

How to Determine Grease Compatibility and Why It's Important

The risks of mixing lubricants and new methods for determining long-term compatibility impacts

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Abstract

Grease compatibility charts have been developed and circulated since the 1980s without much alteration. However, grease technology has changed significantly over the years, and there are many proven examples of performance that contradict several widely used compatibility charts. Recent research shows grease compatibility charts to be contradictory and dated. Changing formulations and complexity in application have rendered grease compatibility charts unreliable. This paper describes the most common examples of incompatible mixing and how to determine if two greases are compatible.

Background

Many organizations rely on compatibility charts to make important maintenance decisions that can have a significant economic impact. Such charts are readily available in some published papers, periodicals, and webpages. However, very few such chart given any reference for the origin of the data or any research utilized to establish the compatibility relationships described.

Working as a lubrication engineer for multiple companies and industries, the author has frequently encountered lubrication program decisions that have been based on these charts. While working in a lab environment to objectively evaluate the compatibility of specific products using laboratory analysis data, significant concerns have been raised about some charts after seeing that greases presented as "Compatible" have proven to be quite incompatible.

Researching Compatibility Charts

As a starting point for this research, a selection of 17 different compatibility charts were found and evaluated for formats and differences. The chart below shows the labels used in these charts, and how many times these descriptions show up in the charts. 17 occurrences would indicate that a grease category was present in each of the charts found, and there were only three such products.

	Prolab	Tribology.com	Amsoil	Lubritene	NSK	Transit Lube	Eastern Marine	Ultra Lube	Accurate Lubricants	PriestOil Chart1	PriestOil Chart2	Thixo Grease	ExxonMobil	Hipertech	Amsoil	Cenex	LubeTalkWeb	Totals	
Aluminum Complex	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Barium					1	1						1			1	1			5
Barium Complex	1	1	1				1	1			1						1		10
Calcium					1	1	1				1	1			1	1			7
Calcium Stearate	1	1	1					1	1				1					1	8
Calcium 12-Hydroxy	1		1		1	1		1	1			1	1	1	1	1	1	1	13
Calcium 12-Hydroxystearate		1							1										2
Calcium Complex	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Bentonite Clay	1	1			1				1						1	1			6
Clay				1		1	1	1		1	1	1	1	1			1	1	11
Lithium					1	1	1				1	1			1	1			7
Lithium 12-Hydroxy	1		1		1	1		1		1		1	1		1	1	1	1	12
Lithium 12-Hydroxystearate		1							1										2
Lithium Complex	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Sodium					1	1	1				1				1	1			6
Polyurea	1				1	1	1				1	1			1	1			8
Polyurea (Conventional)		1	1					1	1			1					1	1	7
Polyurea (modified)	1																		1
Polyurea Shear Stable		1	1						1	1				1			1	1	7
Polyurea (LUB-LM type)								1											1
Calcium Sulfonate	1	1	1					1		1				1			1	1	9
Silica Gel															1				1
Silica	1																		1
Polyurea (Lubriline)												1							1
Lithium Stearate												1					1	1	3

Figure 1: Compilation of 17 grease compatibility charts from the internet

The three products that appeared in each of the tables were Aluminum Complex, Lithium Complex, and Calcium Complex. However, the commonality ends there. A total of 25 different product descriptions were found in the 17 tables. Some may have been referring to the same product categories, but failed to use common nomenclature, so it is difficult to determine where there might be overlap.

Contradictions

Several contradictions were found among the various charts. For example, the chart found at Tribology.com indicated that Barium Complex grease is COMPATIBLE with Clay thickened grease. However, charts from Amsoil, Transit Lubricants Ltd., UltraLube, and others indicate that this mixture is INCOMPATIBLE. Charts from Lubritene and Transit Lubricants indicate that “Polyurea” grease is BORDERLINE COMPATIBLE with Calcium Complex. A chart provided by Amsoil shows both “Polyurea (shear stable)” and “Polyurea (conventional)” are COMPATIBLE with Calcium Complex. And a chart from Thixogrease shows Calcium Complex to be INCOMPATIBLE with both “Polyurea (conventional)” and “Polyurea (Lubriline)”.

Perhaps one of the most common inadvertent mixing of greases occurs when a Lithium Complex grease, commonly specified or used as a factory fill in bearings in fans and pumps, meets up with a Polyurea grease, often used in electric motors. It is quite easy for a plant where strict guidance is not given or adhered to, for these two products being used side-by-side (in the pillow block bearings and motor of a fan, for instance) to be mixed. Upon consulting charts for this important mixing condition, a chart from NSK bearings calls Polyurea and Lithium Complex INCOMPATIBLE. Charts from Lubritene, Priest Motor Repair, and Transit Lubricants show them to be BORDERLINE COMPATIBLE. And the most commonly seen charts, including Tribology.com, Cenex, and those published in ReliablePlant magazine show “Polyurea (conventional) to be INCOMPATIBLE, and “Polyurea (Shear Stable)” to be COMPATIBLE. However, there is no definition given for “Compatible” Polyurea. Certainly no Product Data Sheets describe Polyurea greases as “conventional”. If this term is thought of as being a differentiation from

“Shear Stable” Polyureas, there is likewise no definition to describe what would be considered “Non-Shear Stable” greases.

Shear stability, in fact, is determined by the ASTM methods using a grease worker for extended number of strokes, and measurement of changes in the penetration value relative to the standard 60 double-stroke result. Meaning, that shear stability is actually a scale, where greases can be described as having “Excellent” shear stability (<5% reduction in penetration after extended working), “Very Good”, “Good” and “Poor”. So which of these would be labelled “Shear Stable” and which would be labeled “conventional”? In order to rely on a chart for the correct course of action regarding mixing compatibility, it would mean the difference between tearing down a machine to remove all traces of grease, versus taking no action because the chart says “Compatible”.

Chart Origins

If it can be said that there are significant disagreements between the various charts, it is true that they all have one thing in common. Few of the 17 charts that were researched provided any link or reference to research that was conducted to develop them. That is to say, that charts being used to make significant engineering and design decisions are contradictory, and do not indicate the source of information or research used to compile them.

Upon observation, it becomes obvious that several of the charts are derivative from others. The various descriptions used lead to a certain differentiation that implies that some may have been copied from others. Many charts include a disclaimer, usually stating that it would be preferable to either clean out all old grease and avoid any mixing, or stating that the charts are believed to be accurate at the time of publication, but the publisher takes no responsibility for the guidance included in the chart. Some charts that are obviously derived from these with such a disclaimer are stripped away from the disclaimer in the re-publication. One that did supply information regarding the source for chart development was the Acculube chart, which states, “There are libraries full of good compatibility charts, but many contradict each other. The critical consideration for the compatibility of greases is the type of thickener used in the formula- and also the type of base fluid used. Here's what Acculube believes is a good basic compatibility guideline, based on its 25+ years of experience working hands-on with users of commercial greases. We've assigned each "combination" a rating:

- **C** when the mixture is compatible
- **N** for when it is not compatible, and
- **?** when the combination is questionable. (This means it might be compatible, but needs to be tested.)”

Certainly an honest assessment of the available compatibility charts, but basing their recommendations on extensive experience. It is not known, however, if this experience is anecdotal, or part of a carefully conducted compatibility study between groups of greases with different thickeners under carefully controlled and repeatable testing.

Another well documented chart was featured in a Machinery Lubrication magazine article.ⁱ This chart, originally in an article in Plant Services magazine, dated from 1997, and was based on research of 10 greases conducted by NSK bearing company. Perhaps the most detailed backing information provided, the results were based on two greases which were first tested separately and then blended at three different ratios. The worked penetration test was used on the greases after being blended at room temperature and again after storage at 250°F. This result produced the following chart (Figure 2), as it appeared in Machinery Lubrication magazine:

Legend:	Aluminum Complex	Barium	Calcium	Calcium 12-Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12-Hydroxy	Lithium Complex	Polyurea
● Compatible										
▲ Borderline Compatible										
■ Incompatible										
Aluminum Complex		■	■	●	■	■	■	■	●	■
Barium	■		■	■	■	■	■	■	■	■
Calcium	■	■		●	■	■	■	▲	■	■
Calcium 12-Hydroxy	●	●	●		▲	●	●	■	●	■
Calcium Complex	■	■	■	▲		■	■	■	●	●
Clay	■	■	■	●	■		■	■	■	■
Lithium	■	■	■	●	■	■		●	■	■
Lithium 12-Hydroxy	■	■	▲	●	■	■	■		■	■
Lithium Complex	●	■	●	●	■	■	■	■		■
Polyurea	■	■	■	■	●	■	■	■	■	

Figure 2: Gebarin, Sabrin, "Recommendations for Mixing Greases", Machinery Lubrication, June 2006

Legend:	Aluminum Complex	Barium	Calcium	Calcium 12-Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12-Hydroxy	Lithium Complex	Polyurea*	Sodium	Calcium Sulphonate	Silica
● Compatible													
▲ Borderline Compatible													
■ Incompatible													
Aluminum Complex		■	■	●	■	■	■	■	●	■	■	■	●
Barium	■		■	■	■	■	■	■	■	■	■	▲	●
Calcium	■	■		●	■	■	■	▲	■	■	■	N/A	N/A
Calcium 12-Hydroxy	●	●	●		▲	●	●	■	■	■	■	N/A	N/A
Calcium Complex	■	■	■	▲		■	■	■	■	■	■	■	■
Clay (Bentone)	■	■	■	●	■		■	■	■	■	■	■	■
Lithium	■	■	■	●	■	■		■	■	■	■	■	■
Lithium 12-Hydroxy	■	■	▲	●	■	■	■		■	■	■	■	N/A
Lithium Complex	●	■	●	●	■	■	■	■		■	■	■	■
Polyurea*	■	■	■	■	■	■	■	■	■	*	■	■	■
Sodium	■	■	■	■	■	■	■	■	■	■		■	■
Calcium Sulphonate	■	▲	N/A	N/A	●	■	■	■	■	■	■	■	N/A
Silica	●	●	N/A	N/A	●	■	■	N/A	■	■	■	■	■

* Not all polyurea greases are mutually compatible

Figure 3: Unreferenced chart:

<http://www.machinerylubrication.com/Read/29337/understanding-grease-compatibility>

Grease Compatibility Chart												
	Aluminum Complex	Barium Complex	Calcium Stearate	Calcium 12-Hydroxystearate	Calcium Complex	Calcium Sulfonate	Bentonite Clay	Lithium Stearate	Lithium 12-Hydroxystearate	Lithium Complex	Polyurea (Conventional)	Polyurea (Shear Stable)
Aluminum Complex	-	I	I	C	I	B	I	I	I	C	I	C
Barium Complex	I	-	I	C	I	C	I	I	I	I	I	B
Calcium Stearate	I	I	-	C	I	C	C	C	C	B	C	I
Calcium 12-Hydroxystearate	C	C	C	-	B	B	C	C	C	C	I	C
Calcium Complex	I	I	I	B	-	I	I	I	I	C	C	C
Calcium Sulfonate	B	C	C	B	I	-	I	B	B	C	I	C
Bentonite Clay	I	I	C	C	I	I	-	I	I	I	I	B
Lithium Stearate	I	I	C	C	I	B	I	-	C	C	I	C
Lithium 12-Hydroxystearate	I	I	B	C	I	B	I	C	-	C	I	C
Lithium Complex	C	I	C	C	C	C	I	C	C	-	I	C
Polyurea (Conventional)	I	I	I	I	C	I	I	I	I	I	-	C
Polyurea (Shear Stable)	C	B	C	C	C	C	C	C	C	C	C	-

Figure 4: Turner, David, "The Skinny on Grease Lubrication", Machinery Lubrication, Jan 2007

Two other charts that have been published by Noria are included here as well. The chart in Figure 3 contains the following: "A note of caution: not all polyurea thickeners are compatible. Be thorough in reviewing the compatibility of the greases used at the motor rebuild shop and at the site. Ideally use

the same grease for both.” So if nearly every chart we have seen shows that all Polyurea thickened greases are “C”-compatible with Polyurea thickened greases, how can we reliably use these charts?

While they were published at different times, and therefore we do not necessarily expect these to be identical, it does underscore the challenge of finding a single, authoritative chart to be used with confidence when making decisions regarding grease mixing.

Basis for Grease Compatibility

It is interesting to note, that all such charts that can be found on grease compatibility focus only on the family of thickener involved. There are, in effect, three components to any formulated grease: the base oil, the additives and the thickener. When dealing with mixing of oils, the key considerations are the viscosity of each product, the base oil type, and the thickener. Somehow, though, these critical parameters are overlooked when utilizing grease compatibility charts. This is somewhat understood, since the most common reason for grease mixing problems is related to differences in grease thickener. However, that is not the only issue.

Base oil compatibility

Greases are manufactured from both mineral oil and synthetic oil bases. Some synthetic base oils are incompatible with mineral oils and other types of synthetics, just as in mixing of lubricating oils. Therefore, it is important to consider the type of base oil in the grease when determining compatibility. If the grease thickeners are compatible, but the base oils are not, the resulting mixture can be problematic and a poor performer. Viscosity is critical when selecting any lubricant. Likewise, when greases are mixed where the base oil viscosities are significantly different, the resulting mixture will not be optimized for the application.

Additive compatibility

It is well understood that when oils are mixed, any incompatibility in the additive packages will result in poor performance, and often additive reactions creating deposits. While reacting additives will not settle to the bottom in grease, as is the concern in oil, the changes can be problematic, impacting additive effectiveness, and in some cases creating corrosive conditions in the grease. Additive compatibilities with metallurgy of the lubricated component must also be considered.

Thickener compatibility

Mixing of greases with incompatible thickeners can cause the most immediate and obvious changes which interfere with effective lubrication. Many mixtures will initially soften, often to the point of migration through seals or away from lubricated surfaces. Some mixtures will cause the thickener to release the oil, and the separated phase will run freely from the bearing, gear or housing. Other mixtures harden initially, and cause component load issues, and poor grease motility. This potential effect is not easily determined. Simply mixing two greases together to observe changes may not provide any obvious difference. But carefully mixing the greases in different ratios, and subjecting them to

mixing, working, and heating cycles can result in measureable changes in properties to predict their performance in a machine.

Testing for Grease Compatibility

So if this research has demonstrated the unreliability of the many different and contradictory grease compatibility charts found in publications and accessible on the internet, it is important to discuss what additional steps can be taken to evaluate compatibility of greases. ASTM D6185 is the “Standard Practice for Evaluating Compatibility of Binary Mixtures of Lubricating Greases”. This method involves the mixing of the intended greases in ratios of 25:75, 50:50, and 75:25. The resulting mixtures are evaluated for changes in dropping point, shear stability and storage stability. The second two of these involve measuring changes in the cone penetration value.

While this 2011 standard has greatly improved the uniformity to which greases can be tested for compatibility, it should be noted that the three evaluation tests are static in nature. While there is some mechanical working of the grease prior to testing, this is minimal mechanical perturbation. When a grease mixture is introduced into a machine, such as a motor bearing, it will undergo significant mixing and working in a relatively short period of time. This compares to the 60 double strokes utilized to mix and work the binary mixture evaluated in the standard. A mixture of greases introduced in a common ball-bearing operating at 1750 rpm will see nearly 30 million mixing and working events in just 3 days of operation. This mixture will be subjected to continuous dynamic forces, and its performance and possible degradation will be influenced by this more than the static response seen in cone penetration or dropping point measurements. The ability of this testing to adequately predict inservice mixtures may be reasonably questioned.

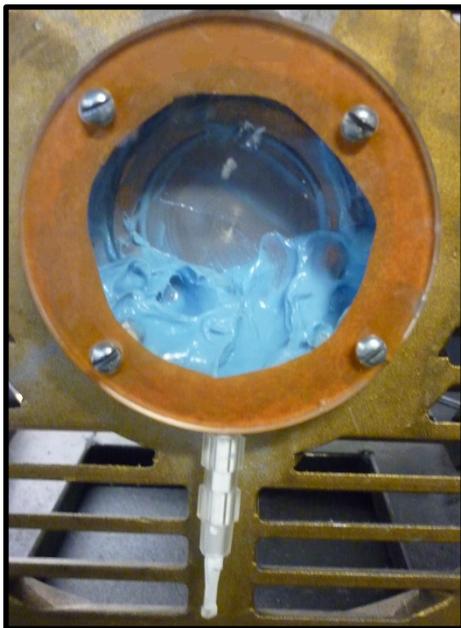


Figure 5: Grease Mixing Test Stand

Working in a Bearing Simulator

Some studies have been performed to improve the mixing and working of the greases to better simulate machine conditions. Included is an electric motor test stand developed for the Electric Power Research Institute’s *Effective Grease Practices* guideline. This test stand consists of the end bell from a 60 hp electric motor, mounted with a ball bearing in a stub shaft. The shaft is turned by a fractional horsepower motor, coupled to a turned-down shaft. The housing of the end bell is removed and replaced by a Plexiglas window to observe the condition of the grease under dynamic conditions. For the purpose of testing grease mixtures, the 25:75, 50:50, and 75:25 ratios are placed sequentially into the bearing by hand packing, and packing the adjacent housing area to ½ full. This is then run for 72 hours, to achieve the 30 million plus perturbations of the grease. The conditions observed are noted, and the grease is removed from

the bearing from the load zone area.

Dynamic Analysis

The resulting mixture is analyzed by Fourier Transform Infrared Spectroscopy (FTIR) to note any reaction or unexpected oxidation of the components in the grease. The grease is also evaluated by elemental spectroscopy to likewise evaluate for unexpected final ratios of additives, as compared to the anticipated averaging of values seen in the original products, adjusting for mixing ratios. Finally, the grease is tested in a controlled stress rheometer to evaluate changes in flow and shear properties as compared to the original products. The values that are measured include the yield stress, which can predict the hardening or softening the grease may undergo; the oscillation stress, which can give insight into the likelihood of oil separation and other effects; and recoverable compliance, which can help to identify those mixtures that might experience “channeling” or “tunneling” in the equipment housing. Taken together, these tests may provide a more comprehensive picture of the potential effects of mixing two grease products together, and help a user avoid reliability issues from grease mixing, even of products that might otherwise appear to be “Compatible” on charts.

Examples of Grease Compatibility Testing

The following are results of testing of binary mixtures of greases using the methods described in this paper and using the grease mixing test stand to mix and work the samples. The first example is of two commonly used Polyurea thickened greases. This mixture was chosen for a company looking to consolidate the number of greases being used in their facility. One area of the facility utilized Chevron SRI in all electric motors, while the remainder utilized Mobil Polyrex EM. The goal was to consolidate to one product for all motors. However, it would not be possible to completely clean all of the grease out of the motors of the grease being replaced, and thus it became necessary to verify that one polyurea grease could be directly added to a motor containing the other. According to most grease compatibility charts, Polyurea greases are compatible with each other, and such a transition would be allowed.

Table 1 shows the product Information for Chevron SRI-2 and Mobil Polyrex EM Grease

Test	Chevron SRI Grease 2 [1]	Mobil Polyrex EM [2]
NLGI Grade	2	2
Thickener Type	Polyurea	Polyurea
Penetration, Worked, ASTM D217	280	285
Viscosity of Oil, ASTM D445 cSt @ 40 C	116	115

These greases are very comparable based on their consistency and viscosity of the base oils.

Table 2 shows differences between elemental spectroscopy (RDE) values for the reference greases and the 50:50 mixture of Chevron SRI Grease 2 and Mobil Polyrex EM. The area highlighted in yellow is where there is contrast between the products and evidence of mixing is observable.

	Fe	Cr	Pb	Cu	Sn	Al	Ni	Ag	Si	B	Na	Mg	Ca	Ba	P	Zn	Mo	Ti	V
Polyrex EM	1.1	0.5	0.0	0.6	0.0	3.5	0.6	0.1	2.0	0.1	0.5	0.2	1.2	8.2	123.6	2.3	1.4	0.0	1.3
SRI	4.9	1.0	0.2	0.3	0.0	1.4	1.7	0.1	1.6	0.2	1.0	21.5	3.4	15.6	0.0	576.8	1.9	0.0	2.2
50:50 SRI2/Poly EM	0.8	0.4	0.0	0.3	0.0	0.0	0.3	0.1	1.7	0.6	0.8	10.2	5.1	4.6	31.8	301.7	1.1	0.0	0.5

These differences show an obvious formulation difference between these products with regard to (most likely) anti-wear additives, but that alone would not be sufficient to disqualify the mixture for compatibility, if the resulting product still functioned effectively with regard to wear resistance.

Table 3 shows rheological values for the two worked reference samples and the 50:50 worked mixture. Areas highlighted in red indicate values of concern.

Trial	G' (Pa)	Expected G'	Yield Stress (Pa)	Expected Yield Stress	Recoverable Compliance (%)	Expected R-C %
Chevron SRI2 Worked	31690	--	872	--	34%	--
Polyrex EM Worked	12480	--	386.6	--	29%	
50:50 SRI2:Polyrex Worked	8605	22085	354.1	629	59%	31%

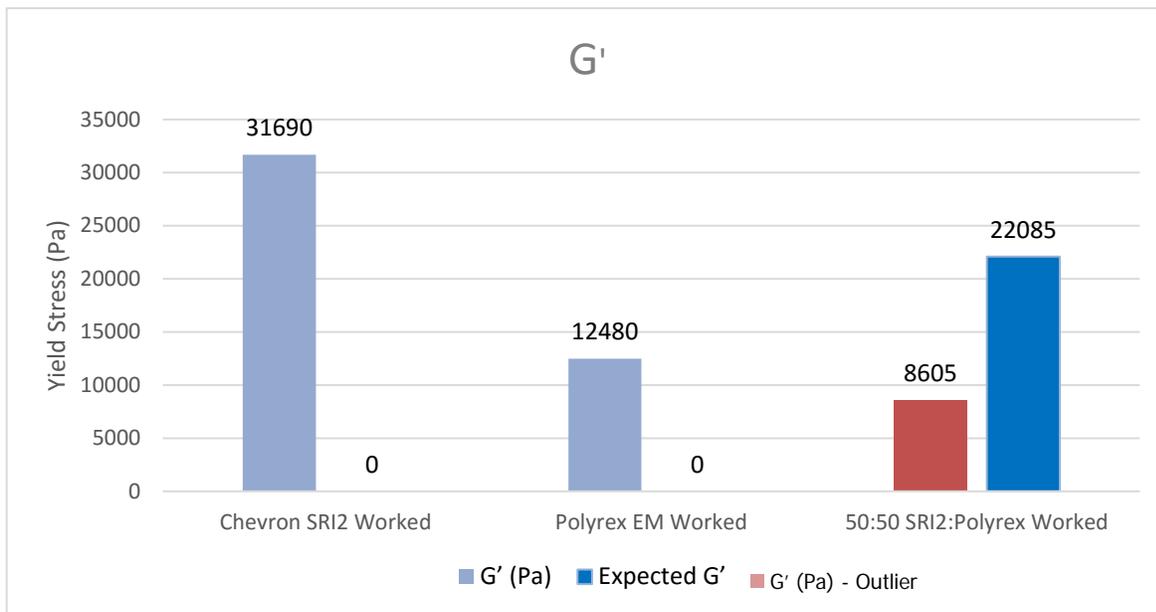


Figure 6 shows the expected G' values and the actual G' values for the 50:50 mixture of Chevron SRI Grease 2 to Mobil Polyrex EM and the reference greases.

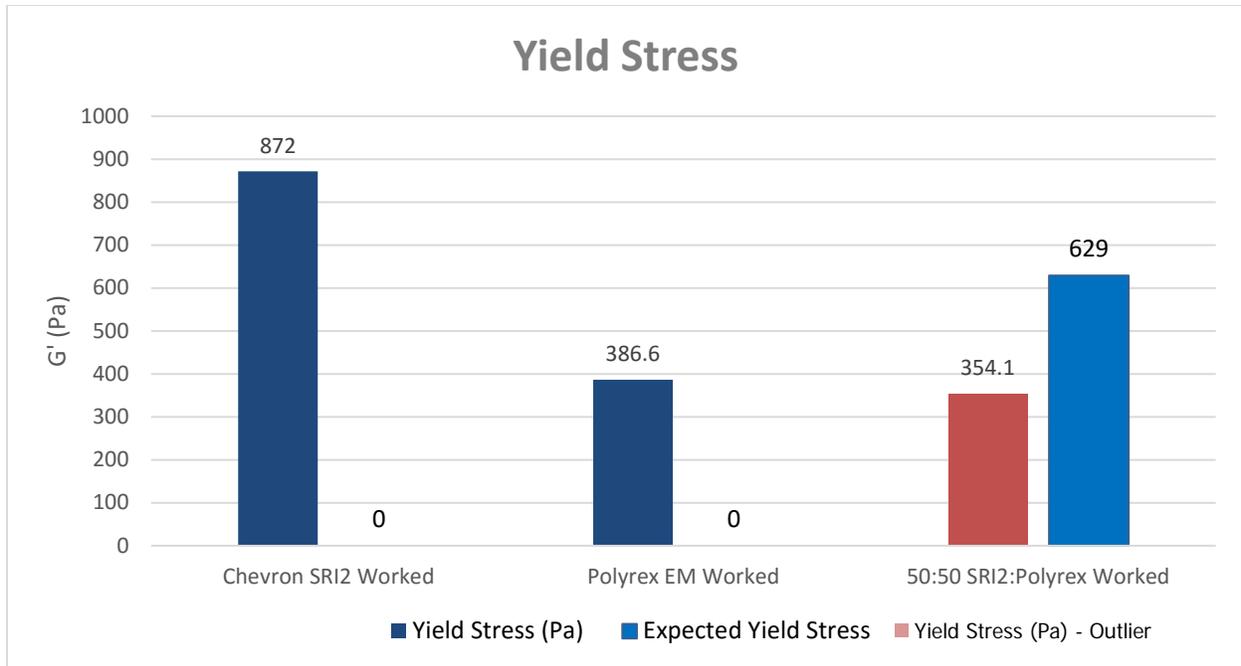


Figure 7 shows the expected yield stress values and the actual yield stress values for the 50:50 mixture of Chevron SRI Grease 2 to Mobil Polyrex EM and the reference greases.

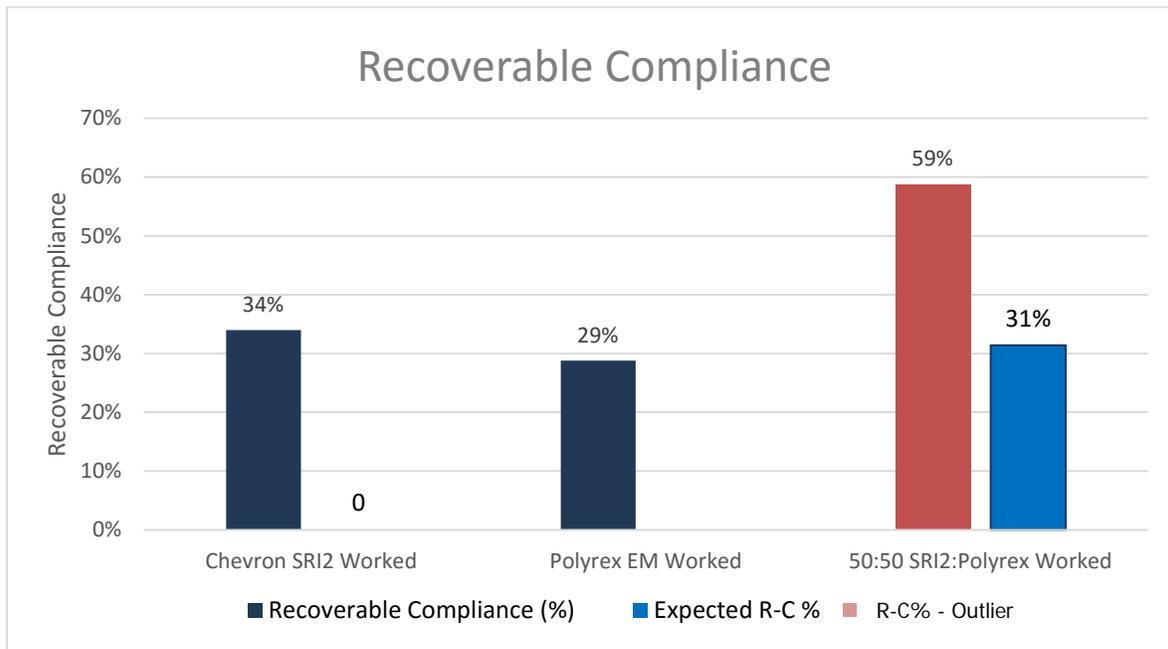


Figure 8 shows the expected recoverable compliance values and the actual recoverable compliance values for the 50:50 mixture of Chevron SRI Grease 2 to Mobil Polyrex EM and the reference greases.

In this case, each of the values of the 50-50 mixture is significantly different than the expected numerical average of the unmixed products. This demonstrates a change in properties due to mixing, and raises a concern about this mixture's performance in the long-term. It could be expected that this mixture could be subject to softening, some oil separation, and a tendency to channel when allowed to

persist in a mixed state in the motor housing. For this reason, this mixture was not permitted for this customer site, and the decision was made to keep two greases in place at the facility, until a future time when the motors could be removed and thoroughly cleaned of the existing product.

Strategies to Minimize Mixing Effects

It can be difficult to avoid mixing of greases altogether in a plant environment, but there are several steps that can be taken to minimize the impact and likelihood of mixing of incompatible greases.

Step 1: Provide clear guidance

All personnel involved in applying greases to equipment should be trained and receive instructions on the proper product to use on each piece of equipment and location. This includes employees and contractors that may be working in the facility. Provide labels and color codes where possible to minimize confusion.

Step 2: Involve purchasing in grease specification

A common area for grease mixing is in new and rebuilt equipment. Even when all plant personnel are given clear guidance and adhere to the correct products, equipment can be returned to the facility with a grease that is different than what will be added while in service. And new bearings, gears, motors, etc., often come supplied with a product incompatible with the grease being used to relubricate.

Step 3: Consolidate lubricants

Identify the minimum number of products required to meet the design of equipment in use in the facility, and consolidate to that number. Do not stock additional products for convenience or brand loyalty. This increases likelihood of mixing.

Step 4: Test potential mixtures

If the wrong grease has been inadvertently added to a machine, or a consolidation is required that will transition the use of a product in a machine, perform simulated mixing and working of the mixtures, and dynamic properties testing to evaluate the mixture's performance. For those mixtures which prove to be incompatible, the extra effort must be taken to thoroughly clean all traces of grease from the housing, supply lines, and bearings/gears to ensure long life and reliable operation of the machinery.

Grease compatibility charts may seem a convenient and easy way to make decisions based on actual or potential grease mixing. However the unreliability of these charts, and the complex interaction of base oils, additives and grease thickeners require that a more certain approach is taken to ensure optimal equipment performance. The effort taken to avoid mixtures where possible, and to test mixtures for compatibility issues and take appropriate action, is an investment in reliability that will pay dividends.

¹ Gebarin, Sabrin, "Recommendations for Mixing Greases", *Machinery Lubrication*, June 2006.