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Sullivan, Shane M. ***A Study of Centrifugal Pump Packing For Injection/Injectable Style Packing Glands***

Abstract

The goal of this project is to improve upon the injection style packing formulation that Darley has been using for the past 40 years in the centrifugal fire suppression pumps they manufacture. Packing is a soft or fibrous material that is compressed within a gland to create a seal around the rotating pump impeller shaft to keep water from entering the gearcase. Injectable packing can be installed and compressed through a port in the gland, without pump disassembly. The current Garlock style 926-AFP injection packing that Darley has been using has had quality and inconsistency issues for a number of years. It also contains a large amount of lead (approximately 55 to 65 percent of its weight) which has a good chance of being regulated because of the hazards it poses to people in contact with it. The purpose of this study is to come up with a replacement for the Garlock style 926-AFP that will perform better than the current product, and does not contain any hazardous materials.

After researching lead-free packing formulations from companies such as Garlock, Chesterton, John Crane, US Seals, and American Seal & Packing it was determined that products from Garlock and Chesterton fit the requirements for a replacement. The determining factors were speeds, pressures, and the ability to be compressed into pellet form (so it can be installed, without an injection cartridge, which is similar to a grease gun). The Chesterton CMS 2000 and lead-free Garlock packings were then tested and observed through the use of a testing fixture and Darley pump. Performance was specifically measured by the packing's ability to show consistent drip rates through a wide variety of speeds, pressures, and start-stop testing.

The leadless Garlock performed favorably in some situations, but did not hold together under higher pressures. So it was concluded that the lead in the Garlock packing is present to

hold the packing together. The Chesterton CMS 2000 packing outperformed both the current and leadless Garlock formulations. It is suggested that Darley take the next step and come up with a plan to switch to the Chesterton CMS 2000 injectable packing.

Acknowledgments

First and foremost I would like to thank my family for the support that I have received through not only this research but the last two years of Graduate school. This was motivation not to quit, but continue on when there seemed to be no end in sight. I would also like to thank my colleagues at Darley who were willing to work with me on testing, problems, and any requests that seemed pointless at the time but in the end led to a thesis that was a learning experience for me and the company.

Table of Contents

List of Tables

List of Figures

Chapter I: Introduction

W.S. Darley is a manufacturer of centrifugal fire pumps and accessories. Impeller shaft seals are subjected to extreme performance demands, including shaft speeds of up to 10,000 rpm, pressures up to 600 psi, and vacuum conditions during priming, while being forgiving enough to allow a small amount of water through to dissipate heat from the shaft. Darley uses an injection packing, (interchangeably referred to in the pump industry as injectable packing) for impeller shaft seals. This is a fibrous material that flows into a packing gland and forms a tight seal around the shaft. Most injection packings are installed by the use of an injection cartridge, which is similar to a grease gun. Darley's packing is manufactured into pellets, where it can be placed into a packing gland and adjusted by a screw. An effective alternative shaft sealing method is a mechanical seal, which utilizes a spring to hold two silicon carbide faces together. Injection packing is often preferred because it is easier to replace and adjust in the field.

The injection packing used in Darley pumps with stuffing boxes is supplied by Garlock. It consists of lead, acrylic fiber, grease, and various other materials listed on the MSDS sheet found in Appendix A. It comes from the manufacturer loose in a bag (see Figure 3 for reference), and is compressed into pellets by a machine. This is done by inserting the packing into a fixture which utilizes multiple air cylinders and timers to compress the packing, and shoot it into a container. See Figure 2 for a picture of the injectable packing in pellet form.

Figure 1

Darley Pump and Gearcase Cross Section

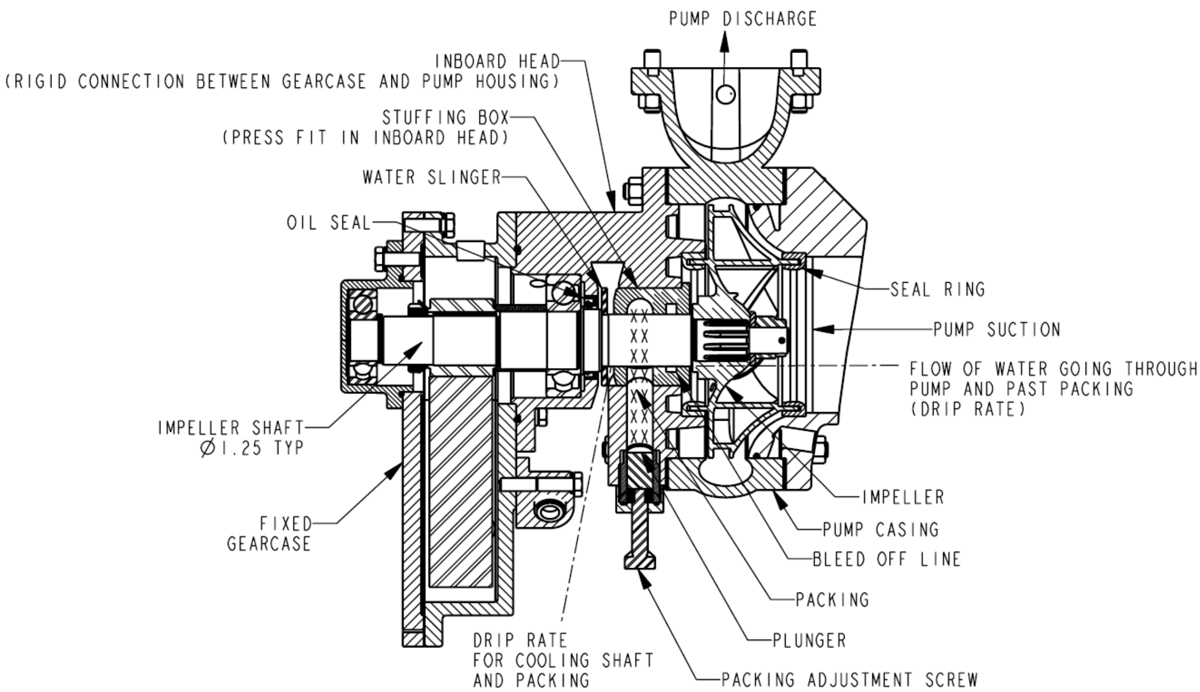


Figure 2

Packing Pellet

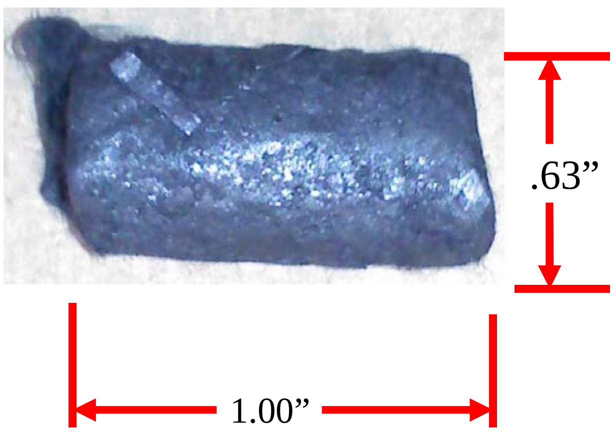


Figure 3

Loose Bulk Packing

The packing pellets are inserted into the stuffing box of the pump through a 5/8” hole until no more pellets can be inserted by hand. The packing screw is then inserted and screwed in all the way. More pellets are inserted into the packing hole until 24 in-lb of torque can be felt, without bottoming out the adjustment screw. The final packing adjustment must be made when the pump is running.

The packing creates a seal around the impeller shaft so water cannot enter into the gear case. This seal is designed to leak a small amount so that the shaft will remain cool and lubricated. This is generally referred to as the drip rate, which in the case of the Garlock packing, is between 6 and 60 drops per minute at operating speeds and temperatures. Through the life of the pump, adjustments will need to be made whenever the packing is dripping more than 60 drops per minute. Adjustments can be made while operating the pump until the packing gland adjustment screw has reached the end of its travel. At this time the pump must be shut down and a new pellet added. For complete instructions see Appendix B Darley Injection Type Stuffing Box Adjustment.

Figure 1 Darley Pump and Gearcase Cross Section shows the flow of water through the pump end of a Darley configuration. Water enters the suction side of the pump and is pressurized by the rotating impeller. The impeller is driven by the impeller shaft, which is driven by the gearcase, and engine it is attached to. The stuffing box, which holds the packing, is pressed and Loctited into the inboard head or pump casing, depending on the model of pump. The stuffing box, which is made from brass bar stock, includes a semicircular 5/8” groove for packing, and a smaller square 3/16” groove which diverts water back to the suction side of the pump, reducing pressure. Immediately after the stuffing box on the gearcase side is a synthetic water slinger designed to throw any water travelling down the shaft away from the gearcase. (This is only necessary when the packing is out of adjustment and dripping more than 60 drops per minute). The drip rate is determined by counting the drops coming out the gearcase side of the stuffing box, illustrated in Figure 1. For a complete cross sectional drawing, and typical gland and shaft dimensions refer to Appendix C.

Through the years Darley has had quality issues with the Garlock Style 926-AFP injection packing. The quality issues involve inconsistencies between batches. Some batches are wet, some are dry, and some have different concentrations of lead. The inconsistencies have proven problematic when the concentration of lead is not correct. When the consistency of lead is not correct the packing will either not stabilize, because of voids (See Figure 4), or the packing will glaze over from being too hot. In the case of a packing failure, the pump is disassembled, the parts are inspected, and the packing is analyzed. In most cases the machined parts are in tolerance, and there are high concentrations of lead on the inside diameter of the packing ring. If all of the parts are within their specified tolerances, and the testing is done by a certified test technician, it can be concluded that the failure was caused by the concentration of lead.

Since Darley is the only company to use this style of packing it is suspected that the inconsistency issues are caused by the manufacturing process. As Garlock has explained it, the materials are put into a machine that mixes the packing for an extended period of time. Since Darley is the only customer for this formulation, it is safe to assume that the mixer is not solely used for Style 926 AFP. If the machine is not cleaned out properly between batches, there will be contamination which may explain why consistency differs between batches.

Another concern is that the recipe for making it is nearly 50 years old, and has not taken advantage of material advances in the last half century. The presence of lead flakes in a fibrous loose bulk material is a concern, because there is no way of ensuring that the same amount of lead is present in each pellet, and in turn each stuffing box. Failures have occurred when there is too much or too little lead present. These failures include packing that will not stabilize because of voids in the gland (See Figure 4), or glazing due to high lead concentrations. Packing's have been a recurring problem for Darley for quite some time but; it receives little attention because the failures happen only occasionally.

When the packing is out of adjustment or the consistency is not correct, the pump will not perform as designed. If packing is dripping more than desired the pump will not hold vacuum and it will leak excessively causing a loss in performance there is also a greater chance of water entering the gearcase. It has been proven through testing that when the consistency is not right, the adjustment screw is over tightened, or the pump is operated without water, the friction between the impeller shaft and packing will generate a great amount of heat causing the packing to burn up. Although some of these factors include operator error, packing quality and consistency play a major role. Since the Garlock style 926-AFP has a tendency to exhibit failures, it would be beneficial for Darley to find a replacement.

Darley does not have an acceptance standard for packing material. The material consistency varies from batch to batch; some wet, some dry, some has more lead flakes, etc.

There are obvious steps that could be taken to create a standard, including setting up density control limits and weighing batches of pellets to ensure the correct amount of lead is present. But with Darley manufacturing over 35,000 pellets each year this process would be time consuming and expensive; and it would produce a large amount of defective pellets that would have to be reworked or scrapped. Other reasons that Darley does not want to develop a standard for the current Garlock formula, is that they would like to explore new materials and products that can be produced in larger batches, with the goal of finding a more consistent product.

Statement of the Problem

Finding a replacement injection packing without lead and the obvious variability problems experienced with Garlock's current formulation that will accommodate shaft speeds of 3000 fpm and pressures over 600 psi. This would increase the quality and life of the centrifugal fire fighting pumps Darley manufactures.

Purpose of the Study

The purpose of this study is to gather information for a replacement lead-free injection packing from various manufacturers. It has been concluded that lead flakes and the manufacturing process for Garlock Style 926-AFP causes inconsistencies while being hazardous. Candidates for a replacement will be accessed by a number of criteria, including speed ratings, compressibility, pressure ratings, and the lack of hazardous materials. Once this criteria has been satisfied, side-by-side testing will be performed in a test fixture. If results are promising actual pump testing will be performed to see if the product is a viable replacement.

Assumptions of the Study

W.S Darley has been using injection style packing since the 1930's and the same company has been making it for Darley since the 1960's. There are some assumptions and guidelines to follow while conducting this research. The first and most important assumption is that although there are alternatives to packing pumps, such as mechanical seal pumps, Darley wants to continue offering packing style pumps. The second assumption is that there are Darley pumps still in service that were manufactured in the 1930's, so any standard or new type of packing must work with that design. An assumption that must be made is that Darley will be able to handle, package, and manufacture the bulk material into pellets so they can be shipped and will fit into the fill hole on the stuffing box.

Definition of Terms

Injection Packing. Plastillic (also spelled Plastallic) material used to create a seal around a shaft to prevent water from moving past it while lubricating the shaft.

Centrifugal Pump. A rotodynamic pump that uses an impeller to increase the velocity of a liquid.

Mechanical Seal. A device which helps join systems together by preserving pressure and preventing leakage.

PSI. Pounds per square inch.

GPM. Gallons per minute

Packing Gland. Area within a pumping system between the pump casing and drive system which holds a malleable compound that creates a seal around the impeller shaft.

Prime. Process of creating a vacuum in a pump, so water can be lifted to the impeller.

Packing. Fibrous malleable material which is compressed into a gland to create a dynamic seal around the impeller shaft of a pump.

Plastillic. Also spelled Plastallic, which is a term used by Garlock to describe the physical appearance of their packing. A malleable plastic-like material.

Draft. Use of a suction to move a liquid from a body of water below the intake of the pump.

Limitations of the Study

Limitations to the research are that Darley will not be redesigning nor doing anything different mechanically. The reason is that it would not be retro-fittable, and since packing is a wear item it would be a costly and difficult transition. No comparisons will be made to mechanical seals as this is a completely different type of seal, and Darley wants to continue offering packing pumps.

Management has also set limitations. Building and testing pumps is expensive so all testing and R&D must first be approved by management.

Methodology

Research will be conducted on various types of packing’s and manufacturers. If a product meets the speed requirement of 10,000 RPM, it can be compressed into pellet form, and lacks hazardous materials samples can be brought in and tested. Since visual inspection is difficult and can be inconclusive, physical testing will be conducted. Physical testing will be performed in a testing fixture as well as various pumps. Testing in pumps will be performed to NFPA requirements for pressure, flow, and vacuum; the drip rate and functionality will be recorded throughout the tests. NFPA testing requirements state that a pump must meet its rated capacity (flow) at 150 PSI, and half its rated capacity at 250 PSI. It also states that the pump must obtain and hold certain vacuum levels for a period of time which is measured in inches of mercury. Destructive testing will also be performed to simulate operator error, to ensure damage is minimal, and make sure there is no danger to the operator when a failure occurs. A conclusion will be drawn from testing to see if there is a viable packing to replace the current Garlock style 926-AFP. These conclusions will be presented to management for direction on how Darley would like to proceed.

Chapter II: Literature Review

Centrifugal Pump Packing

In centrifugal pump design there is a need for a seal between the pump casing and the gear case. The seal is in place to ensure that the substance being pumped does not enter into the gear case or driver causing failures of the gears, bearings, shafts, and oil seals. There are two types of seals that have been recognized as being durable and efficient; a mechanical seal and a packing material.

There are many types of packing and the most common for rotating equipment is compression packing, which includes rope packing and injectable packing (Netzel, 2001). The seal is formed by the packing being squeezed into the stuffing box on the inboard side of the pump through an injection port into a gland, which is then tightened by a gland nut. From there a static seal is created from the sides of the packing ring and the inside diameter of the stuffing box. A dynamic moving seal is formed between the packing and the shaft. When loaded the packing deforms around the shaft controlling the amount of leakage. Although some leakage is necessary to lubricate the shaft, a seal is required so that the pump can hold vacuum (Netzel, 2001).

There are various kinds of compression packing and compression packing manufacturers, the most common being injectable and rope packing. They each have their own particular positive and negative attributes. This research paper focuses on injection packing, and the positive and negative attributes of it's use in Darley centrifugal fire suppression pumps. Darley currently uses Garlock style 926-AFP injection packing which has a history of inconsistencies. This research provides the information necessary to replace the current Garlock packing with a packing that is mass produced and lacks hazardous material.

Review of Pump Packing and Processes

There are many factors that affect the serviceability and functionality of packings', such as the chemical makeup. Carbon or very hard materials are good to minimize friction and wear, although flexibility must be provided so the seal faces can accommodate misalignment, thermal distortion, and shaft runout (Tuzson, 2000). In the early days of centrifugal pumps and packing, asbestos was used as one of the main ingredients. Asbestos is no longer available and now packing can be grouped into three categories: Non-asbestos packing, Flexible graphite, and Metallic packing (Netzel, 2001).

Manufacturers such as Garlock, John Crane, and Chesterton, use different formulas for creating their packing, although they are used for the same purpose. Garlock (Garlock, 2008) and Chesterton (Chesterton, 2009) are two companies that have injection packing that suits Darley's stuffing box design. The following table (Table 1) shows the comparisons of the main ingredients in their respective injection packings.

Table 1

Types of Injection Packing

Company	Main Materials	Hazardous	H20 Solubility	Physical state
Garlock	Lead, grease, Kaolin, Graphite, Acrylic Fiber	Eyes, skin, ingestion, inhalation	Negligible	Semisolid Gray/Black Plastallic
Chesterton	Talc, fibers, others unlisted.	Not serious. Inhalation, Eyes	Slight	Putty like, White

Although it is hard to distinguish good packing from bad packing without operating the pump, the packing must be flexible enough to flow into the stuffing box and create a seal dynamically around the inside diameter of the stuffing box, with few or no voids, while creating a dynamic seal around the shaft with no voids that can accommodate for misalignment and runout (Tuzson, 2000). The design is also important in that it balances the pressure forces on the stationary and rotating faces which in the case of a centrifugal pump would be the impeller shaft.

Unfortunately most packing failures and inconsistencies are not found until the pump has failed. Netzel, 2001 describes the major failures from defective packing and the cures to fix this problem. This information is located in the following table (Table 2).

Table 2

Trouble Shooting Injection Packing Problems

Trouble	Cause	Cure
No Prime	Packing loose or defective	Tighten or replace packing
Not enough/looses prime	Packing loose or defective	Inspect shaft, tighten or replace packing.
Pump pressure low	Packing is defective	Replace packing
Leaks excessively	Defective or loose packing or wrong type of packing	Tighten packing if it continues replace packing
Stuffing box overheats	Defective packing, packing too tight, wrong packing	Release gland pressure; if it continues replace packing.
Packing wears to fast	Defective packing, wrong packing,	Replace packing

Pump takes too much horse power	Packing too tight or wrong type of packing	Release gland pressure if it continues replace packing.

These are problems that occur from either defective, improperly installed, or the wrong type of packing. It is also recommended that the surface finishes of the components in direct contact with the packing be checked as well (Netzel;2001).

Since packing is a mixture of various types of raw materials and chemicals, there are many things that could lead to less than desired consistency. As many of these products are not produced in large batches, human error can be a factor. Human errors can be outlined into four categories (Attwood, 2007).

- *Slips* are when there is faulty action execution or actions do not happen as planned. An example would be that the operator knows what they are supposed to be doing but somewhere along the way it just doesn’t happen as it should.
- *Lapses* are associated with failures of memory. The operator knows what they are supposed to do although a step or part is omitted or repeated. This is often associated with almost automatic or routine tasks.
- *Mistakes* are when the execution is perfect but the plan or process itself failed to meet the objective.
- *Violations* are situations when the operator deliberately carries out actions that are contrary to the rules or procedures for the plan or process. This is often a case when the plan is out of date, the operator feels that the plan is not important, or the operator feels they have a better way of doing the task.

Chapter III: Methodology

One of the main components that dictate whether a centrifugal pump will perform to its potential, or fail causing major damage, is the seal around the impeller shaft. Although there are many types of seals, this research deals with a common seal known as injection packing. Injection packing is a fibrous material consisting of various materials such as acrylic fiber, lead, grease, and bonding materials. The nature of the product makes it hard to distinguish good packing from bad packing with usual inspection methods at pump manufacturers and municipalities. For the past 50 years, Darley has been using Garlock style 926-AFP. During this time, Darley has seen periods of failures and inconsistencies in the product. However, it is to be used as a benchmark in testing because it is what is currently supplied. The following will illustrate how packing was selected, tested, and analyzed so that conclusions could be drawn to find a viable replacement.

Subject Selection

Although there are numerous companies manufacturing packing and sealing products, only two have met Darley's criteria for a viable replacement. A major reason for this is because injection packing is not used widely in pumps. Most manufacturers of pumps use either rope packing, which is very similar to injection packing, or a mechanical seal, which creates a seal using machined parts. The injection packing is a great selling point for Darley because of the ease of packing and adjustment, in comparison to rope packing and mechanical seals which require complete disassembly.

Another factor that eliminates many of the other products is the speed the packing can handle. Many of the packings available can only handle around 1500 feet per minute (fpm). For

Darley this would not be acceptable because some of the shafts are turning at more than 3000 fpm.

From research and contact with vendors it was determined that there are two possible replacements that would fit the criteria of compressibility, speed, and price. The first of these is not a new product but a revision of the existing Garlock style 926-AFP with the lead removed. There is currently no way of controlling the amount of lead per pellet. When too much lead is present it creates voids in the sealing surface, allowing excessive leakage. For examples of these voids, see Figure 4.

Figure 4

Packing Voids Created by Lead Flakes

The next product that meets the criteria for a replacement is a product from AW Chesterton named CMS 2000. This product is a white fibrous material composed of acrylic fibers, talc, and other unlisted materials. This product can be compressed into pellets (see Figure 5) and given the speeds and stuffing box dimensions, the company was able to rate this at 3000 FPM. The company was also able to confirm that an injection cartridge would not need to be used, and the packing screw that Darley uses would be sufficient for packing the pump. These two products will be put through a multitude of tests so conclusions can be made to determine which is a viable replacement.

The other products that were looked at from companies such as John Crane, US Seals, and American Seal and Packing were found to be unacceptable. The companies were unable to verify that the product would work effectively if the injection cartridge was not used. Some of the products were also not capable of the required speed of 3000 fpm or pressures of 600 psi.

Figure 5

Chesterton CMS 2000

Instrumentation

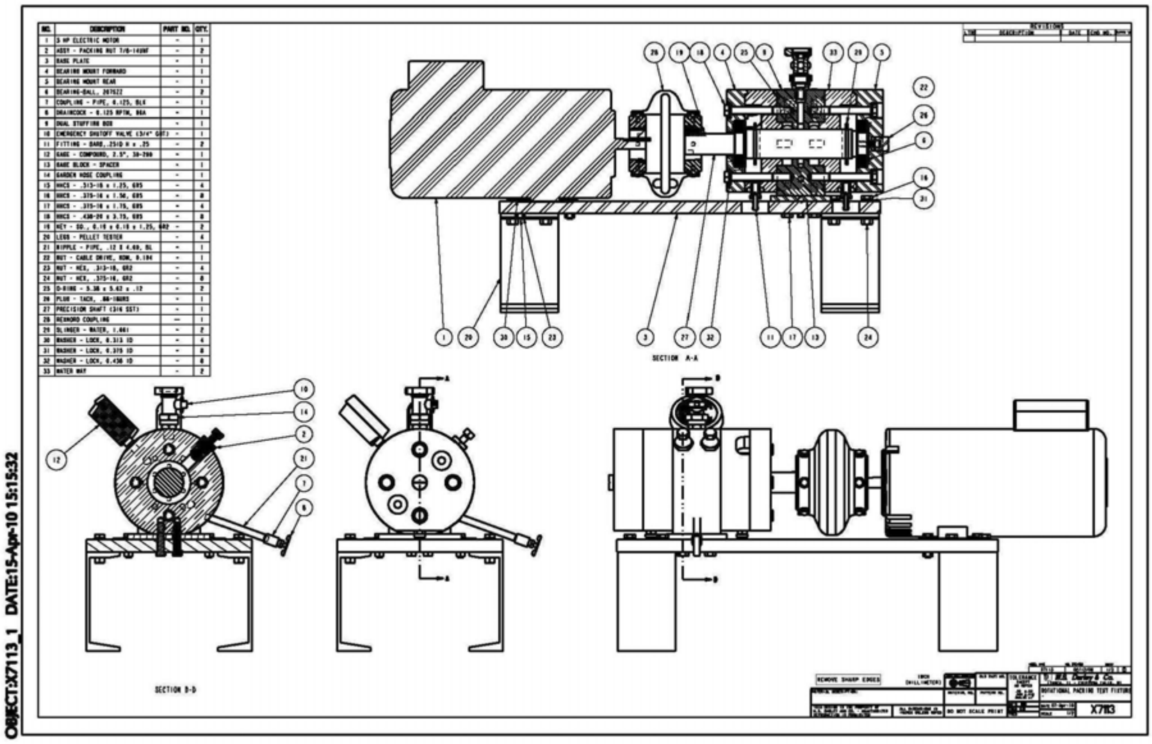
As packing is a product that is not easily inspected by typical inspection methods, testing will be the means for validating the products. This testing will be benchmarked against the Garlock style 926-AFP.

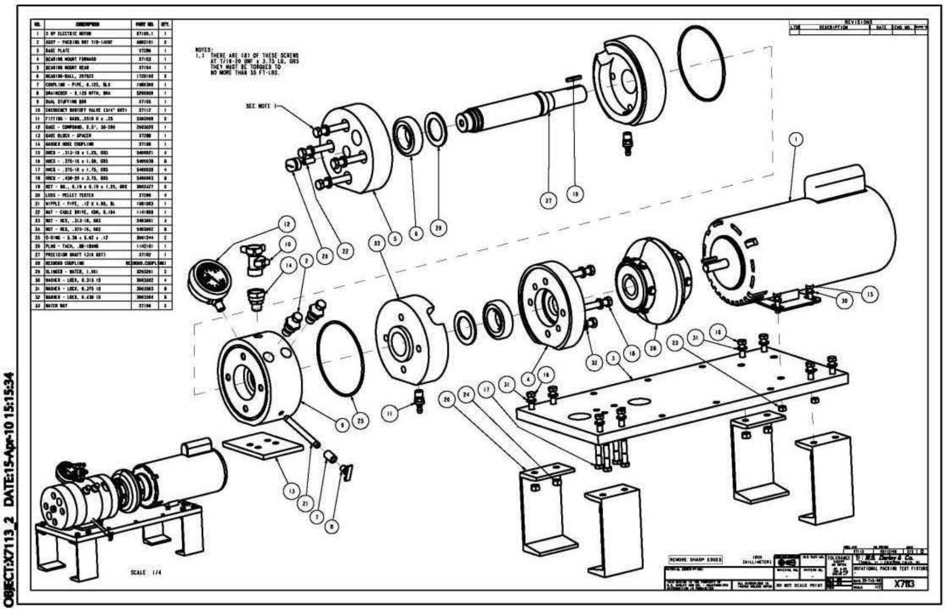
Testing packing in an actual pump will be the most accurate representation of how it will be used in the field. To do all testing in a pump is not cost effective, so a fixture has been designed to do preliminary and duration testing on the packing. Once a product performs favorably in the fixture it will be tested further in a pump, which will simulate real life applications.

The test fixture consists of a five horsepower (hp) electric motor that drives a simulated impeller shaft. The impeller shaft is modeled from a Darley pump and will be surrounded by a water chamber, two simulated stuffing boxes, and two water chambers on the output side of the stuffing box that will capture water leaking through the packing. This process allows for visual inspection of the shaft and components during operation. The impeller shaft is supported on either side of the shaft by shielded ball bearings and bearing blocks. The fixture is supplied water through a garden hose connected to the main water chamber that is surrounded by the dual stuffing boxes. A pressure gauge is plumbed to the internal water chamber so that pressures can be recorded during testing. There is also a drain which is cracked during operation to simulate the flow of water in a pump and to dissipate heat. When adjusted to Darley's standards the stuffing box allows a drip rate of 6 to 60 drops per minute. The water which passes through the packing will be captured in the outboard water chambers and drip though the ports drilled in the bottom; this is where the drip rate can be recorded. The water slingers are in place to protect the bearings from receiving a direct water splash from water traveling down the shaft. For a cross sectional and exploded view drawing refer to Figure 6.

Figure 6

Rotational Packing Fixture





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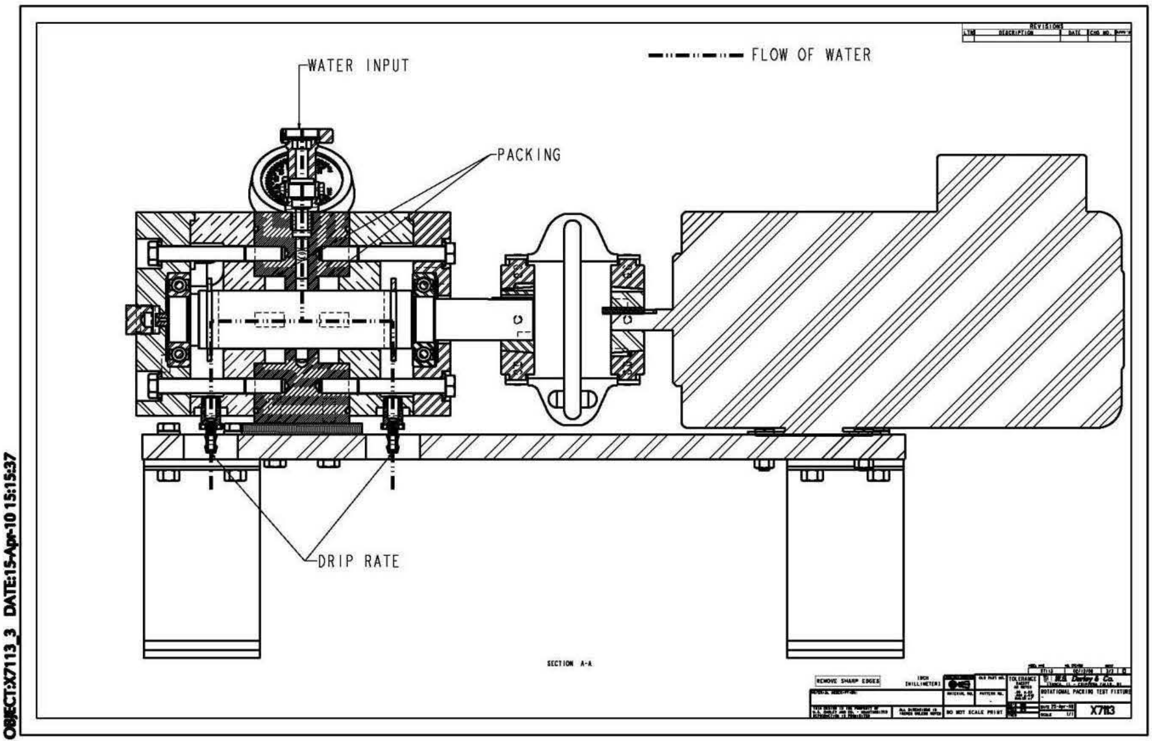

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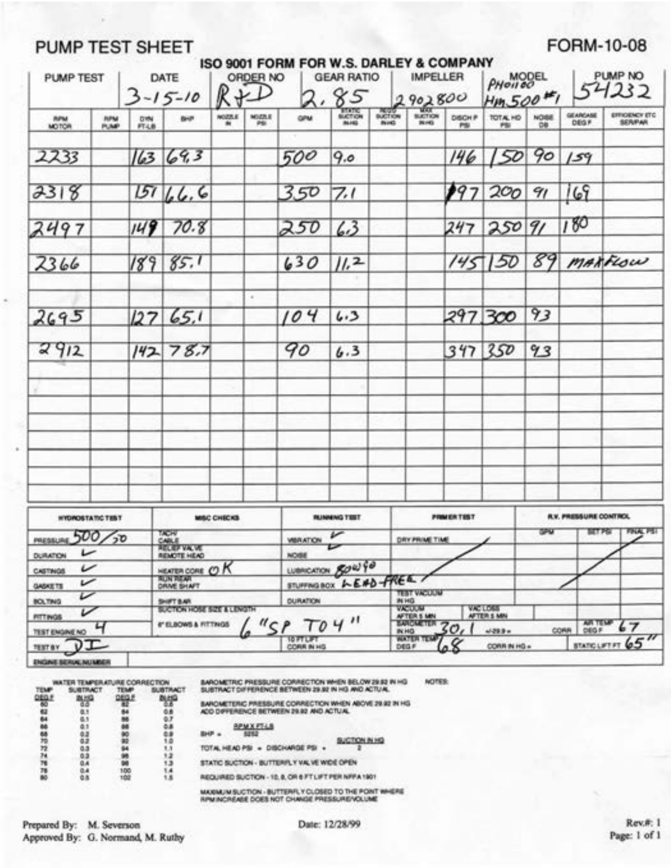
In order for the packing to be tested in a pump, the packing must perform well in the fixture, in comparison to the current style of packing. Pump testing will be performed to NFPA standards that are applicable to the style pump it is used in. In this case the pump that will be used is an HM. This is a very popular and versatile pump that can achieve moderate flows and above average pressures. NFPA states that a pump must pass a hydrostatic pressure test at double the rated pressure, and must pass a vacuum test. NFPA also states that the pump must be tested to 100% of its rated capacity at 150psi, 70% of its capacity at 200psi, and 50% of its capacity at 250psi. The testing will be conducted as follows;

- Hydrostatic pressure test to 500 psi
- Vacuum test
- 30 minutes at rated performance in this case 150psi @ 500gpm
- 15 minutes 200psi @ 350gpm
- 15 minutes 250psi @ 250gpm
- Max flow at 150psi

If the packing has passed the NFPA testing which will be defined as a consistent drip rate at each test condition, further testing can be done at more extreme limits that will generally not be used often or ever in the field. This will include a test at the maximum pressure of the pump which is 350 psi in this case. See Figure 7 for sample test sheet.

Figure 7

Test Sheet



PUMP TEST SHEET FORM-10-08

ISO 9001 FORM FOR W.S. DARLEY & COMPANY

PUMP TEST	DATE	ORDER NO	GEAR RATIO	IMPELLER	MODEL	PUMP NO
	3-15-10	R+D	2.85	2902800	PH01100 HM500 #1	54232

RPM MOTOR	RPM PUMP	DYN FT-LB	BHP	NOZZLE IN	NOZZLE PSI	GPM	STATIC SUCTION IN HG	REQ'D SUCTION IN HG	MAX SUCTION IN HG	DISCH P PSI	TOTAL HD PSI	NOISE DB	GEARCASE DEG F	EFFICIENCY ETC SER/PAR
2233		163	69.3			500	9.0			146	150	90	159	
2318		151	66.6			350	7.1			197	200	91	169	
2497		149	70.8			250	6.3			247	250	91	180	
2366		189	85.1			630	11.2			145	150	89	MAX FLOW	
2695		127	65.1			104	6.3			297	300	93		
2912		142	78.7			90	6.3			347	350	93		

HYDROSTATIC TEST	MISC CHECKS	RUNNING TEST	PRIMER TEST	R.V. PRESSURE CONTROL
PRESSURE 500/50	TACH/CABLE	VIBRATION ✓	DRY PRIME TIME	GPM / SET PSI / FINAL PSI
DURATION ✓	RELIEF VALVE REMOTE HEAD	NOISE ✓		
CASTINGS ✓	HEATER CORE OK	LUBRICATION 80W90		
GASKETS ✓	RUN REAR DRIVE SHAFT	STUFFING BOX LEAD-FREE		
BOLTING ✓	SHIFT BAR	DURATION	TEST VACUUM IN HG	
FITTINGS ✓	SUCTION HOSE SIZE & LENGTH		VACUUM AFTER 5 MIN / VAC LOSS AFTER 5 MIN	
TEST ENGINE NO 4	6" ELBOWS & FITTINGS 6" SP TO 4"		BAROMETER IN HG 30.1 +/-29.9 = CORR	AIR TEMP DEG F 67
TEST BY DI		10 FT LIFT CORR IN HG	WATER TEMP DEG F 68 CORR IN HG =	STATIC LIFT FT 65"
ENGINE SERIAL NUMBER				

WATER TEMPERATURE CORRECTION

TEMP DEG F	SUBTRACT IN HG	TEMP DEG F	SUBTRACT IN HG
60	0.0	82	0.5
62	0.1	84	0.6
64	0.1	86	0.7
66	0.1	88	0.8
68	0.2	90	0.9
70	0.2	92	1.0
72	0.3	94	1.1
74	0.3	96	1.2
76	0.4	98	1.3
78	0.4	100	1.4
80	0.5	102	1.5

BAROMETRIC PRESSURE CORRECTION WHEN BELOW 29.92 IN HG SUBTRACT DIFFERENCE BETWEEN 29.92 IN HG AND ACTUAL

BAROMETERIC PRESSURE CORRECTION WHEN ABOVE 29.92 IN HG ADD DIFFERENCE BETWEEN 29.92 AND ACTUAL

BHP = RPM X FT-LB / 5252

TOTAL HEAD PSI = DISCHARGE PSI + SUCTION IN HG / 2

STATIC SUCTION - BUTTERFLY VALVE WIDE OPEN

REQUIRED SUCTION - 10, 8, OR 6 FT LIFT PER NFPA 1901

MAXIMUM SUCTION - BUTTERFLY CLOSED TO THE POINT WHERE RPM INCREASE DOES NOT CHANGE PRESSURE/VOLUME

NOTES:

Prepared By: M. Severson
Approved By: G. Normand, M. Ruthy

Date: 12/28/99

Rev.#: 1
Page: 1 of 1

Data Collection

The rate at which a packing may leak without consequences is defined as 6 to 60 drops per minute. If it is less than 6 drops per minute there is a possibility of overheating the shaft and causing bearing and shaft failure. If it is more than 60 drops per minute the pump will not perform to its capabilities, and has the possibility of losing vacuum.

When doing testing in the packing fixture the operator will insert packing into the stuffing box and record the amount of pellets used. The operator can then adjust the packing by tightening the packing gland until the two packing glands have the same drip rate which will be between 6 and 60 drops per minute. The operator is also to take notes, as to how well the packing stabilized and the number of adjustments made. Once the packing is adjusted the operator will take measurements as to how much the packing is dripping every 30 minutes for the duration of the test. Obviously a better packing will hold a consistent drip rate for the longest period of time. Another test to be performed is to stop the motor after the packing has been running for a period of time, wait for one minute, then start the engine again. In normal pump operation the packing should return to the same drip rate as it had before being shut down. So the operator will know what the drip rate is before shutdown and what the drip rate is after restart and how long it takes to stabilize or return to the previous drip rate.

The pump test will be conducted to NFPA conditions which are shown in Figure 5. Besides the analysis that is done with every pump test, the operator will be monitoring the drip rate and taking readings at the beginning of each new test point and periodically throughout the test. The operator will also be analyzing the amount of adjustment required for the packing to become stable at the beginning of testing, and recording any changes or occurrences that are out of the ordinary for a typical pump test with standard packing. This could include high horsepower or packing being pushed out of the stuffing box.

Limitations

Given the extensive product line that Darley offers, the packing will not be tested in every pump. Most of Darley’s products are custom ordered so anything built for testing would need to be reconfigured to suit the customer’s needs. This would expensive and would result in a large stock of pumps that may not be ordered for a long period of time.

If all testing is favorable for the two types of packing there may be further testing in a worst case scenario pump, which would be the U4 which is capable of producing 1500psi @ 60gpm while spinning over 12000 rpm. Since our standard packing does not hold up to this pump it would not be a good benchmark but instead an extreme test that would confirm the packing is far superior.

Another limitation is that destructive testing will not be performed unless either of the new packings show great potential of being superior to the Garlock 926-AFP. In the case that one of the packings is a superior product, a test of over tightening the adjustment screw will be performed to show how the packing reacts, and a test in which the pump is ran without water to see how long the packing will last and what the failure mode is.

Summary

The testing that will be completed in this study will give Darley a good feel of whether or not there are any products being produced that could replace the current packing that is being used. Testing our current packing and the current packing without the lead will give us some insight as to why the lead is present. With the recipe being over 50 years old Garlock has not been able to give a reason why the lead is present, or if it will function as intended without the lead.

The research being done will be a stepping stone as to what is available and how Darley should move forward with testing, researching, and future product lines that will hopefully lead to a more consistent reliable product that is environmentally friendly.

Chapter IV: Results

Through research and testing several questions were answered. One product showed great promise as a future replacement for the Garlock Style 926-AFP. The purpose of the extensive research and testing performed on such a small part of a pump is the functionality it provides to the entire pump system and the repercussions of a failure in packing.

Finding a replacement for the packing in Darley centrifugal pumps was the main goal but the research and testing gave many insights into how packing works and what doesn't work. The metric used to describe the packing is the amount of water allowed to pass through the packing and drip out the outboard side of the packing gland while maintaining vacuum, performance, and cooling of the shaft. This is referred to as the drip rate. This seal allows the pump to draft water and hold suction so it can continue getting water, which will in turn maintain the desired performance.

The data was collected through a multitude of tests and benchmarked against the current packing as this is the standard that is used as of now. These tests included testing in a rotational packing fixture which allowed the researcher to conduct side by side testing for a long period of time, cost effectively. Once promise was shown in the initial testing using the test fixture, the packing's were subjected to multiple tests in a Darley pump to simulate operation in the field. Data was also collected from individuals in the test room and assembly, to get some insight into how easy or difficult it would be for a customer to replace or adjust the packing in the field.

As explained above, the data received was categorized into three sections which will first be looked at independently in this section and then as whole. This is done to see which product would be a viable replacement for the standard. The information will then be given to management with recommendations on how the researcher feels the company should proceed.

Rotational Packing Fixture

All analysis and testing is to be benchmarked against the Garlock Style 926-AFP as this is the current standard. With the rotational packing fixture utilizing two packing glands, the testing involved filling one gland with the Garlock Style 926-AFP and the other with the new product that was to be tested.

The first test involved packing the fixture with the Garlock Style 926-AFP in one gland and packing the other with the Garlock packing consisting of the same materials but lacking the hazardous lead flakes. The water supply was hooked into the fixture using a standard garden hose faucet. The pressure from the faucet was found to be 50 psi. The packing glands were both filled, each utilizing eight packing pellets. This was expected because the glands were identical and the density of the packing's very similar. The gland nuts were tightened to 2 ft-lb, as specified in the instructions Darley provides their customers for packing a pump.

With everything in place the water was turned on and the drain valve cracked to allow a flow of water through the drain, this simulates the flow of a pump while dissipating the heat. At the start both packings leaked a steady stream of water, which is outside of the recommended 6 to 60 drops per minute. The gland which contained the standard Garlock Style 926-AFP was adjusted first. This allowed the researcher to get a benchmark for approximately how many turns until the packing was in adjustment which was approximately 6 turns. This brought the drip rate to about a drop every 6 seconds or 10 drops per minute, which is in the standard operating range. The new Garlock packing was then adjusted in the same fashion and it was found that it took 7 turns until the packing reached a drip rate of 10 drops per minute. This can be considered very similar, considering the variations in threads of the packing screw and small amount in which the packing screw moves over one turn. The speed of the impeller shaft was recorded at 3,500 RPM, via a tachometer connected to the end of the impeller shaft.

The packing was examined for ten minutes, and the drip rates remained consistent at 10 drops per minute. The fixture was then left to run for four hours and checked every thirty minutes. See Table 3 for results.

Table 3

Garlock Style 926-AFP VS. Garlock Style 926-AFP Leadless

Time	*Garlock Style 926-AFP Drip Rate*	*Garlock 926-AFP Leadless Drip Rate*
30	*10*	*10*
60	*12*	*13*
90	*11*	*9*
120	*10*	*10*
150	*12*	*12*
180	*9*	*11*
210	*10*	*10*
240	*11*	*10*

Judging from this test it was concluded that the new Garlock packing will seal around the shaft and stabilize as well as the standard packing. As Table 3 shows there is some slight variation in the packing throughout the duration of the test although nothing out of the ordinary or alarming.

After the four hour test, the electric motor was shut down and left idle for approximately one hour to see how the packing would react upon restart. The motor was turned on and brought to full speed at 3500 rpm. Both packings leaked at approximately 30 drops per minute at restart, after one minute the Garlock Style 926-AFP stabilized at 13 drops per minute. The leadless Garlock packing stabilized at 14 drops per minute. This restart further proved that the leadless packing is comparable to the standard packing at low pressures in the fixture. To learn any more, testing must be done in a pump rather that the test fixture.

Once the testing was completed the packing fixture was disassembled and cleaned so that the following tests would have no bias of already being run and stabilized. During this period the packing was taken out intact so that the ring which formed around the packing could be analyzed. Figure 2 shows the Garlock Style 926-AFP which as you can see has voids from large concentrations of lead while Figure 8 shows the leadless packing which appears to form a much smoother surface around the shaft. In this case it appears as though the leadless packing provides a more desirable seal against the shaft, although further testing at higher pressures will need to be done to confirm that the leadless packing is indeed superior.

Figure 8

Garlock Style 926-AFP Leadless Packing Ring

This cleaning is also necessary so that there is no contamination between packings which could yield false results.

Once the fixture was cleaned, reassembled, and water lines connected, the stuffing box was packed. In this test the Garlock Style 926-AFP was placed in one gland and the Chesterton CMS 2000 in the opposing gland. It was noted that the gland using the Garlock packing took 8 pellets while the gland using the Chesterton CMS 2000 only took 7 pellets which shows that the density of the CMS 2000 is greater than that of the Garlock, because using the same torque it takes less material to fill the packing gland.

The same procedures were followed to ensure there was no bias from testing. Again, the Garlock packing took approximately six turns to be stabilized at 10 drops per minute, however the CMS 2000 packing only took two turns to become stable at 10 drops per minute. This quick stabilization was noted and will be a great attribute if this quick adjustment can be duplicated in a pump. This would save copious amounts of time and frustration for assemblers, test room technicians, and customers.

The fixture was again observed for 10 minutes to ensure that the packing was indeed stable and the fixture was running as designed. The fixture was then left running for four hours during which readings were taken every half hour. See Table 4 for results.

Table 4

Garlock Style 926-AFP VS Chesterton CMS 2000

Time	*Garlock Style 926-AFP Drip Rate*	*Chesterton CMS 2000 Drip Rate*
30	*10*	*10*
60	*11*	*11*

90	*13*	*10*
120	*10*	*10*
150	*10*	*9*
180	*11*	*11*
210	*12*	*10*
240	*10*	*10*

After analyzing the test data it was determined that the Chesterton had a more consistent drip rate throughout the four hour run test in the Rotational Packing Fixture. As with the previous test the electric motor was shut down and allowed to sit idle for one hour. After the hour the electric motor was started and run up to the operating speed of 3500 rpm. The Garlock packing was dripping at approximately 25 drops for a minute, after which it stabilized to 13 drops per minute. The CMS 2000 packing stabilized almost immediately to 11 drops per minute and continued there for 10 minutes. The instant stabilization, constant drip rate, and ease of adjustment showed that the CMS 2000 has great promise and should be tested further in a pump.

With testing in the fixture complete, the fixture was disassembled so the packing rings could be examined (see Figure 9)

Figure 9

Chesterton CMS 2000 Packing Ring

The packing ring created by the Chesterton CMS 2000 shows a very smooth inside diameter without voids, meaning that the seal around the shaft is without voids and should be more consistent in a pump versus a packing that has voids and inconsistencies which cause excessive leaking and loss of performance. Note that the black color is due to handling after testing.

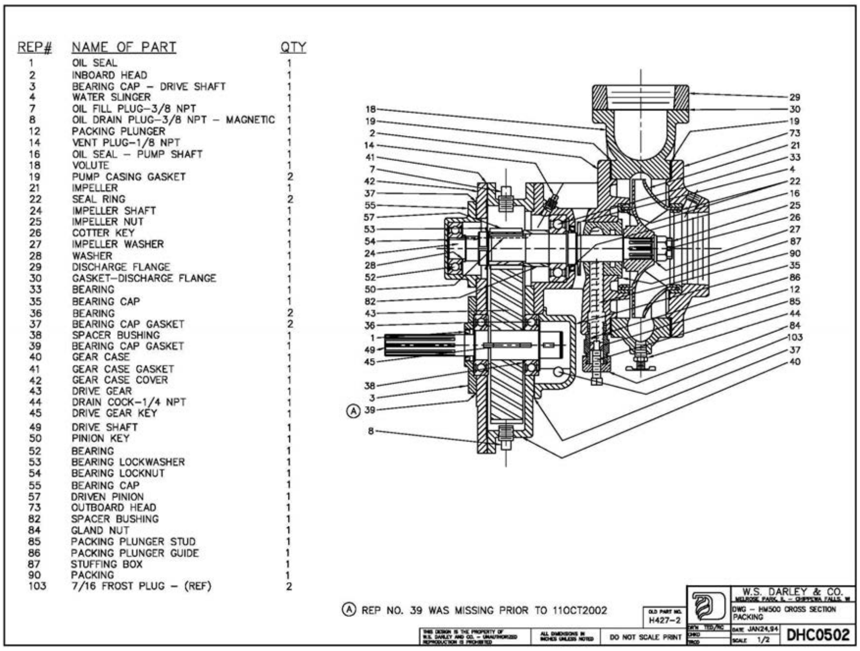
Conclusions have been drawn from the first round of testing that both packings show promise in being a replacement for the Garlock Style 926-AFP. The Chesterton and leadless Garlock packing performed to Darley standards of easy adjustment, constant drip rates, and start and stop testing. Further testing in a pump will be performed to simulate use in the field.

Pump Testing

With the initial testing in the packing fixture complete, and both new products showing promise in being a viable replacement, it was concluded that further testing in a pump should be done. A Darley HM 500 was built to be used in R&D testing because it is a versatile and popular pump that can achieve the desired pressures and speeds that most of the product lines will experience. The HM 500 is a single stage centrifugal pump that is used as a midship pump. A midship pump utilizes a PTO from the truck's transmission to drive the Darley gearcase. The gear case is available in a range of gear ratios to accommodate different engine speeds and power curves. The gear ratio used in this case is a 2.85 to 1 ratio because this is a popular ratio and can be rebuilt easily and sold after testing. The HM 500 is rated as a 500gpm pump meaning that it can produce 500gpm @ 150psi and can perform half the rated capacity at 250psi. These will be two of the tests being performed along with a multitude of other tests. All pumps are tested to NFPA and customer standards before being shipped; these tests and procedures are listed in various work instructions which are specific to each line of pumps. So this will be the starting point for testing, after which if the product performs favorably further testing will be done. (Figure 8 HM 500)

Figure10

HM 500 Cross Sectional Drawing



As with all pumps the packing gland is pre-packed in assembly before the pump is brought into the test room. The assembler will snug the packing gland up enough so that the drive shaft can still be turned by hand and so the pump can pass the pressure and vacuum tests. To keep the experiment as close to actual usage and standard practice this was done for the first packing being tested which was the Garlock Style 926-AFP leadless. The pump was packed with 8 pellets and the packing gland was tightened for pressure and vacuum tests.

The pressure test is performed first utilizing a hydrostatic pressure tester which pressurizes water without operating the pump to ensure it doesn’t leak, the castings hold, and all the fasteners and fittings are tightened and leak free. This process is done by hooking a line from the hydrostatic pressure tester to the pump which has all valves and inlets closed. The operator will then run the pressure up to 500psi in the case of the HM 500. The line will be shut off and pump will sit pressurized with water for five minutes, during which time the operator will inspect the castings and fittings to ensure there are no visible leaks. At the end of the five minutes the pressure will be checked to ensure the pump held the 500psi for the allotted time. The leadless packing passed this test and was moved to the next test which is the vacuum test.

The vacuum test is performed while the pump is hooked up to the power source and plumbing which is used for testing in the test room. A line will be run from a primer pump to an inlet on the suction side of the pump. The vacuum primer will be started and the pump will be primed from a six foot draft, meaning the pump suction will be six feet above the water line. The vacuum will then be recorded and vacuum primer line turned off. Again the pump will sit for a few minutes so the operator can monitor the vacuum reading. If the pump maintains the vacuum it has passed the test and can proceed to pump testing, if the vacuum is not held the pump will be rejected and sent to engineering for rework. In the case of the leadless packing the pump passed vacuum and pump testing could begin.

As stated earlier pump testing is to be conducted per Darley standards for an HM pump. The researcher was on hand for all testing while a test room technician operated the pump and adjusted packing to standards. Throughout the test the behavior of the packing was observed and recorded. The test procedure and observations were as follows. To see horsepowers, torques, and speeds see actual test sheet Figure 5.

- Pump was brought up to 150psi @ 500gpm. Packing was leaking extensively and required approximately 5 turns of adjustment to stabilize between 6 and 12 drops per minute. The test room technician stated this was more adjustment than the standard packing required. It remained at this drip rate for the duration of the test which was 30 minutes.
- Pump was sped up to 200psi @ 350gpm. Packing required less than a quarter turn of adjustment to stay within the 6 to 12 drops per minute. It was dripping at 15 drops per minute before adjustment. The packing remained at a constant drip rate for the remainder of the test which was 15 minutes.
- Pump was run up to 250psi @ 250gpm and the drip rate remained constant at 6 to 12 drops per minute for the remainder of the 15 minute test.
- Pump was then tested for maximum flow which was 150psi @ 630gpm

According to Darley standards for an HM 500 with leadless Garlock packing the pump passed the test. Although to further simulate what the product will see in the field, and what it is capable of, further testing is required. The pump was shut down and allowed to sit idle for one hour to see what a start-and-stop would do to the performance of the packing. Along with the start-stop test the pump will operated at higher pressures and speeds to see how it will react in case the pump is run past the rated RPM. The following testing was performed and observations recorded after allowing the pump to sit for one hour.

- Pump was brought up to 150psi @ 500gpm where the packing stabilized at 6 to 12 drops per minute with no adjustment. The packing remained stable at this pressure for five minutes.
- Pump was sped up to 250psi @ 250gpm where the packing remained stable for the duration of the five minute test.
- Pump was sped up to 300psi @ 104gpm where the packing dripped at 10 to 16 drops per minute for the duration of the 5 minute test.
- Pump was sped up to 350psi @ 90gpm which at this point the packing became unstable and began dripping at 1 to 2 drops per second. It was also noted that packing was being pushed out the back side of the stuffing box and being thrown from the slinger.

Once it was noticed that the leadless packing was being pushed out the back of the stuffing box there was no need to continue the test, because this is not something that happens with the standard packing. The 350psi test not only confirmed that the Garlock Style 926-AFP did not have the necessary quality or durability but also gave some insight in to why the lead flakes are present in the packing. Through testing it can be concluded that the lead is present to bond the other materials together and give some stability at higher pressures. Although the packing was a failure the testing in general was not; Darley now has an understanding of why the lead is present and if another product is not found there is the possibility of Darley and Garlock working together to find a material of similar properties to replace the hazardous lead.

As with previous testing in the Rotational Packing Fixture the HM 500 was completely disassembled and cleaned to ensure there will be no contamination between materials. Once reassembled the Chesterton CMS 2000 was packed and tightened in assembly by the same assembler following the same procedure outlined above. The pump was packed using seven pellets compared to the eight used for the leadless Garlock test. The pump was wheeled into the test room where pressure and vacuum tests were performed by the same personnel under the same procedures outlined in the previous test. The CMS 2000 passed both tests and pump testing could begin.

All testing and analysis were performed in a consistent matter so that the products could be benchmarked against each other, and the standard packing. The following observations are from the Chesterton CMS 2000 test.

- Pump was started and brought up to 150psi @ 500gpm and was leaking at approximately 20 drips per minute. After a quarter turn of adjustment the packing stabilized between 6 and 12 drops per minute. For the duration of the 30 minute test.
- Pump was sped up to 200psi @ 350gpm during which the packing remained stable at 6 to 12 drops per minute for the entire 15 minute test.
- Pump was sped up to 250psi @ 250gpm where the packing remained stable with no adjustment for the entire 15 minute test.
- A max flow test was performed during which the pump achieved 150psi @ 630gpm during which the packing remained stable at 6 to 12 drops per minute.

The Chesterton CMS passed the pump test criteria for an HM 500 with less adjustment than the standard Garlock Style 926-AFP. As with previous testing the pump was shut down and allowed to sit for one hour to simulate a start and stop scenario. Once the pump was started after the hour the following observations were recorded.

- Pump was run up to 150psi @ 500gpm where the drip rate quickly returned to 6 to 12 drops per minute without adjustment for the duration of the 5 minute test.
- Pump was run up to 200psi @ 350gpm where the packing remained stable for the duration of the 5 minute test.
- Pump was run up to 250psi @ 250gpm during which the packing remained stable at 6 to 12 drops per minute for the duration of the 5 minute test.
- Pump was run up to 300psi @ 104gpm during which the packing remained under 12 drops per minute for the duration of the 5 minute test.
- Pump was run up to 350psi @ 90gpm during which the packing stayed stable at approximately 12 drops per minute. This was the maximum pressure the HM can handle and the packing remained stable for 15 minutes until the pump was shut down.

Through pump testing the Chesterton CMS 2000 continued to perform favorably and at this point it appears as though it is a product which could ultimately replace the Garlock packing being used at this point. Although the first start-stop test showed that the packing could perform and be consistent during shut down, it was determined that the packing should sit in a pump for a longer period and be tested a week later. This would simulate a pump being operated and then sitting in the fire station until another fire occurred. After the week was up the packing was tested again with the same results, signifying that it has the ability to perform well in a pump at the standard test points required in most applications.

The tests that were performed made assumptions that in many cases cannot be ignored when investigating a packing failure. As outlined in this research, one of the main causes of failure when dealing with packing is mechanical failure, or parts that are not made to specifications. The pump and all the components which it entails were thoroughly inspected to ensure they were within tolerances called out on the engineering drawings. This included inspection of the parts manually and on the CMM. The final pump assembly was also inspected to be sure that shaft was running true and within tolerance to the aligning components. Another cause of packing failure as outlined in the research section is operator error. The pump was assembled and tested by personnel who have been building and testing pumps for over 20 years and were supervised by the researcher to ensure standard procedures were used.

Shop Floor Input

As with any new product or change in standard practice it is always helpful to talk to the people who will be building, testing, and using the new products or processes every day. Through the process of testing the researcher was able to be in close contact with the personnel and was able to get some of their input on the new packing materials being tested.

As far as assembly how do the new products compare to the Garlock Style 926-AFP?

"The Garlock without the lead appears to be the same just minus the lead flakes; it uses the same amount of packing and is just as messy. The CMS looks considerably different and I had my doubts at first but after assembling it; it appears to work fine. It takes a little fewer pellets and is clean so overall it seems to be a great product if we can prove that it works.

As far as testing how do the new products compare to the Garlock Style 926-AFP?

The CMS 2000 was great, it required hardly any adjustment and kept the same drip rate throughout the entire testing which was nice because I could concentrate on hitting the test points in a timely matter without messing with the packing. The Garlock without the lead was not much different the standard and probably worse. It required more adjustment and came out of adjustment at higher pressures which could be a problem on some of our other product lines.

Through testing and input from employees who deal with packing everyday it can be concluded that CMS 2000 shows a lot of promise in becoming a new standard for Darley in the future. It should also be noted that although the leadless Garlock packing did not perform to the required criteria, there were lessons learned as to why the lead is present. In the future this could lead to partnership with Garlock to find a material similar to the lead but less hazardous.

Chapter V: Discussion

The research concerned an ongoing problem with the pump packing used in Darley pumps. The sole purpose was to find a replacement for a standard packing which has a 40 plus year old recipe, and has shown periods of inconsistencies, while containing the hazardous material lead. With many companies and society in general going “GREEN” and all the products Darley has going overseas there will come a time when this will not be acceptable. Alternative packings were researched and two showed promise; a Garlock which has the same recipe although excluding the lead and a completely different type of injection packing called Chesterton CMS 2000.

Testing of these two products included testing in a fixture and testing in an actual pump under various scenarios, pressures, and speeds so that actual use can be simulated as closely as possible. The purpose of this chapter is to draw conclusions and recommendations based on the data acquired to satisfy the purpose of the study.

Limitations

Due to the high costs of testing and building pumps, limitations where drawn out by management. Testing was to be done in the test fixture to validate the properties of the packing before testing was done in a pump. When the components passed initial testing the promising products would be tested in a stock HM 500 pump as it is a very popular pump and is something the company would be able to rebuild and sell cost effectively and in a timely manner. In saying this one can also assume that destructive testing was not to be done unless great promise of bettering the current standard was shown, and it would require approval. If the pump is run to destruction, it will require more extensive repairs then just wear items, such as bearings and seals.

From research of packing failures and the experience of the researcher, some failure modes could be eliminated. All the components of the pump were thoroughly inspected through manual and computer aided inspection methods to ensure that everything was within tolerance. One failure mode is when a pump is not mechanically correct, such as runout of the shaft, imperfections in ceramic coating, or surface finishes. The other failure method which could be ignored was operator error; everything was assembled and tested under the supervision of the researcher, and the personnel working with the product are professionals who have been in current positions for over 20 years. With these two failure methods avoided the testing and data could focus on the packing material.

Conclusions

Through the extensive testing and research it is believed that there are products available that can serve as a replacement for Garlock packing. Chesterton CMS 2000 was a product that exhibits the desired qualities, and should be considered a viable option for replacing the existing packing.

Testing showed that although the lead in Garlock packing is undesirable it is necessary at higher pressures and speeds. This was proven by testing Garlock packing which did not have lead present. At higher pressures and speeds the packing extruded out of the stuffing box which will lead to more frequent adjustments and premature failure of the pump and gearcase.

It was also proven that the Chesterton packing could serve as a replacement for the Garlock packing. In the HM500 pump under standard operating conditions the Chesterton packing performed as desired. With Darley's extensive product line and customer applications the packing should be pushed to the extremes to insure the product will meet the demands; and should a failure occur it not be harmful to the operator or the rest of the system.

Recommendations

In a case such as this it is hard for a company to switch from a product they have been using for decades to something that is completely new to them. Through the research and testing of this study many questions were answered, conclusions were drawn, and yet there is still more that should be done before a new standard can be put in place. The purpose of the study was to find a product that could be a viable replacement for the Garlock Style 926-AFP. At this point it appears as the Chesterton CMS 2000 is this replacement however further testing should be done before this product is sent into the field.

The first recommendation is that the packing should be tested in a pump that will push the material to its extreme limits. This pump would be the U4 which is a four stage centrifugal pump that has an impeller shaft capable of spinning over 12,000 rpm. This would push the packing to and past its rated speed which would answer many questions as to how the product will handle the abuse of being pushed past its limits. The U4 is also capable of creating pressures of 1,500 psi at 60 gpm. This pump has not been sold in years because of the extreme stresses it puts on the components at these pressures and speeds, and therefore requires extensive maintenance and monitoring which is very costly for municipalities.

The next recommendation would be to do destructive testing on the Chesterton CMS 2000 to see how the product will react when the pump is not operated properly. This would include a test in which the packing is over tightened which generally leads to no water dripping past the packing and produces an excessive amount of heat which in the case of the Garlock packing causes the packing to glaze over ruining the shaft and stuffing box. This is a failure that is seen often when the pump is being operated by personnel not familiar with a packing pump.

This test would show what damage will be done, if any, and if there is any possible danger to those operating the pump.

The last recommendation would be to give a loyal customer a pump which utilizes the Chesterton CMS 2000 packing. This customer would be able to use the product for an allotted amount of time and monitor how the packing performs in the field. In doing this Darley would be able to catch any failures or potential downfalls of the product that may have been overlooked in the testing included in this study and the recommendations above.

If Darley is willing to invest more time and money into finding a replacement for the Garlock packing, the recommendations above have outlined the steps that need to be taken. In doing this Darley has the potential of producing a better end product that will improve the usability and customer satisfaction of their pumps while decreasing costs induced by an inconsistent packing.

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Appendix A: Garlock MSDS Sheet

MATERIAL SAFETY DATA SHEET

GARLOCK
An EnPro Company
SEALING TECHNOLOGIES

Date-Issued:02/19/2003
MSDS Ref. No:M47003-1
Date-Revised:02/21/2003
Revision No: New MSDS

Style 926-AFP Loose/Bulk

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Style 926-AFP Loose/Bulk
PRODUCT DESCRIPTION: Product Code 47003-2680

MANUFACTURER
EnPro
Garlock Sealing Technologies
1666 Division Street
Palmyra, NY 14522
Contact: Michael P. McNally
Product Stewardship: 315-597-4811

24 HR. EMERGENCY TELEPHONE NUMBERS
Emergency Phone: 315-597-3080 9:00 A.M. - 4:00 P.M. Mon-Fri

2. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	Wt.%	CAS#	EINECS#
Lead	~55 - 65	7439-92-1	231-100-4
Graphite (natural)	~10 - 20	7782-42-5	
Kaolin	~5 - 15	1332-58-7	
Silica, crystalline	<0.5	14808-60-7	238-878-4
Titanium dioxide	<0.5	13463-67-7	2366755

EEC LABEL SYMBOL AND CLASSIFICATION

EEC Toxic - "T"

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

PHYSICAL APPEARANCE: Gray Black Plastallic

IMMEDIATE CONCERNS: May be fatal if swallowed.

POTENTIAL HEALTH EFFECTS

EYES: May cause significant irritation to the eyes.

SKIN: May cause significant irritation to the skin.

SKIN ABSORPTION: Lead and lead compounds may be absorbed through the skin on prolonged exposure; the symptoms of lead poisoning described for ingestion exposure may occur.

INGESTION: May cause significant irritation to the digestive tract.

INHALATION: Lead can be absorbed through the respiratory system. Local irritation of bronchia and lungs can occur and, in case case of acute exposure, symptoms such as mettallic taste, chest and abdominal pain, and increased lead blood levels may follow.

MEDICAL CONDITIONS AGGRAVATED: Persons with pre-existing kidney, nerve or circulatory disorders or with skin or eye problems may be more susceptible to effects of lead.
Diseases of the respiratory and cardiovascular system are generally aggravated by exposure to graphite.

4. FIRST AID MEASURES

EYES: Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. Get medical attention.

SKIN: Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. Seek medical attention. Wash contaminated clothing and shoes before reuse.

INGESTION: Call a physician immediately. Induce vomiting immediately as directed by medical personal. Never give anything by mouth to an unconscious person.

INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

5. FIRE FIGHTING MEASURES

FLASHPOINT AND METHOD: ~ (360°F)COC (Cleveland Open Cup)

AUTOIGNITION TEMPERATURE: ~ (959°F)

EXTINGUISHING MEDIA: Foam, Dry Chemical, Carbon Dioxide or Water Spray (Fog)

HAZARDOUS DECOMPOSITION PRODUCTS: Composition of by-products from the result of fire or thermal decomposition will vary depending on specific conditions. Hazardous gases / vapor include smoke, carbon monoxide, hydrogen cyanide; and oxides of sulfur, nitrogen and lead. There may be others unknown to us.

6. ACCIDENTAL RELEASE MEASURES

GENERAL PROCEDURES: Scrape or shovel. Any remaining material may be removed with a suitable organic solvent or strong detergent. Do not allow contaminated solvent or rinse water to enter drains or waterways. Disposal must be in accordance with all local, state and federal regulations.

RELEASE NOTES: If spill could potentially enter any waterway, including intermittent dry creeks, contact the local authorities. If in the U.S., contact the US COAST GUARD NATIONAL RESPONSE CENTER toll free number 800-424-8802.

In case of accident or road spill notify:
CHEMTREC in USA at 800-424-9300
CANUTEC in Canada at 613-996-6666
CHEMTREC, other countries, at (International code)+1 703 527 3887

7. HANDLING AND STORAGE

HANDLING: Handle and use in a manner consistent with good industrial/manufacturing techniques and practices. Use appropriate personal protective equipment as specified in Section 8. Areas in which exposure to lead metal or compounds may occur should be identified bt signs or appropriate means, and access to area should be limited to authorized persons. Containers of this may be hazardous when empty since they retain products residues.

STORAGE: Keep in a tightly closed container, stored in a cool, dry, ventilated area.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE GUIDELINES:

OSHA HAZARDOUS COMPONENTS (29 CFR 1910.1200)

		EXPOSURE LIMITS					
		OSHA PEL		ACGIH TLV		Supplier OEL	
		ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Lead							
Graphite (natural)	TWA	15		2.0[1]			
Kaolin	TWA	10*[2]		10*[3]			
Silica, crystalline	TWA	NL[4]	(0.1)	NL	(0.1)	NL	NL
	STEL	NL	NL	NL	NL	NL	NL
Titanium dioxide	TWA	NL	10	NL	10	NL	NL
	STEL	NL	NL	NL	NL	NL	NL

OSHA TABLE COMMENTS:
1. Respirable Dust
2. * = Total dust, ^ = Respirable fraction
3. * = Total Dust
4. NL = Not Listed

ENGINEERING CONTROLS: If vapor or dust levels exceed the occupational exposure limits, then use process enclosures, local exhaust ventilation, or other engineering controls to control airborne level to below recommended exposure limits. The need for local exhaust ventilation should be evaluated by a professional industrial hygienist. Local exhaust ventilation systems should be designed by a professional engineer.Maintain and test ventilation systems in accordance with OSHA regulations (29CFR 1910.94)

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: Wear safety glasses with side shields or goggles when handling this material.

SKIN: To prevent any contact, wear impervious protective clothing such as neoprene or butyl rubber gloves, apron, boots or whole bodysuit, as appropriate.

RESPIRATORY: If airborne dust is present, use a NIOSH approved particulate respirator.

PROTECTIVE CLOTHING: Wear impervious clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.

WORK HYGIENIC PRACTICES: Good personal hygiene practices should always be followed.

OTHER USE PRECAUTIONS: Eating, drinking, and smoking should not be permitted in areas where solids or liquids containing lead compounds are handled, processed, or stored. See OSHA substance specific standard for more information on personal protective equipment, engineering and work practice controls, medical surveillance, record keeping, and reporting requirements. (29 CFR 1910.1025)

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: Semisolid
ODOR: Slight Petroleum Odor.
APPEARANCE: Gray Black Plastallic.
pH: Not Applicable
VAPOR PRESSURE: <0.01 mmHg
VAPOR DENSITY: >5 (Air=1)
BOILING POINT: > (550°F)
DENSITY: Not Determined

COMMENTS:

WATER SOLUBILITY: Negligible

10. STABILITY AND REACTIVITY

STABLE: YES

HAZARDOUS POLYMERIZATION: NO

CONDITIONS TO AVOID: Heat, flames, ignition sources and incompatibles.

INCOMPATIBLE MATERIALS: Ammonium nitrate, chlorine trifluoride, hydrogen peroxide, sodium azide, zirconium, disodium acetylide, and strong oxididants such as liquid chlorine, fluorine, peroxides and concentrated oxygen.

11. TOXICOLOGICAL INFORMATION

CARCINOGENICITY:
IARC: Crystalline Silica : Group 1 (Known Human Carcinogen)

Lead: Group 2B (Possible Human Carcinogen)

CARCINOGENICITY COMMENTS: Titanium Dioxide (Identified as a potential carcinogen by NIOSH.)

GENERAL COMMENTS: Toxicity data is available on individual components. Call 315-597-4811 for information.

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL DATA: Not Available

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose of waste at an appropriate waste disposal facility according to current applicable laws and regulations.

PRODUCT DISPOSAL: Dispose of at a supervised incineration facility or an appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

GENERAL COMMENTS: Refer to Section 6, Accidental Release Measures for additional information.

14. TRANSPORT INFORMATION

DOT (DEPARTMENT OF TRANSPORTATION)
PRIMARY HAZARD CLASS/DIVISION: Not Regulated

15. REGULATORY INFORMATION

EUROPEAN COMMUNITY
EEC LABEL SYMBOL AND CLASSIFICATION

Toxic

EEC Toxic - "T"

CALIFORNIA PROPOSITION 65: This product contains chemicals known to the state of California to cause cancer and birth defects or other reproductive harm.
(Lead / Crystalline Silica)

STATES WITH SPECIAL REQUIREMENTS

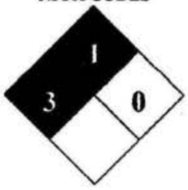
Silica, crystalline	Massachusetts:AW1542MMA New Jersey:AW1542NJ Pennsylvania:AW1542PA

16. OTHER INFORMATION

PREPARED BY: MP McNally

REVISION SUMMARY New MSDS

NFPA CODES



MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Appendix B: Darley Injection Type Stuffing Box Adjustment

W. S. DARLEY & CO.

DARLEY INJECTION TYPE STUFFING BOX ADJUSTMENT

Prop 65 Warning: This product contains lead, a chemical known to the State of California to cause cancer, birth defects, and other reproductive harm. Wash hands after handling.

Caution: Do not attempt to use anything but Darley injection packing. Using the wrong packing material in your pump may cause catastrophic failure of the pump shaft sealing components.

Only use W.S. Darley & Co.'s plastallic injection packing material. It is made of a special composition of shredded fibers, and a special bonding and lubricating compound.

It is important that the stuffing box is completely filled solid with packing and compressed firm during adjustment to prevent formation of voids and excessive leakage.

To pack the stuffing box when empty and assembled in the pump, remove the packing screw and nut assembly, and insert pellet form packing into the packing plunger guide. Replace the packing screw assembly and use a hand speed wrench to force the pellets into the gland. DO NOT USE A POWER TOOL! Repeat pellet additions while turning the impeller shaft by hand until resistance to turning is felt when the stuffing box is almost full. Continue turning packing screw by hand using a standard 6" long 9/16" end wrench until 4 lb. of force is felt at the end of the wrench. This is equivalent to 2 ft-lb or 24 in-lb torque. Continue turning until a few flakes of packing are extruded out the opening between the impeller shaft and the stuffing box hole. The gland is now ready for pressure testing or pumping.

After priming the pump with water, start the pump and raise the discharge pressure to 50 psi. Tighten the packing screw using a 6" long 9/16" end wrench until 4 lb. force is felt at the end of the wrench (24 in-lb torque). Continue operating the pump at 50 psi for 5 minutes to dissipate packing pressure against the shaft and permit cooling water to flow between the shaft and stuffing box hole. Make sure that water actually does come through before operating pump at any higher pressure. The normal drip rate may vary between 5 and 60 drops per minute.

Operate the pump for 10 minutes at the highest normal operating pressure flowing sufficient water to prevent overheating. Do not run the pump blocked tight. Lower discharge pressure to 50 psi and repeat the packing screw tightening procedure outlined above.

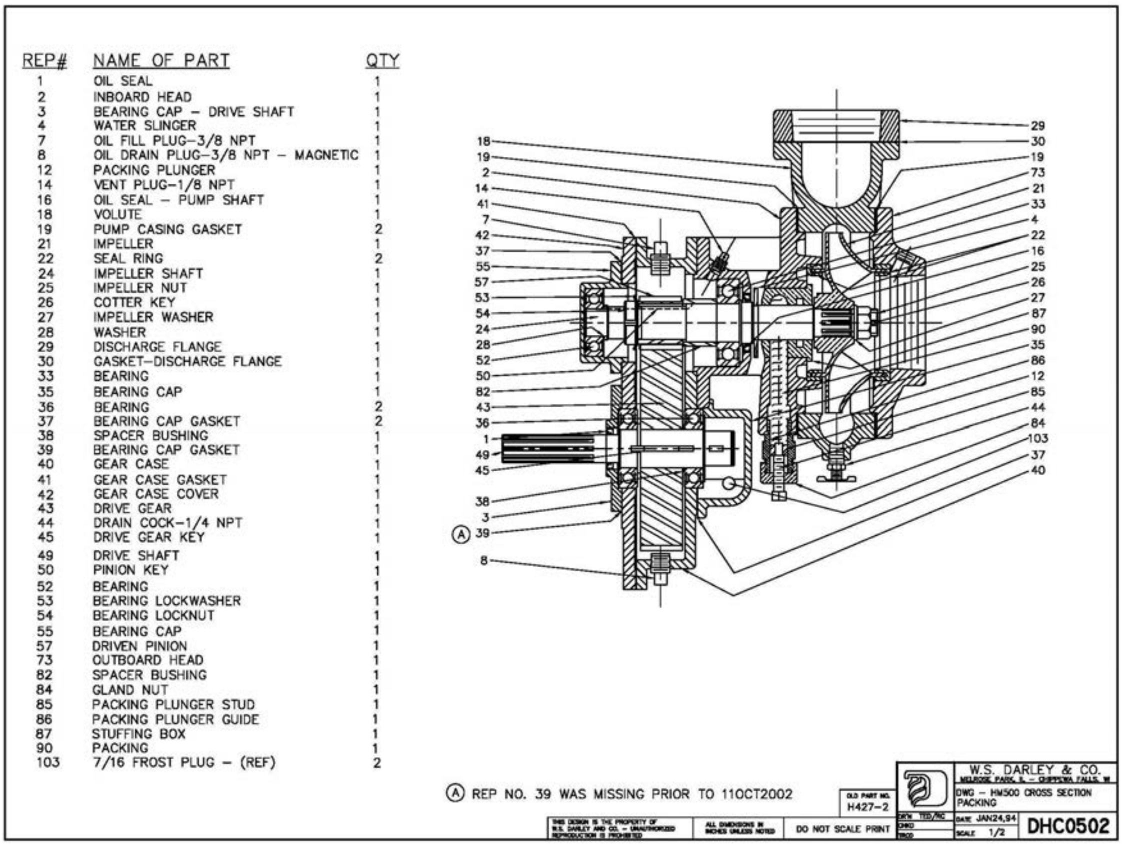
The pump may now be operated for any time period required within its rated capacity. However, the drip rate should be monitored more frequently during the first few hours, and adjusted if necessary to achieve a stable flow rate. Several more adjustments may be required.

For a list of approximate quantity of packing pellets required by model (completely repacked), see below:

Model		Approximate # Packing Pellets
A	....	6
2BE	....	6
EM	....	15
H	....	8
JM	....	8
KD	....	10
KS	....	8
LD	....	15
LS	....	9
P	....	10
U2	....	5
U4	....	10

If further information is needed, call **W.S. DARLEY & CO.**
at Chippewa Falls, WI. at 800-634-7812 or 715-726-2650

Appendix C: HM500 Cross Section and Tolerances



Stuffing Box Fill hole Diameter – 5/8” drill

Shaft Diameter – 1.246/1.245

Stuffing Box hole Diameter – 1.2525/1.2535

This provides a diametral clearance of .006 to .008 if the measurement exceeds a diametral clearance of .012 the impeller shaft and stuffing box should be replaced.