings

Monitor machine performance
Phase shift or Strain gauge

METASTREAM

Contents

- **Introduction**
- **Types of coupling in use**
- **Membrane couplings**
  - Disc type
  - Diaphragm style
- **API Reliability and Safety issues**
- **Good Alignment practices**
- **Special designs**
- **Conclusion**

Conclusion

The Ideal Coupling

- Infinite misalignment / end float capacity
- No reaction forces on bearings
- No mass - zero out of balance
- Torsionally rigid
- and Zero torsional stiffness
- Fails safely when necessary
- plus
- Zero cost

JUST A DREAM ???

Couplings

The Overlooked Component

Specify them correctly