GENERAL PURPOSE *VS* SPECIAL PURPOSE COUPLINGS

by
Jon Mancuso
Engineering Manager
Kop-Flex Inc.
Baltimore, Maryland

Jon R. Mancuso is Engineering Manager of Kop-Flex Inc, Power Transmission Products. He has almost 30 years experience in the coupling field and is author of many papers on couplings for various publications, societies and symposia.

He is also author of book on couplings, Coupling and Joints *and editor and author of several chapters in* Mechanical Power Transmission Handbook *to be published in the fall of 1994 (Marcel Dekker). He has been involved with many design, research, and development projects relating to couplings, and is co-inventor of several patents with couplings and clutches.*

Mr. Mancuso graduated from Gannon University, with a B.S. degree in Mechanical Engineering, and has an M.S. degree in Engineering Science from Pennsylvania State University.

He is chairing the ASME Committee on Couplings and Clutches. In addition, he is a member of the AGMA Coupling Committee, and also serves on the API Committee on Couplings for Special Purpose Applications.

INTRODUCTION

Flexible couplings are a vital part of a power transmission system. What type is selected, how much the coupling costs, and how much effort one spends on selecting a coupling and determining how it interacts with a system should be a function of the cost of the equipment and how critical it is to the plant. In some cases, the coupling used will be a general purpose coupling and the selection process will take little time.

However, for more critical equipment, the coupling used maybe a special purpose coupling and the selection process may take a great deal of time. When selecting couplings, one must also consider the application and past experience. One must evaluate the coupling's initial cost and also the ease of maintenance and replacement of the flexible elements, along with the lubrication schedule or lack of it. Then one must trade off features and characteristics of available couplings and pick the best one suited for the application.

The American Petroleum Institute (API) has a detailed specification for "Special-Purpose Couplings For Refinery Service," API 671. But not much is said about *general purpose couplings* in API 610 titled, "Centrifugal Pumps for General Refinery Service" (Seventh Edition). This specification states that couplings must have a diameter concentric to the bore within 0.003 TIR to aid alignment. This standard also requires that couplings meet balance requirements of *AGMA 515 class 8,* (Note: the latest AGMA balance specification is AGMA-9000 which supersedes AGMA 515). There are not many other industry standards that specify any additional requirements for couplings. More importantly, these specifications and requirements do not explain how couplings work or help in the selection process. So how does one know what to use for *general purpose* and *special purpose* applications? One simple answer is to apply API 610 for *general purpose* couplings and API 671 to *special purpose* couplings or apply API 671 or parts of API 671 to all couplings, or just use what's been used in the past.

FUNCTIONS OF FLEXIBLE COUPLINGS

Flexible couplings join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. The three basic functions of a flexible coupling are to (Figure 1):

- Transmit power
- Accommodate misalignment
- Compensate for end movement

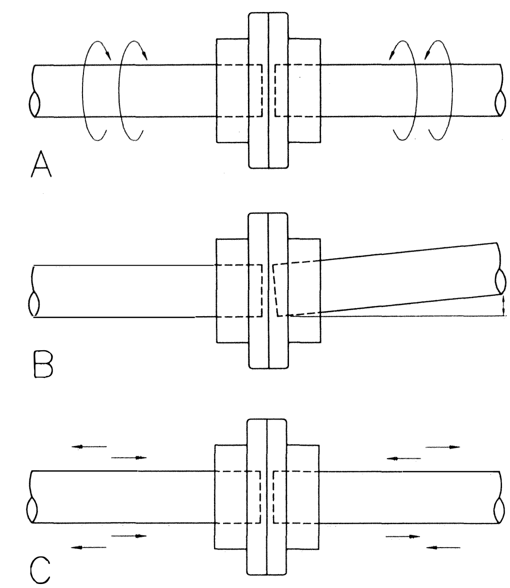


Figure 1. The Three Basic Functions of a Flexible Coupling.

Transmit Power

Couplings are primarily used to transmit mechanical power from one machine to another.The power is in the form of mechanical torque at some speed, or work per unit of time, In general, the power lost by a flexible coupling is small, although some couplings are more efficient than others.

Misalignment

Flexible couplings must accommodate three types of misalignment (Figure 2):

- Parallel offset the axes of connected shafts are parallel but not in the same straight line
- Angular the axes of shafts intersect at the center point of the coupling, but not in the same straight line.
- Combined angular and offset the axes of shafts do not interest at the center point of the coupling and are not parallel.

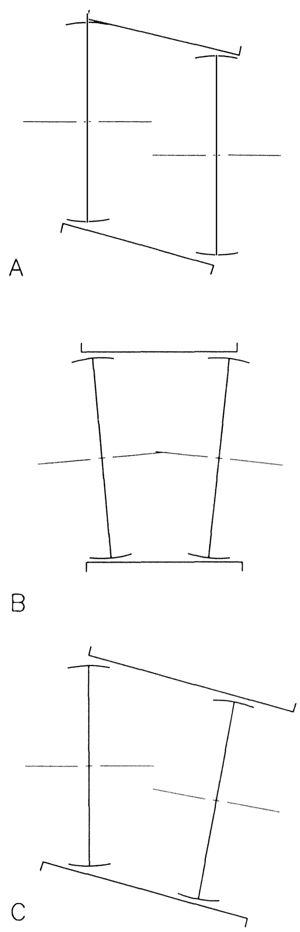


Figure 2. Types of Misalignment.

It is important to recognize that while the equipment may see these three types of misalignment, the coupling sees only angular and axial displacement. The *flexible elements* see only angular misalignment and axial movement, therefore, most equipment needs a couplings with more than one flexible element to accommodate offset. The exception being some elastomeric element couplings that can accommodate all three types of misalignments.

End Movement

Most flexible couplings are designed to accommodate axial movement of equipment or shaft ends. In pumps that are driven by sleeve bearings motors, the couplings are usually required to limit the axial float of the equipment to prevent internal rubbing.

TYPES OF FLEXIBLE COUPLINGS (GENERAL)

There are three basic types of couplings:

- Mechanical Element
- Elastomeric Element
- Metallic Element

The *mechanical element* types generally obtain their flexibility from loose-fitting parts or rolling or sliding of mating parts or from both. They require lubrication unless one moving part is made of a material that supplies its own lubrication need (e.g., a nylon gear coupling). The *elastomeric element* types obtain their flexibility from stretching or compressing a resilient material (rubber, plastic, etc.). The *metallic element* types obtain their flexibility from the flexing of thin metallic disc or diaphragms.

TYPES OF GENERAL PURPOSE COUPLINGS

General Purpose Couplings can generally be classified according "size." Under 100 hp is classified as small. Between 100 and 1000 hp is characterized as medium. Usually hp over 1000 is considered critical and, therefore, will be covered in the SPECIAL PURPOSE COUPLING section.

If a small piece of equipment (i.e., pump) shuts down, it usually does not affect the plant operation. This equipment uses a coupling type where the flexible element can be easily inspected and replaced, often considered "throw always parts." The couplings are very flexible and require very simple alignment techniques, calipers, scales, and perhaps, if one gets sophisticated, a dial indicator. A failure from over-torque or over-misalignment is usually of the flex element and little or no damage usually occurs to other components. A few examples of these coupling types on the market are grid, disc and elastomeric. Also found on this equipment are small gear couplings, somewill have the outer sleeve made of nylon or plastic and, therefore, require nolubrication.

Medium size equipment (100 to 1000 hp) are not normally critical to the operation of the plant, but are problematic and costly if constant maintenance and downtime is required. They use grid, gear, disc, and elastomeric type couplings. Which one to use is probably based on what comes with the equipment. Each equipment manufacture bases the selection on past price, experience, preference to work with one coupling manufacturer over another. Usually if one fails, "Get me one just like the one that failed." But if lots of problems occur, failures, too much time to install, constant lubrication and lots of maintenance problems, someone starts to question if there is something better out there. Over time, maintenance departments eventually develop a preference based on pump duty, type of maintenance performed, and sometimes just personal preference. This group of couplings usually fail because of lack of proper installation, lubrication, and improper alignment.

HOW GENERAL PURPOSE COUPLINGS WORK

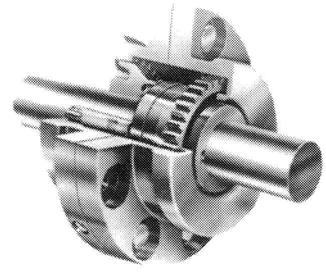
The various types of *General Purpose Couplings,* include gear, grid, compression donut, block, jaw, urethane tire, corded tire, shear donut, and disc (Figure 3).

Gear Couplings

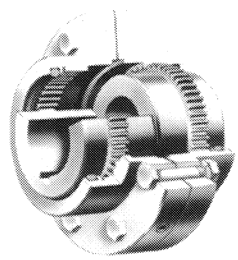
Gear type couplings consist of two hubs with external teeth that engage internal teeth on a two- or one-piece sleeve. The teeth maybe straight or curved (crowned). For application requiring over 1/4 degree, curved teeth may be better.

These couplings obtain their flexibility due to the looseness (backlash) between the mating teeth. Gear couplings are used for medium and large equipment applications, and is the most power dense type available. They require periodic lubrication, one to two years, depending duty and type of lubrication. If properly maintained (good lubrication and reasonable alignment), these coupling have a service life of three to five years and in many cases five to 10 years and sometime over 20 years.

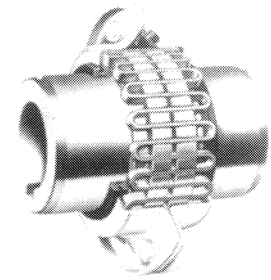
Some gear couplings have sleeves that are made of plastic (nylon, high molecular plastic). These do not require lubrica-



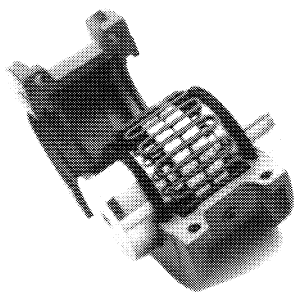
Mechanical Element Coupling
Gear
Straight Tooth



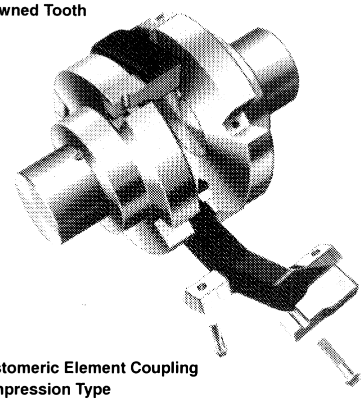
Mechanical Element Coupling
Gear
Crowned Tooth



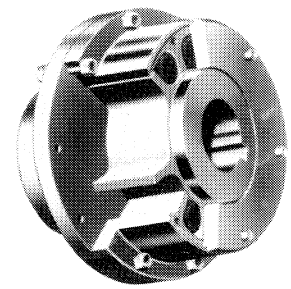
Mechanical Element Coupling
Chain
Vertical Split Cover



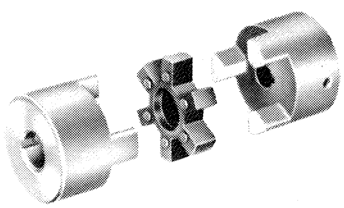
Mechanical Element Coupling
Chain
Horizontal Split cover



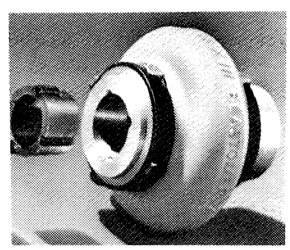
Elastomeric Element Coupling
Compression Type
Donut Type



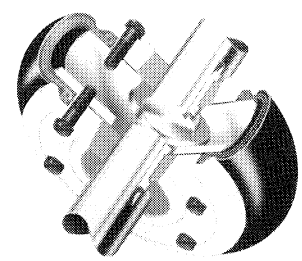
Elastomeric Element Coupling
Compression Type
Block Type



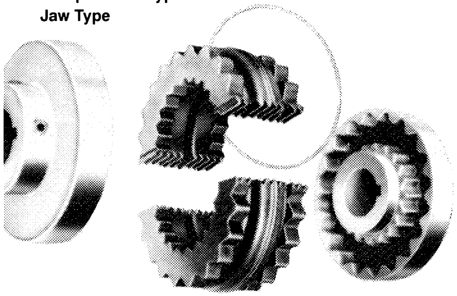
Elastomeric Element Coupling
Compression Type
Jaw Type



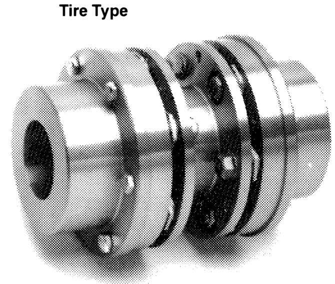
Elastomeric Element Coupling
Shear Type
Tire Type



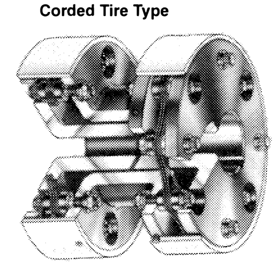
Elastomeric Element Coupling
Shear Type
Corded Tire Type



Elastomeric Element Coupling
Shear Type
Donut Type



Metallic Element Coupling
Disc Type
Continious Disc Type



Metallic Element Coupling
Disc Type
Link Type

Figure 3. Types of General Purpose Couplings.

tion. These have much lower torque capacities than the all-steel couplings and are used mainly on small pumps.

Grid Couplings

Grid type couplings are very similar to gear couplings. Usually composed of all metal they have some degree of resilience. These couplings can dampen vibration and reduce peak or shock loads by 10 to 30 percent. They have two hubs with serrations (grooves) rather than teeth. The grooves are connected by a steel grid. A cover keeps the lubrication in. The covers are either vertically split or horizontally split. These couplings do not transmit as much power (per the same outside diameter) as gear couplings, but are usually less costly. Grid couplings are used for medium and small equipment applications.

Compression Donut Couplings

Compression donut couplings have a precompressed elastic element. Screws force the donut to a smaller diameter. All legs of the donut are in compression before the load is applied. Medium and some small equipment incorporate these couplings.

Block Couplings

Block couplings use rubber in compression. The rubber blocks are installed in cavities formed by internal sleeve blades, external hub blade and two end plates. This type is unique among couplings due to its "fail-safe" feature. If the elastomer fails the coupling may run for sometime on the metal blades. These couplings can provide up to 1/2 degree of misalignment and parallel offset capabilities of 1/64 in to 1/4 in. Sometimes medium and small equipment will use these couplings, because if properly aligned they require no maintenance (except for replacement of blocks every three to five years).

Jaw Couplings

Jaw couplings have their elastomers in compression. The flex element can be one piece or split to facilitate replacement. They also have a "fail-safe" feature. Flex elements are made of many types of elastomeric materials, such as rubber, urethane. The properties (that is, hardness, resilient, etc.) can be varied to suit required loads. These couplings are used primarily to accommodate misalignment and transmit power. Small and medium size equipment employs these couplings. Be careful, since sometimes they are used to absorb energy and dampen loads, particularly when equipment is engine driven. Also be careful, because some times they are used because they are torsionally soft and were used to tune a system out of a torsional critical mode.

Urethane Tire Couplings

Common on small type equipment, urethane tire couplings have their elastomeric element in shear and are made of urethane. The tires are split to enable easy assembly without removing the hubs. Urethane couplings offer a high degree of flexibility. When the coupling fails, usually only the elastomeric element is replaced,

Corded Tire Couplings

Corded tire couplings also have their elastomeric elements in shear. They use a reinforced element (similar to belted auto tires). Because of the reinforcement in the element, the torque capacity is greater per outside diameter than the urethane tire type. Most small and some medium size equipment applications use these couplings.

Elastomeric Donut Couplings (Unclamped)

Another type common on small equipment, elastomeric donut couplings have their elastomeric elements in shear. They provide low torsional stiffness and low reactionary forces. Oversizing can lead to premature failure by wearing of the engaging teeth rather than material failure from flexing.

Disc Couplings

Disc couplings transmit torque by a simple tensile force between alternating driving and driven bolts on a common bolt circle. Misalignment is accomplished from the flexibility that comes from the length of material between the bolts. Disc couplings have been around for years, but with the use of finite element analysis, this type can and has been optimized for optimum characteristics. These couplings are composed of all metal, and do not require lubrication. The discs are usually continuous, but can be individual links. Most disc couplings use multiple thin discs rather than one thick disc/link, because stresses from misalignment are proportional to T^3 vs Nt^3. These couplings are used in medium size equipment applications. If the misalignment is beyond 1/2 to 3/4 degree during operation, the flexible element will probably fail in fatigue.

SPECIAL PURPOSE COUPLINGS

This category of couplings is thoroughly covered in API 671. There are two categories "lubricated" and "nonlubricated." There is some older equipment that still use "lubricated" couplings. Most new equipment or upgrade equipment will have "nonlubricated" couplings. Generally, the types are gear coupling *(mechanical element)* that require oil or grease lubrication and *metallic element* types that require no lubrication. There are many subgroups for gear couplings, however, they are only variations, these couplings are usually made of alloy steel and have surface hardened teeth (usually nitrited). There are two primary types of nonlubricated couplings (metallic element couplings) these are used for *special purpose* applications; the diaphragm type and the disc type. For some large equipment *elastomeric element* type are used, these couplings are covered in Appendix 5 of API 671.

High Performance Gear Couplings (Mechanical Element Type)

The sealed lubricated gear coupling (Figure 4) was adapted and modified during the 1950s and 1960s to carry more power at higher speeds. The major problem with gear couplings is lubrication. Grease separate under centrifugal force and over time O-ring type seals leak. Continuously lubricated (Figure 5) designs, using the coupled machines bearing oil, are more common for these types of applications. There are several variations of designs, couplings with external teeth on or with the external teeth on the spacer in the "marine" type (Figure 6). This design could be used with integral flanges on the machine shafts such as on ship propulsion turbines and gears, hence the name "marine" type. Reduced moment versions were readily also used. If proper lubrication is maintained these coupling will and have operated successfully for years. Lubrication or lack of it is the biggest cause of failure. The coupling itself tends to act as a centrifuge and separates dirt particles out of oil. This produces "sludge" (Figure 7), which can cause the coupling to "lock-up," which causes increased equipment vibrations. The most common mode of failure for a gear coupling is wear due to lubrication problems. If proper lubrication is maintained, these couplings will, and have, operated successfully for years.

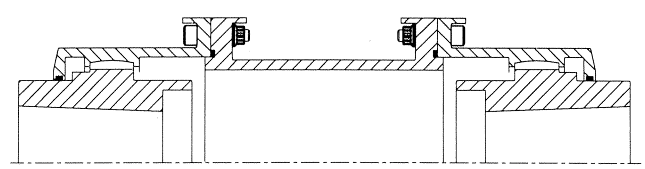


Figure 4. Special Purpose Sealed Lubricated Gear Coupling.

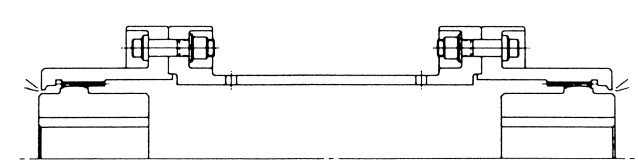


Figure 5. Special Purpose Continuously Lubricated Gear Coupling.

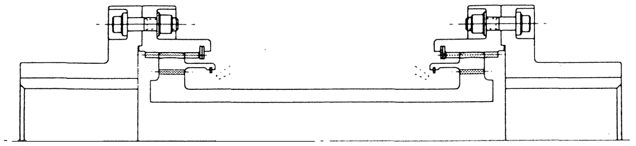


Figure 6. Special Purpose Marine Style Gear Coupling.

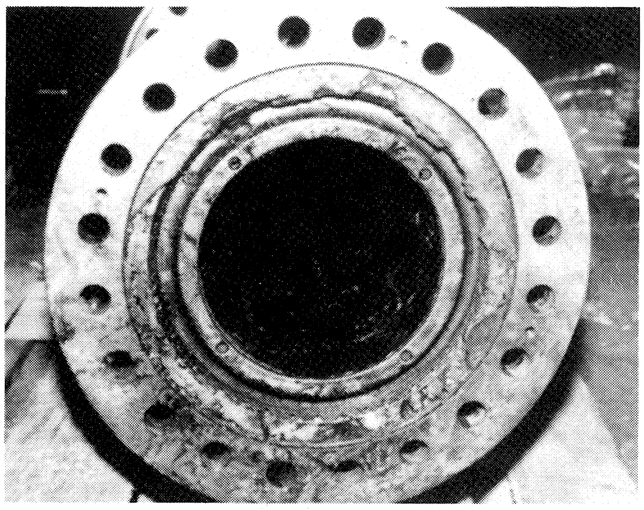


Figure 7. Sludged up Gear Coupling.

Metallic Element Couplings

Metallic element coupling use for *special purpose* applications started in the late 1960s and early 1970s.

There are two basic type of Disc type and diaphragm type.

Disc Type

The disc coupling is available in a number of forms (Figure 8); all having driving and driven bolts on the same bolt circle. The amount of misalignment that each type can handle depends upon the length of material between bolts. Torque is transmitted by driving bolts pulling driven bolts through the disc material in tension. More bolts provide greater capacity but reduce the coupling flexibility. For *special purpose* applications, the discs are provided as a pack. Some disc packs are factory installed, while others are supplied with pilot rings for installation in the field. They are available in many styles, including reduced moment (Figure 9) and marine (Figure 10).

Diaphragm Type

The diaphragm coupling comes in two basic forms; a single tapered profile or multiple modified profile (contoured or cutout). Both forms have profile modification that reduce size, increase flexibility, and control stress concentration. Torque path is through the diaphragm member in the radial direction; from the outer diameter to the inner diameter. They are used in most *special purpose* applications and are available in many shapes and styles, including marine (Figures 11 and 12) and reduced moment (Figure 13)

Elastomeric Block Couplings (Elastomeric Element Type)

Large critical equipment (such as synchronous motor driven equipment) use elastomeric block couplings (Figure 9) in *special purpose* applications to reduce vibratory torques or to torsionally "tune" a system (using its torsional "softness").

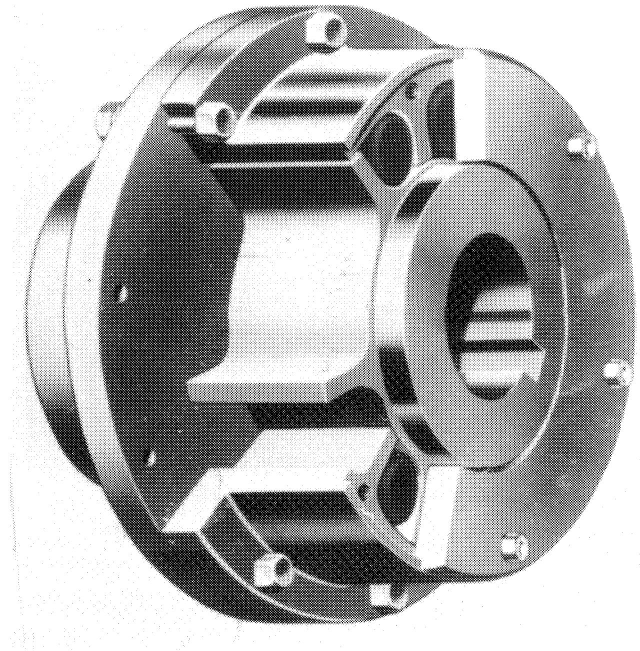


Figure 8. Various Disc Forms.

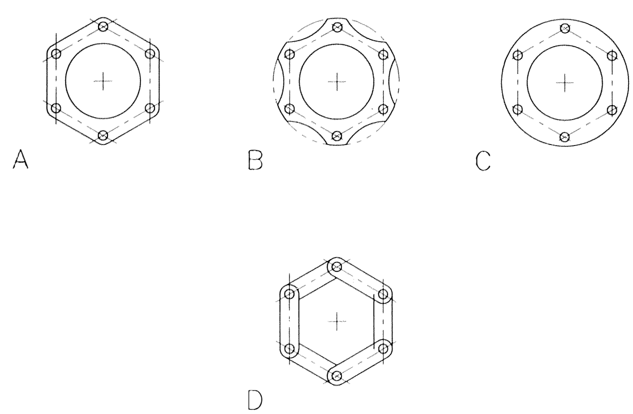


Figure 9. Reduced Moment Special Purpose Disc Coupling.

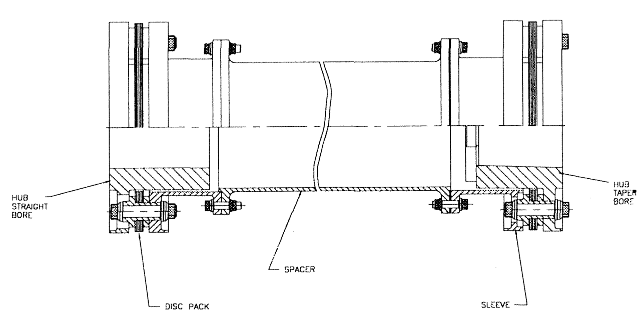


Figure 10. Marine Style Special Purpose Disc Coupling.

Block couplings use rubber in compression. The rubber blocks are installed in cavities formed by internal sleeve blades, external hub blade and two end plates. This type is unique among couplings due to its "fail-safe" feature. If the elastomer fails, the

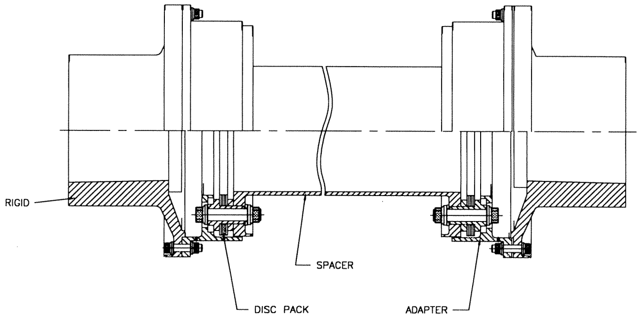


Figure 11. Marine Style Special purpose Diaphragm Coupling (EB Welded Design).

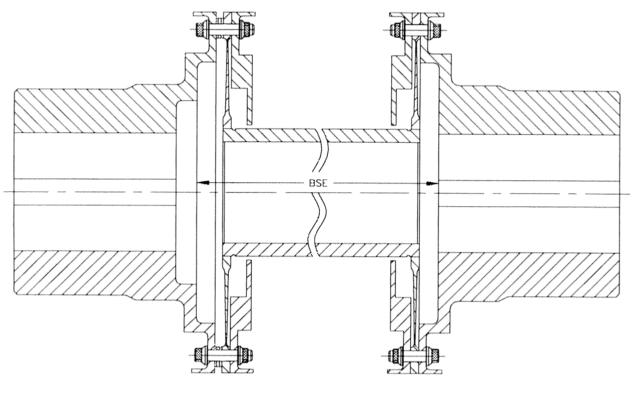


Figure 12. Marine Style Special Purpose Diaphragm Coupling (One Piece Diaphragm).

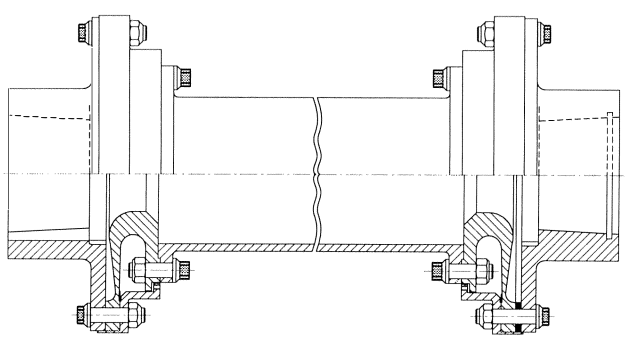


Figure 13. Reduced Moment Special purpose Diaphragm Coupling.

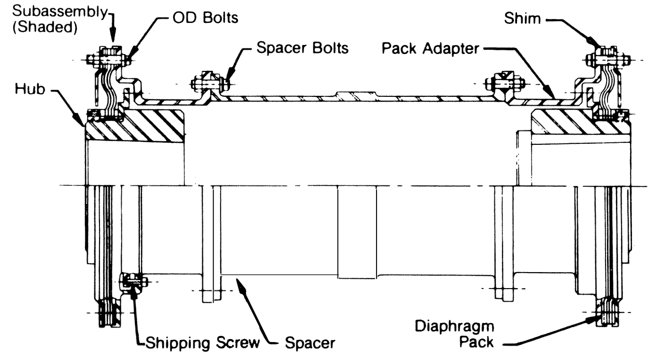


Figure 14. Special Purpose Elastomeric Block Coupling.

Table 1. General Purpose Coupling Evaluation Characteristics.

GENERAL PURPOSE COUPLING TYPE	AXIAL FORCES	TORQUE CAPACITY TO OD	HIGH SPEED CAPACITY	INHERENT BALANCE	FLEXIBLE ELEMENTS EASILY REPLACED	TORSIONAL STIFFNESS	BACKLASH	LUBRICATION	EASY OF ASSEMBLY	RELATIVE COST	LIFE OF FLEXIBLE ELEMENT
MECHANICAL ELEMENT TYPE											
GEAR TYPE											
STRAIGHT TOOTH	M-H	H	H	G	N	H	M-H	Y	E	M	3-5
CROWNED TOOTH	M-H	H	H	G	N	H	M-H	Y	E	M	3-5
GRID TYPE											
VERTICAL SPLIT COVER	M	M	M	G	Y	L-M	M	Y	E	L-M	2-3
HORIZONTAL SPLIT COVER	M	M	M	G	Y	L-M	M	Y	E	L-M	2-3
ELASTOMERIC ELEMENT TYPE											
COMPRESSION TYPE											
DONUT TYPE	L-M	L-M	M	F-G	Y	L	N	N	E	L	3-5
BLOCK TYPE	M	M-H	L	F-G	Y	M	N-L	N	G	M-H	3-5
JAW TYPE	M	M	M	F-G	Y	L-M	N	N	E	L	3-5
SHEAR TYPE											
TIRE TYPE URETHANE	S	L	L	F	Y	L	N	N	G	L	2-3
TIRE CORDED	S	L	L	F	Y	L	N	N	G	L-M	3-5
DONUT TYPE	S	L	L	F	Y	L	N	N	G	L	2-3
METALLIC ELEMENT TYPE											
DISC TYPE											
CONTINUOUS TYPE	L-M	M-H	H	E	Y	M	N	N	G	M-H	4-8
LINK TYPE	L	M-H	H	G	Y	M	N	N	F	M-H	4-8

M = MEDIUM H = HIGH E = EXCELLENT Y = YES
S = SMALL L = LOW G = GOOD N = NO/NONE
F = FAIR ? = MAYBE

Table 2 . Special Purpose Coupling Evaluation Characteristics.

SPECIAL PURPOSE COUPLING TYPE	AXIAL FORCES	TORQUE CAPACITY TO OD	HIGH SPEED CAPACITY	INHERENT BALANCE	FLEXIBLE ELEMENTS EASILY REPLACED	TORSIONAL STIFFNESS	BACKLASH	LUBRICATION	EASY OF ASSEMBLY	RELATIVE COST	LIFE OF FLEXIBLE ELEMENT
MECHANICAL ELEMENT TYPE											
GEAR TYPE											
SEALED LUBES	M-H	H	H	G	N	H	M-H	Y	E	M	3-5
CONTINIOUS LUBED	M-H	H	H	G	N	H	M-H	Y	E	M	3-5
MARINE STYLE	M-H	H	H	G	N	H	M-H	Y	E	M	3-5
ELASTOMERIC ELEMENT TYPE											
COMPRESSION TYPE											
BLOCK TYPE	M	M-H	L	F-G	Y	M	N-L	N	G	M-H	3-5
METALLIC ELEMENT TYPE											
DISC TYPE											
MARINE TYPE	L-M	M-H	H	E	Y	M	N	N	G	M-H	4-8
REDUCED MOMENT	L-M	M-H	H	E	Y	M	N	N	G	M-H	4-8
DIAPHRAGM TYPE											
TAPERED TYPE	M	H	H	E	?	H	N	N	F	H	5-10
MULTIPLE TYPE	M	H	H	E	?	H	N	N	F	H	5-10

M = MEDIUM H = HIGH E = EXCELLENT Y = YES
S = SMALL L = LOW G = GOOD N = NO/NONE
F = FAIR ? = MAYBE

coupling may run for sometime on the metal blades. These couplings can provide up to 1/2 degree of misalignment and parallel offset capabilities of 1/64 in to 1/4 in.

HOW TO SELECT COUPLINGS

When selecting couplings, how do you know which one is best? There is no one answer, as is shown in Tables 1 and 2. In general, unless there are lots of problems, the best coupling to use is the type that originally came with the equipment. When selecting couplings, one must look at the application, its history, and then trade off features and characteristic of available couplings, and pick the best one suited for the application.

THE DOS AND DON'TS IN SELECTION

When selecting couplings, it must be decided what is best for the equipment and the plant. One needs to look at a coupling's initial cost along with how easy is it to maintain?; how often must it be lubricated?; how easy can the flexible element be replaced?; and what forces do the coupling react back into the equipment? How does one do this? One should build a file of the most recent coupling catalogues. Most of the time the coupling selected is usually based on past experience, good or bad. Let's say the plant has used grid couplings for years and has had no significant problems, so why change? But if the plant has been using these couplings for years and has had problems, failures, or has found that the cost to maintain them is high, lots of downtime due to lubrication and alignment problems, it is time to consider changing the coupling type. But before they change, they should look closely at all the other types available to see if its characteristics are better suited for the application. Get in touch with the coupling manufacturer you are considering and ask lots of questions. Just changing one coupling for another could be exchanging one problem with another and sometimes for bigger problems, if the change is not done with some thought and planning. The amount of time spent in selecting a coupling and determining how it interacts with a system should be a function of the cost of the equipment and also on its criticality to the plant, and also how much downtime it will take to replace the coupling or repair a failure. In some cases, the process may take only a little time and be based on past experience, however as the equipment becomes bigger and is more critical to the plant operation, the more detail one should get in selecting a coupling for the equipment.

If the type of coupling is going to be changed, one should see that all maintenance personnel in the plant understand what will be required. For example, changing from a gear coupling to a disc type coupling will require a different set of instruction for setting a motor on its magnetic center. Also alignment procedures are different. It is important to review all coupling changes to assure success.

INFORMATION REQUIRED TO PROPERLY SELECT A COUPLING

Preliminary Information
(Minimum for General Purpose Couplings)

- Horsepower and/or torque
- Speed
- Type of equipment being connected
- Shaft size and keyway information

Other Information That May Be Important
(Particularly for Special Purpose Couplings)

Remember as equipment criticality goes up, more needs to be known about equipment and application.

- Environmental condition, temperature, corrosive atmosphere
- Space limitation
- History of equipment, any previous coupling problems?
- Expected misalignment conditions
- Balance requirements
- Stiffness requirements
- Bearing load restrictions
- Potential excitation or critical frequencies

SAFETY FACTORS, SERVICE FACTORS, SELECTION AND RATING TERMS

In the recent history of couplings, it has become more and more confusing as to what safety factor and service factor (also application or experience factor) really mean. Many people use service factors and safety factors interchangeably. There is an important distinction, however, and understanding the difference is essential to ensure a proper coupling selection for a particular application. Service factors are known and determined by the makers and users of the equipment, since they are directly related to how the equipment is operated. Safety factors are known and determined by the coupling manufacturers, since they are directly related to the coupling component design and materials.

Selection Precautions

It is important to use the selecting process provided in the coupling manufacturer's catalogue. There is no industry standard that deals with coupling ratings. Not only will one find differences in what and how ratings are established for different types of couplings, but one may find the same type may even have different ratings from different suppliers. Therefore, it is important to obtain the coupling manufacturers' catalogues and use their recommended procedure and service factors, if one wants to assure success.

Safety Factors

Safety factors are used in the *design* of a coupling. Coupling designers use safety factors because there are uncertainties in the design. The designer's method of analysis uses approximations to model the loading and, therefore, the calculated stresses may not be exact. Likewise, the material properties such as modulus, ultimate strength, and fatigue strength have associated tolerances that must be considered.

Today, with the use of such computational tools as FEA, stress analysis isgenerally capable of more accurate results than in the past. In addition, the properties of the materials used in high performance products are more controlled and better known. Therefore, couplings designed today vs those designed 20 years ago can indeed operate safely with lower calculated safety factors. Also, the design factor for flexible-element couplings can be lower than gear couplings simply because the *"safeness"* is more accurately predicted.

Generally, torque is the most significant load contributor to the overall stress picture in *gear* couplings. The fatigue factor of safety of a *flexible-element* coupling is generally not as affected by torque, because the failure mode in dry couplings is not very sensitive to torque during continuous operating conditions.

But how safe is safe? If the coupling designer knows all, then a safety factor of one (1.0) is sufficient. However, this is not practical or recommended.

Service Factors

Service factors, on the other hand, are used to account for the higher operating torque conditions of the *equipment* to which the coupling is connected. In API 671, a service (or experience) factor is applied to the normal operating torque of, for instance, a turbine or compressor. This factor accounts for torque loads that are not normal, but which may be encountered continuously, such as low temperature driver output, compressor fouling, or possible vibratory torques. Also service factors are some times used to account for the real operating conditions, which may be five to 20 percent above the equipment rating.

Different service factors are used or recommended depending on the severity of the application. Is it a smooth running gas turbine driven compressor application or will the coupling be installed on a reciprocating pump application? Also note that service factors should be applied to continuous operating conditions rather being used to account for starting torques, short circuit conditions, rotor rubs, etc.

API 671 defaults to a 1.75 service factor that is to be applied to the normal operating torque. Note: API cautions that if reasonable attempts to achieve the specified experience factor fail to result in a coupling weight and subsequent overhung moment commensurate with the requirement for rotordynamics of the connected machines, a lower factor may be selected by mutual agreement of the purchaser and the vendor. The selected value shall not be less than 1.25. *API does not address factors as related to factors of safety on design.* Therefore, it does not ask or answer the question as to how safe a coupling must be for an API 671 application.

Selection and Rating Terms

Factor of Safety (F.S.) is used to cover uncertainties in a coupling *design;* analytical assumptions in stress analysis, material unknowns, manufacturing tolerances, etc. Under given design conditions, the F.S. is the ratio of strength (or stress capacity) to actual predicted stress; where the stress is a function of torque, speed, misalignment, and axial displacement. A design factor of safety (DFS) is the factor of safety at the catalog *rated conditions* of torque, speed, misalignment, and axial displacement. It is used by the manufacturer to establish the coupling rating, because it is the maximum loading that the manufacturer says his coupling can safely withstand. The factor of safety that most would be interested in however, is the factor of safety at the particular set of application loads that the coupling is continuously subjected to. We have defined this to be an *application factor of safety* (AFS). In fact, the application factor of safety is the measure of safety which answers the question "How Safe Is Safe?" It is by definition a measure of the *"safeness"* under *actual operation.*

Service Factor (application factor or experience factor) (SF) is normally specified by the purchaser (although assistance is sometimes given by the manufacturer). It is a *torque multiplier.* It is applied to the operating torque (called the normal operating point in API 671) of the connected equipment. The service factor torque multiplier is used to account for torque loads that are beyond the normal conditions and are of a recurring nature. Couplings are generally selected by comparing the selection torque (SF × normal operating torque) to the coupling's maximum continuous rating. Service factors account for conditions such as a compressor fouling, changes of the pumped fluid (molecular weight, temperature or pressure), or any other repetitive loading conditions that may occur over 10^6 revolutions of the coupling. And sometimes service factors are used to account for the real operating conditions of the equipment, which may be five to 20 percent above the equipment rating. Service factors should not be applied to account for starting torques, or short circuit torques, although these conditions are sometimes stated as being a multiple of normal torque.

Endurance limit is the *failure strength limit* of a coupling component subjected to combined constant and alternating stresses. Beyond this limit, the material can be expected to fail after some finite number of cyclic loads. Below this limit the material can be expected to have infinite life (or a factor of safety of greater than 1.0).

Yield limit (YL)—is determined by the manufacturer to be the *failure strength limit* of a coupling component that *will cause detrimental damage.* If this limit is exceeded, the coupling should be replaced.

Coupling rating—is *a torque capacity* at rated misalignment, axial displacement, and speed. This applies to the ratings given below.

Maximum continuous rating (MCR)—is determined by the manufacturer to be the torque capacity that a coupling can safely run continuously and has an acceptable design factor of safety.

Peak rating (PR)—is determined by the manufacturer to be the *torque capacity* that a coupling can experience *without having localized yielding* of any of its components.

Additionally, a coupling can handle this torque condition for 5,000 to 10,000 cycles with out failing.

Maximum momentary rating (MMR)—is determined by the manufacturer to be the *torque capacity* that a coupling can experience *without ultimate failure,* where localized yielding (damage) of one of its components may occur. A coupling can withstand this occurrence for one brief duration. After that, the coupling should be inspected and possibly replaced. (This is also sometimes called the short circuit torque rating.)

Peak and maximum momentary conditions and factors of safety—Just like continuous torque ratings, there are different ways to rate a coupling's capability to handle non-continuous peak torques or low frequency high cyclic torques. These can be caused by such things as motor startups, short circuit conditions, compressor surges, or other transient conditions. Some questions to ask are: What is the nature of the load? Is it due to a synchronous motor startup with hundreds of high torque reversals during a daily startup? Is it a single unidirectional torque induction motor driver application?

BALANCING REQUIREMENTS

Like coupling ratings, when and to what level to balance a coupling appears to be almost as mystifying, however, they are rather simple once a basic understanding is achieved of what contributes to unbalance and how it affects a system. Once this is understanding is obtained, the *"arbitrary balance limits"* can be put into perspective.

Why a Coupling is Balanced

One important reason for balancing a coupling is that the force created by unbalance could be detrimental to the equipment, bearings, and support structures.

The amount of force generated by unbalance is

$$F = 1.77\left[\frac{\text{rpm}}{1000}\right]^2 \times \text{oz-inches} = \text{lb} \qquad (1)$$

$$F = \frac{\text{microinches}}{1000000} \times \text{weight} \times 16\left[\frac{\text{rpm}}{1000}\right]^2 = \text{lb}$$

According to these equations, the amount of force generated by unbalance is proportional to the square of speed. Therefore, one key element to the balance level required for a coupling is how fast it rotates.

The other key element of coupling balance is that a coupling is an assembly of components. Some couplings have inherent "sloppy" fits that are required to accommodate misalignment, make it more economical to manufacture in volume, therefore if one balances a coupling to very low limits, one does not substantially improve the amount of unbalance force it will produce in operation. To improve coupling balance, one must close up the fits and tolerances used to make the coupling.

Things That Contribute Coupling Unbalance

- Component Eccentricity. This any eccentricity of mating surfaces that permit radial displacement of the mass axial of mating parts

- Component Clearances. This is the clearance that permits relative radial displacement of the mass axis of coupling components

- Hardware unbalance: This from clearance of hardware, weight difference in them, etc.

- Balancing Errors. Runouts of fixtures used, clearances and eccentricity of assembly on fixtures.

There are *two basic Industry standards for balancing couplings.* Note: ISO is not a coupling balance specification but applies to rigid rotors. The two standards are; AGMA 9000. this usually applied to *general purpose Couplings.* In fact, API 610 calls out an AGMA level 8 class requirement. Whereas, API 671 for *special purpose Couplings* calls out 4W/N, or 0.0008W (50 microinches) or 0.01 oz-in, which ever is greatest for *residual* *unbalance limits.* For *potential unbalance limits* API 671 calls for the assembly to be with in 40W/N, or 0.008W (500 microinches or AGMA 11) or 0.1 oz-in which ever is greatest.

Balancing Limits

The balance limit placed on a coupling should be its *potential unbalance* and not its *residual unbalance* limit. The *residual unbalance limit* usually has little to do with the true coupling unbalance *(potential).* The *residual limit* is the level the a component or a coupling is balanced to on the balancing machine. Whereas the *potential limit* is sum of all the parts usually added by the square root of the sum of the squares of the contributors to the coupling *"real"* unbalance.

The amount of coupling unbalance can be satisfactorily tolerate by any system is dictated by the characteristics of the specific connected machines and can best be determined by detailed analysis or experience. Systems insensitive to coupling unbalance might operate satisfactorily with high unbalance values. Conversely, systems or equipment that are usually sensitive to coupling unbalance will require lower unbalance limits. Factors that must be considered in determining the system's sensitivity to coupling unbalance include

- *Shaft end deflection:* Machines having long and/or flexible shaft extensions are relatively sensitive to coupling unbalance.
- *Bearing loads relative to coupling weight:* Machines having lightly loaded bearings or bearings loads primarily by the overhung weight of the coupling are relatively sensitive to coupling unbalance. Machines having overhung rotors or weights are often sensitive to coupling unbalance.
- *Bearings, bearing supports, and foundations rigidity:* Machines or systems with flexible foundations or supports or supports are relatively sensitive to the coupling unbalance.
- *Machine separation:* Systems having a long distance between machines often exhibit coupling unbalance problems.
- *Others:* Other factors may influence coupling unbalance sensitivity.

Table 3 is taken from AGMA. In general, the selection bands can be put into the following speed classification:

- Low speed: A and B
- Intermediate speed: C, D, and E
- High Speed: F and G

Table 3. Coupling Balance Classes Vs *Selection Bands.*

Selection band	Typical AGMA coupling balance class; system sensitivity to coupling unbalance		
	Low	Average	High
A	5	6	7
B	6	7	8
C	7	8	9
D	8	9	10
E	9	10	11
F	10	11	
G	11		

General Purpose Couplings (API 610) fall in selection band C, AGMA 8 for an average system.

Special Purpose Couplings (API 671) fall in selection band F, AGMA 11 for an average system. Figure 15 is also taken from AGMA 9000. Superimposed on this graph are the most common speed classifications. The graph has also been extended to 2000 lb.

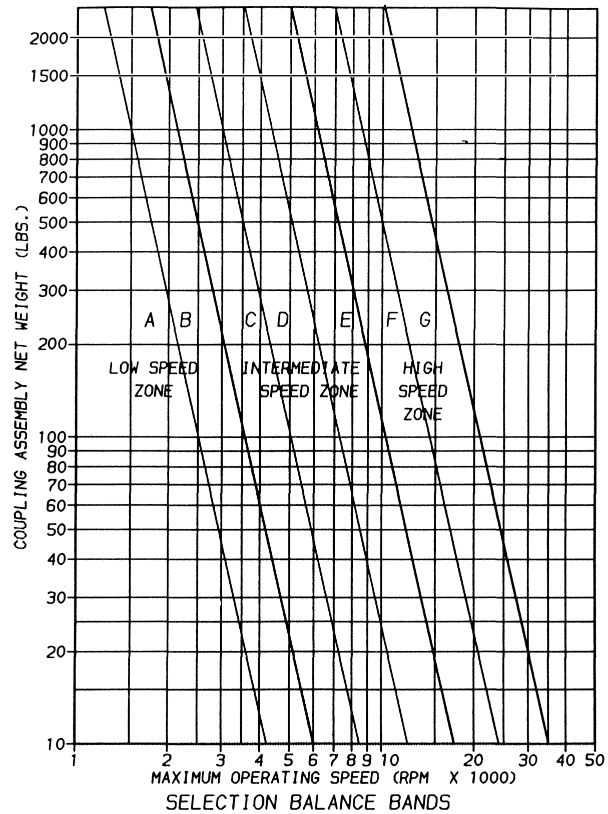


Figure 15. Balance Selection, Weight Vs *Speed.*

AGMA 9000 defines balance limits as a range of unbalance expressed in microinches. The potential unbalance limit classes for couplings are given in Table 4. They are given in maximum root-mean-square (rms) microinches of displacement of the inertial axis of rotation at the balance plane. Limits are given as per displacement plane. AGMA does not address *residual unbalance limits* but as a general rule of thumb if the coupling or its component was to be balanced it would be to the limits shown in Table 5.

The "Arbitrary" Balance Limit

What is meant by "arbitrary" balancing criteria? The limits (residual and potential) are set by specification and have very

Table 4. AGMA Coupling Balance Classes.

AGMA coupling balance class	Maximum displacement of principal inertia axis at balancing planes (rms micrinches)
4	Over 32,000
5	32,000
6	16,000
7	8,000
8	4,000
9	2,000
10	1,000
11	500

Table 5. Practical Residual Unbalance Limits.

Speed class	Residual unbalance limits (microinches)
Low-speed couplings	500*
Intermediate-speed couplings	200
High-speed couplings	50

*Low-speed couplings are usually not balanced.

little relationship to a system other than the couplings weight and the operating speed. The use of the coupling weight is used because it is expected to be proportional to the weight of the equipment and hopefully have some reflection on the systems sensitivity.

The most common is to express unbalance "U" as

$$\text{oz-inches} = \frac{kW}{N} = U \text{ per balance plane} \quad (2)$$

k = 40 to 120 for potential unbalance limits and 4 to 12 for residual unbalance limits
W = weight of the part per balance plane (lb)
N = operating speed of coupling (rpm)

Where as API 671 calls out:

Residual Limit—4W/N or 0.0008W or 0.01 oz-in, whichever is greatest.

Potential Limit—40W/N or 0.008W or 0.1 oz-in, whichever is greatest.

Types of Coupling Balance

Couplings are usually supplied in one of four categories as to balance:

- As manufactured tolerances and fits. Most couplings are supplied as manufactures with no balance. These couplings are the majority of the general purpose couplings. The usually fall into AGMA 7 and 8 classifications, with some of the flexible element type following into AGMA 9.

- Controlled tolerances and fits. Usually provides the most significant improvement in potential unbalance of coupling. This can also substantially increase the price of a coupling. For example, a gear coupling in this category would have 1/2 the tolerance for boring the hub to its piloting diameter. The tip clearance between the hub and sleeve teeth would be reduced. Also, this type of coupling would have pilots to control the eccentricity of a spacer section, no longer off the shelf standard and may cost 2 to 3 times more. This type of coupling would move the AGMA classification up approximately one level, from the off the shelf as manufactured condition.

- Component balance. This can usually produce potential unbalancevalues equal to assembly-balance couplings. Offers the advantage of being able to replace components (as related to balance—some couplings are not interchangeable for other reasons) with out rebalancing. API 671 defaults to component balance with a check on the assembly, unless otherwise stated. Again we are looking at coupling that meet AGMA 11.

- Assembly balance. Usually offers the best balance. Depending on how much fixturing and the type of coupling this type of balance can obtain 20W/N to 40W/N potential unbalance limits. The lower being for couplings with no clearance and for couplings that are rigidized without fixtures. *Caution: On assembly-balanced couplings, parts cannot be replaced without rebalancing the coupling.*

INSTALLATION CONSIDERATIONS

Most couplings failures occur relatively soon after installation or after a coupling has been taken apart and reassembled on the equipment. Why? Because somebody didn't follow the installation instructions supplied. They have been installing couplings for years and who needs to read those boring instructions. Let me tell you, READ THEM!! If you do not have instructions, get them. If you follow them you will have a very high probability of success.

Things Not To Do, A Sure Way to Increase Failures

- It will not fit on the shaft. Get out the torch and heat the "H" out of the hub or open up the bore until it slides on.
- The keys are too tight. Let's grind them until they fall in.
- I lost a bolt. Get one out of our bolt can in maintenance.
- These bolts are snug enough.
- My pump or motor is out of balance, Let's take it all out of (or on) the coupling.
- This part of the coupling looks bad, let's replace with a part of another we took out last year.
- Let's put this grease in this coupling—it works good in our bearings, why not the coupling?
- Check alignment? Why? It ran okay for two years with no problem.
- Give me a coupling to fit on my 3.0 in shaft and put one 1/2 in keyway in it. No other information supplied.
- We can buy this other type of coupling and it is 30 percent less expensive than what we are using now.

Things to Do, A Sure Way to Success

- Consider total cost. Look at initial cost versus total operating cost.
- Provide the coupling manufacturer with as much information asjustified by criticality of equipment.
- Don't change type of coupling just for change sake.
- Assure maintenance people are trained properly in installation and maintenance of the type of couplings being used.
- Use the bolts supplied. If one gets lost, buy a spare set from your coupling supplier.
- Use a torque wrench to torque bolts.
- Align equipment to limits specified by equipment manufacturers and recheck whenever major maintenance is done on equipment.
- Lubricate, asrequired with the right stuff and correct interval.

CONCLUSION

The information herein is just an overview of what is important when considering couplings for an application. The amount of time one spends in properly understanding, selecting, installing, and maintaining couplings is a function of what down time and maintenance cost. down time.

BIBLIOGRAPHY

American Gear Manufacturers Association (AGMA), AGMA 9000, Standard Balanced Classifications for Flexible Couplings (1990).

American Petroleum Institute: Special Purpose Couplings for Refinery Service, API Standard 671, Second Edition (February 1990).

API Standard 610, Centrifugal Pumps for General Refinery Service, Seventh Edition) (February 1989).

Mancuso, Jon, *Couplings and Joints: Design, Selection and Applications,* New York, New York: Marcel Dekker, Inc. (1985).

Mancuso, J. R., Gibbons C. B., and Munyon, C. B., "The Application of Flexible Couplings for Turbomachinery," Proceeding of the Eighteenth Turbomachinery Symposium, The Turbomachinery Laboratory, Texas A&M University, College Station, Texas (1989).