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Final Report

**DESIGN, BUILD, DEVELOP AND TEST A FIELDWORTHY SPIRAL TOOL
AND PACKER FOR CASING REPAIR**

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Design, Build, Develop, and Test A Fieldworthy Spiral Tool and Packer for Casing Repair

1.0 Introduction

The oil and gas industry has an opportunity for protecting the environment and conserving resources by sealing wellbore leakage in damaged wells. This leakage has various causes, such as corrosion damage, cracked or otherwise defective casing, and unneeded perforations. The opportunity comes in the form of a newly designed and partially developed method for internally sealing well casing or tubing to prevent leakage. Once this method is fully developed, our country can realize significant financial savings in addition to the environmental protection and resource conservation benefits.

A new method for sealing casing is under research and development by Nu-Bore Systems. The method involves internally lining a section of the wellbore with a multi-layer spiral wrapping of a high strength, corrosion resistant metal interleaved with a high bond strength, resilient epoxy. The high strength metal is preferably a copper based alloy hardened to a very high strength in order to resist the internal and external pressures of downhole environments. The epoxy adhesive formulation is one that forms a bond between the steel inner wall of the casing and copper alloy strip. The copper alloy strip spiral wraps are interleaved with epoxy, and the whole system provides a high level of outward directed spring force and, thus, resists both internal and externally directed forces. This method has been assessed by the Department of Energy, and the magnitude of the oilfield need and the technology are described in a DoE report entitled, "Downhole Casing Repair System" (OERI Number 013152). In this report, the cost savings to the nation's energy program was estimated to be in the range of hundreds of millions of dollars per year, and the method was judged technically feasible once certain well defined engineering obstacles are overcome.

2.0 Background of the Program

The spiral lining method reduces cost because of its modular tooling and simple process. It increases reliability by using materials resistant to corrosive conditions, and it makes it much simpler to get equipment to remote wellsite locations. The Nu-Bore method needs further development, however, to take it from its current stage in which it is limited to relatively short lining lengths, to a stage closer to commercial operation in which it will be capable of very long lengths.

The current program involves development of a segmented connecting joint for an inflatable rubber packer as summarized in a later report section. Packers are tubular components with a relatively thick wall and are made from vulcanized rubber reinforced with cord much like vehicular tires. They are used in several steps of the spiral sealing method, mainly for firmly anchoring the ends of the downhole tools during installation and for applying outward pressure at the lining/casing interface during the cure cycle for the epoxy adhesive.

In theory, the spiral lining process has no length limitation. In practice however, as the length of lining increases, the length of the pressure cure packer must be increased to match the finished length of the lining itself. The packer currently used in the Nu-Bore method is approximately 40 feet long. This becomes the limiting length of the spiral wrapped lining.

For a lining that is several hundred feet long, a long coiled rubber packer would be required. This would be somewhat difficult to transport and deploy, and extremely difficult to manufacture. If long packers could be built up from smaller segments, manufacture would be simpler and less expensive, and packers would be far easier to transport and to work with in the field. Another consideration is the fact that if a long packer is damaged, begins to leak, or becomes distorted, the entire unit is probably unusable. With a segmented packer, only those lengths affected would need replacement.

The objective of this program, therefore, is to develop a joint between packer segments that is easily assembled before lowering downhole and easily disassembled after the sealing job is done. In addition, this tool joint must expand uniformly as though it were a part of the rubber and must not fail under the relatively high pressure of the epoxy cure cycle.

The overall goal of the work was to design, build, develop, and test a spiral tool and packer into a single universal tool that can repair casings with diameters varying from 4.5 to 7 inches. The overall scope of work was divided into the following tasks:

- Task 1. Define, analyze, and complete the engineering requirements for the subject tool system.
- Task 2. Perform the engineering design.
- Task 3. Complete the engineering drawings for the tool system, including both the overall layout and the individual components.
- Task 4. Complete a materials list, and purchase the materials.
- Task 5. Establish test parameters for the tool system.
- Task 6. Build a prototype.
- Task 7. Perform tests to validate performance of the individual components and the overall assembly.
- Task 8. Prepare final report.

3.0 Engineering Program Plan

The action plan of this program was divided into the following areas:

- Define and analyze engineering requirements for the system.
- Produce layout drawings of the tooling design.
- Select special manufacturing treatments for key components.
- Establish test parameters.
- Build engineering model of the segmented packer joint.
- Perform testing to validate performance of components and overall assembly.

These tasks can be further broken down as follows:

A. Engineering:

Establish design parameters
Detail joint test model
Redesign and Test as required
Design and Detail Full Size Unit
Design Required Tooling (vulcanizing molds, etc.)
Test, redesign, and retest as required
Document for ultimate production

B. Manufacturing

Fabricate Test Models (metal components)
Fabricate mold model
Lay up molded test model
Fabricate prototype mold
Lay up molded prototype
Fabricate test equipment as required

C. Test

Test models
Test prototype

4.0 Program Results and Discussion

4.1 Engineering Overview

Prior to the initiation of this program, a concept had been devised for providing a metallic lining inside the bore of a steel tube such as an oilwell casing. The need for this lining usually exists at depths thousands of feet below the surface of the earth at the wellsite. To be successful, this lining must be bonded to the wall of the well casing with an adhesive, usually an epoxy. To cure an epoxy successfully, it is necessary to maintain a pressure normal to the lining/casing interface to form a structural bond within the cure time of the system, usually between 12 and 48 hours depending on the downhole temperature.

Figure 1 illustrates such a casing system in order to explain the fundamental problem addressed by this program. In this example, the casing section has an overall length of 45 feet, but it could be much longer if desired. In practice, there is no inherent limit to the length that a spiral made by a internal wrapping tool can make, provided that the spiral wrapped strip can be provided in large coils which can be joined end to end as needed. This is conventional technology and is readily available commercially today.

Figure 2 illustrates a conventional packer inflated within the segment of casing. As pressure increases within the packer, the rubber is distended around the edge of the metal end ferrule. Since the rubber is unsupported around the annulus between the end ferrule and the casing, a point of weakness is established. Since the end ferrule is strong and thin, the stress concentration at the transition is often sufficient to cause failure. In the past, conventional packers have been unable to withstand pressures of more than about 1000 psi. The epoxy system in this program would benefit from a cure pressure (working pressure) of 1000 to 1500 psi. Therefore, an increase in test pressure was required.

It has also been found that casing liners much longer than 45 feet are necessary to achieve the full potential of this environmental protection system. It is possible to do this in practice, but when curing epoxy with multiple packers, a situation such as illustrated in Figure 3 often results. Notice that the pressure forces the uncured epoxy into joint areas where it hardens and cures. The casing is restricted as a result. The restricted casing is a potentially serious limit to the overall purpose of the lining system which should, if possible, be thin enough to permit the use of conventional oilfield tools including pumping and well servicing equipment. The solution to this is the packer system developed on this program and illustrated in Figure 4.

Another limitation to the use of conventional packers is that they also undergo considerable distortion as they are pressurized. When pressure is first applied, they shorten in length as the diameter increases. With increasing pressure application, they eventually stop becoming shorter and begin to lengthen again, an effect of the high pressure. The application of cord to the system can cause unusual distortion effects such as twist as the pressure increases. The segmented packer when used with a reasonably high durometer as developed on this program minimizes or eliminates these complications.

4.2 Engineering

The basic components of the segmented packer are the pin and box end pieces and the segmented sections. Final tests have resulted in test pressures on all components of more than 2000 psi, thus providing a high safety factor, leading to assurance of the absence of failures in the packer system, and thus contributing to field worthiness of the overall process. The product specification in Section 4.5 reflects these test pressure capabilities. This specification is the result of initial design plus modifications that were made as the test program progressed through the several iterations to its successful conclusion.

Materials were purchased and equipment modified per this specification and the basic test system was fabricated at the test site. This test system is shown in Figure 5. This figure shows the technician applying water pressure to a packer segment to carefully remove all air from the system prior to testing. After the air is completely removed, the packer will be lifted on a crane into a vertical position and then inserted downward into the casing segment shown on the right of the tank. Pressure application is made with the packer in the casing in the vertical position, and four pressure ports allow observation of the progress of inflation of the joint. In other words, the casing segment consists of a tubular steel container with built-in test stations from which measurements of the outer diameter of the joint can be measured as water pressure is ramped up to the ultimate pressure capability of the joint or until it reaches the program target maximum pressure.

Figure 6 is another view of the test stand and shows the casing sample being removed from the tank after completion of testing. Note that the hydrostatic tank has the capability to be filled with water to aid in detecting slow leaks in the end joint of segmented joint.

Figure 7 is a close view of the pressure application tank with capability of applying hydrostatic pressure from 50 psi to 2000 psi. Figure 8 illustrates an existing hydraulic swaging press that was used to swage the end ferrules onto the packer segments prior to testing. Figure 9 is a closeup of a packer segment inserted into the casing, and illustrates the fitting that is attached to the end support of the packer.

4.3 Testing

All parts of the test packers and joints were submitted to vendors such as machine shops and heat treaters, or vulcanizing sources where appropriate. In most cases where this was done, at least two firm price bids were received. The bids were reviewed and a purchase order placed with the lowest bidder. As the work was completed and the parts received they were inspected and accepted.

Mechanical parts of the prototype joint were assembled at the test facility after the packers had gone through the rubber manufacturing and vulcanizing cycle. The first complete packer was received in April of 1992. Pressure testing continued through a series

Figure 5 System overview illustrating preparation of assembly for hydrostatic testing.

Figure 6 View of stand showing sample being removed from hydrostatic pressure test.

Figure 7 Pressure application tank - 2000 psig capability.

Figure 8 Hydraulic swaging press for end ferrule attachment.

of nineteen design-test-analysis iterations before the test goals were reached. The results of the tests are provided as Appendix A, and discussed in the following paragraphs. Figure 10 illustrates four of the failed end joints showing the ultimate pressure reached, and the general appearance of the rubber and metal after the test.

In each test, failure at the packer end ferrule was analyzed thoroughly, and a failure mode analysis was performed to diagnose the root cause for the failure. As part of this failure analysis, the vulcanized rubber was carefully removed from the metallic components, for thorough examination. Fortunately, several of the metal parts were reusable, and a procedure was developed for subsequent rubber application.

An individual test set consists of from one to four segmented packers. Pressure testing to failure yielded an increasing pressure capability starting at Test Set Number 1 failing at 450 psi up to Test Set Numbers 16, 18 and 19 surviving extended life cycle testing at the equipment pressure limitation of 2000 psi. This life cycle testing involved repeatedly pressurizing to the upper limit, holding for 30 minutes, releasing pressure and repeating the process. These life cycle tests were repeated on multiple packer joint combinations. The failure of the segmented joint in Test Number 17 was related to a problem in the rubber vulcanization and not directly related to the joint itself.

Throughout this test sequence, failure nearly always occurred at an end fitting. The segmented connection always performed as desired with inflation occurring uniformly across the joint. In other words, the major consideration during the course of this project proved to be the design of the end joint. After the first tests, review of alternate designs revealed no satisfactory commercial solutions that were not unduly complex or expensive. This program achieved a practical and inexpensive design that uses a resilient, high strength end joint reinforcement embedded within a multiple hardness rubber section. It proved to be comparatively simple to fabricate and was capable of enduring the high pressures required for service.

The segmented joint (as opposed to the end ferrules) proved to be successful based on the initial design. This was expected to be the major developmental issue of the program, but it the design concept worked the first time and every time thereafter in tests. In other words, the mechanical concept proposed for development during this program proved to be successful early in the program development and continued to show success throughout the entire testing and evaluation phase. We know of no other technology in commercial or developmental practice that solves this expandable joint concept.

Figure 9 Test packer segment in casing illustrating pressure fittings.

Figure 10 Four end joints tested to failure illustrating fracture mode and pressure capability.

4.4 Specification - Segmented Packer

JOINT GEOMETRY - The joint shall be such that the packer will be of constant diameter within 1/8 inch across the joint area after inflation to a minimum pressure of 250 psi. The length of any depression shall be less than 1/4 inch.

JOINT STRENGTH - The joint shall be designed to support a tensile load of 10,000 lbs while under maximum working pressure (1500 psi internal).

PRESSURE CAPABILITY - The joint shall be effective in a pressure range of from 400 psi internal to 1500 psi internal with an ultimate test strength of at least 2000 psi.

MATERIALS - The packer shall be constructed of commonly available materials according to applicable ASTM specifications. These materials shall be commercially available using conventional shop practices.

Rubber durometer, fabric strength and metal hardness and composition shall be reported on each order.

PACKER SEGMENT LENGTH - Packer segments shall be preferably eight to fifteen feet in length to permit feeding through the spiral wrapping equipment.

PACKER DIAMETERS - The uninflated diameter shall be between 4 and five inches in diameter and under constrained inflation shall be no greater than 7 inches. Uninflated, the packer shall pass through the applicable packer ring gage.

FERRULES - End fittings shall be made of AISI grade 1020 steel or equivalent. Preferred thickness in 0.100 inch to 0.130 inch and made from rolled sheet that is formed and fusion welded.

SWAGING - Swaging shall be performed with hardened steel dies by hydraulic methods. A suitable die lubricant such as a hydraulic oil shall be used. Care should be taken to insure that no interaction with this lubricant and the rubber.

Percentage reduction in swaging shall be recorded and used consistently.

REINFORCEMENT - Not generally required with this design, but if desired nylon cord can be used. Care should be used when using cord in immediate area of expandable segment joint termination.

INTERLAYER STRIP - Beryllium copper alloy C17200 strip 0.020" $\pm$ 0.0004 thickness XHM temper has been successful. Stamped and formed parts shall be deburred prior to use.

RUBBER - Nitrile rubber composition is preferred. Compatibility with oil well environments as well as elasticity and strength shall be considered in selection.

5.0 Future Work

As a result of this work, the spiral lining technology has accomplished a major step toward realization of the ultimate benefits of the casing lining technology. Several additional tasks would be desirable for the completed system to be fully operational. These include:

- Optimization of the metal/epoxy/fiberglass composite lining structure.
- Incorporation of a spiral deployment mechanism into the expandable packer system to make a unified compact tool.
- Design and development of a tool for large diameter casing systems.
- Further improvement of the epoxy or other adhesive system for bonding to the inner casing wall.
- Extension of the technology to high temperature, deep well systems.
- Operation with coiled tubing.

Appendix A

TEST RESULTS

TEST NO. 1

TEST TYPE: END JOINT ☒

DATE: 4-20-92

SEGMENT JOINT ☒

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .010 IN.

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 450 PSI

TYPE FAILURE END JOINT

COMMENTS:

PRESSURE RUPTURED THRU
METAL REINFORCEMENT SLOTS

TEST RESULTS

TEST NO. 2

TEST TYPE: END JOINT ☒

DATE: 5-21-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .010 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 350 PSI

TYPE FAILURE END JOINT

COMMENTS:

SAME AS TEST 1

TEST RESULTS

TEST NO. 3

TEST TYPE: END JOINT ☒

DATE: 6-23-92

SEGMENT JOINT ☒

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 850 PSI

TYPE FAILURE END JOINT

COMMENTS:

RUBBER CUT AT END OF
FERRULE

TEST RESULTS

TEST NO. 4

TEST TYPE: END JOINT ☒

DATE: 7-1-92

SEGMENT JOINT ☒

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 1000 PSI

TYPE FAILURE END JOINT

COMMENTS:

SAME AS TEST 3

TEST RESULTS

TEST NO. 5

TEST TYPE: END JOINT ☒

DATE: 7-15-92

SEGMENT JOINT ☐ [4]

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NYLON CORD

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .012 IN.

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 1000 PSI

TYPE FAILURE END JOINT

COMMENTS:

PRESSURE RUPTURED THRU
METAL REINFORCEMENT SLOTS -

TEST RESULTS

TEST NO. 6

TEST TYPE: END JOINT ☒

DATE: 7-92

SEGMENT JOINT ☒

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NYLON CORD

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 400 PSI

TYPE FAILURE END JOINT

COMMENTS:

SAME AS TEST 5

TEST RESULTS

TEST NO. 7

TEST TYPE: END JOINT ☒

DATE: 8-18-92

SEGMENT JOINT ☒

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 800 PSI

TYPE FAILURE END JOINT

COMMENTS:

RUBBER CUT AT FERRULE

TEST RESULTS

TEST NO. 8

TEST TYPE: END JOINT [✓]

DATE: 8-18-92

SEGMENT JOINT [✓]

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NYLON CORD

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 9 IN

RESULTS:

MAXIMUM PRESSURE 800 PSI

TYPE FAILURE END JOINT

COMMENTS:

SAME AS TEST 7

TEST RESULTS

TEST NO. 9

TEST TYPE: END JOINT ☒

DATE: 9-14-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .012 IN.

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11. IN.

RESULTS:

MAXIMUM PRESSURE 1900 PSI

TYPE FAILURE END JOINT

COMMENTS:

(RE CONFIGURED END JOINT -)
(LONGER REINFORCING METAL)
FEELER DISTORTED BY PRESSURE

TEST RESULTS

TEST NO. 10

TEST TYPE: END JOINT ☒

DATE: 9-15-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NYLON CORD

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 800 PSI

TYPE FAILURE END JOINT

COMMENTS:

RUPTURED THRU METAL REINFORCEMENT
RUBBER PULLED OUT FROM UNDER
FERRULE

TEST RESULTS

TEST NO. 11

TEST TYPE: END JOINT ☒

DATE: 9-16-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NATURAL

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NYLON CORD

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 1600 PSI

TYPE FAILURE END JOINT

COMMENTS:

RUBBER CUT AT FERRULE
FERRULE DISTORTED AT END

TEST RESULTS

TEST NO. 12

TEST TYPE: END JOINT [✓]

DATE: 9-17-92

SEGMENT JOINT []

PACKER MATERIAL

RUBBER TYPE NATURAL

RUBBER DUROMETER 50

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN.

RESULTS:

MAXIMUM PRESSURE 150 PSI

TYPE FAILURE END JOINT

COMMENTS:

LEAKED THRU LAYERS

SPLIT OUTER LAYER

TEST RESULTS

TEST NO. 13

TEST TYPE: END JOINT ☒

DATE: 10-5-92

SEGMENT JOINT []

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 50

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .012 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 150 PSI

TYPE FAILURE END JOINT

COMMENTS:

SAME AS TEST 12.

TEST RESULTS

TEST NO. 14

TEST TYPE: END JOINT ☒

DATE: 10-5-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .015 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 2000 PSI

TYPE FAILURE NONE

COMMENTS:

FERRULE MADE FROM THICKER
MAT'L

TEST RESULTS

TEST NO. 15

TEST TYPE: END JOINT ☒

DATE: 10-23-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NATURAL

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .015 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 500 PSI

TYPE FAILURE END JOINT

COMMENTS:

TEST RESULTS

TEST NO. 16

TEST TYPE: END JOINT ☒

DATE: 10-23-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .015 IN

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 2000 PSI

TYPE FAILURE NONE

COMMENTS:

METAL REINFORCEMENT DISTORTED -
LIFE CYCLED 1 SAMPLE 20/30 CYCLES

TEST RESULTS

TEST NO. 17

TEST TYPE: END JOINT [✓]

DATE: 10-12-92

SEGMENT JOINT [✓]

PACKER MATERIAL

RUBBER TYPE NATURAL

RUBBER DUROMETER 70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .015 in

TEMPER 1/2 HM

NO. LAYERS 3

LENGTH 11. in.

RESULTS:

MAXIMUM PRESSURE 150

TYPE FAILURE SEGMENT JOINT

COMMENTS:

TEST RESULTS

TEST NO. 18

TEST TYPE: END JOINT ☒

DATE: 10-12-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 50/70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE BeCu

THICKNESS .020

TEMPER XHM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 2000

TYPE FAILURE NONE

COMMENTS:

LIFE CYCLED 2 SAMPLES

40/50 CYCLES

TEST RESULTS

TEST NO. 19

TEST TYPE: END JOINT ☒

DATE: 12-8-92

SEGMENT JOINT ☐

PACKER MATERIAL

RUBBER TYPE NITRILE

RUBBER DUROMETER 50/70

INTERLAYER REINFORCEMENT (SEGMENT) NONE

END JOINT REINFORCEMENT

TYPE Be Cu

THICKNESS .020 IN

TEMPER XHM

NO. LAYERS 3

LENGTH 11 IN

RESULTS:

MAXIMUM PRESSURE 2000 PSI

TYPE FAILURE NONE

COMMENTS:

LIFE CYCLED 1 SAMPLE

40/50 CYCLES

END

**DATE
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