DEVELOPMENT OF GEOTHERMAL CAPABLE ELASTOMERS FOR USE IN RAM TYPE BLOWOUT PREVENTERS PHASE IV TESTING AT GEOTHERMAL WELLSITE

Bruce G. Parker
Technical Marketing Manager

Cooper Elastomer Technology
Cooper Oil Tool Division/Cooper Cameron Corporation
29501 Katy Freeway
Katy, Texas 77494

ABSTRACT

One of the major limitations which occurs in the drilling of a geothermal well is the high temperature capability of elastomeric sealing elements used in ram type blowout preventers (BOPs). Typical well drilling equipment used for oil and gas drilling is designed to operate up to 250° F and under special conditions up to 350° F. For geothermal wells, drilling equipment elastomeric sealing elements must be capable of operating in steam and brine up to 500° F (260° C).

This paper reports on the final phase of a joint development project between ENEL (Italy) and Cooper Elastomer Technology (CET) in which high temperature elastomers were tested in ram type BOPs under geothermal conditions. Tests were conducted at ENEL's Secolo #1 geothermal well near Larderello, Italy in the period from November 1990 to April 1991. The final phase testing demonstrated improved high temperature elastomer compounds and specially designed ram packer plates would permit operation at 425° F and 1800 psi for significantly longer periods of time than the test goal of 54 hours.

INTRODUCTION

At the August 1990 GRC Conference, CET presented Development of Geothermal Capable Elastomers for use in Ram Type Blowout Preventers, Geothermal Resource Council Transactions, Vol. 14, Part 1, August 1990, page 431 through 438. In this paper, CET reported on the results of the first three phases of this material development program. This paper presents the results of phase IV, the final phase of the project in which full size BOP elastomeric components were tested on a flowing geothermal well. The components tested were ram packers, top seals, bonnet seals, and connecting rod seals. Figure 1 shows a typical ram type blowout preventer and the primary wellbore elastomeric sealing elements, ram packers and top seals. Figure 2 shows the location of connecting rod seals and bonnet seals in the BOP.

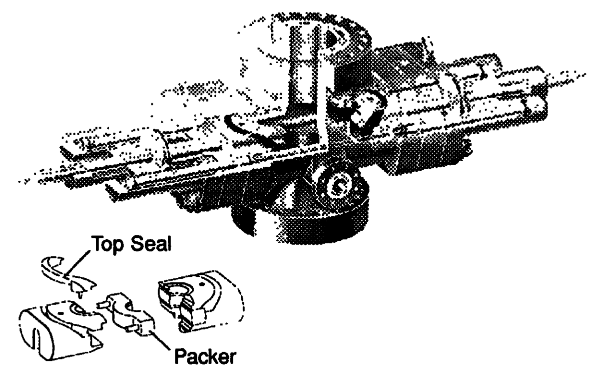


Figure 1: U Blowout Preventer

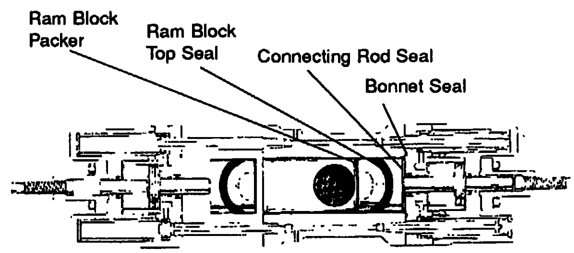


Figure 2: U BOP Hydraulic Control System

The joint project with ENEL was divided into the following four phases:

Phase I - Elastomeric material selection and screening. Laboratory testing of selected elastomers under geothermal conditions using a modified life prediction techniques.

Phase II - Selection of candidate materials for fabrication into elastomeric BOP components. Development of rubber to metal bonding techniques for high temperature service. Development of material processing techniques for candidate geothermal elastomers.

Phase III - Full scale laboratory evaluation of four candidate elastomeric materials. The two best performing elastomeric materials in laboratory testing were to be sent to ENEL (Italy) for evaluation on a operational geothermal well.

Phase IV - Full scale testing of candidate BOP elastomeric components on a producing geothermal well.

Phase I, II, and III were completed in the spring of 1990 and results were reported in GRC paper mentioned earlier in this paper.

REVIEW OF PHASE I, II, and III TESTING

Phase I - Materials screened in this phase were nitrile elastomer (baseline), EPDM elastomer (formulated for geothermal service), fluoroelastomers (FKM elastomers such as Viton™ and Fluorel™), perfluoroelastomers (FFKM such as Kalrez™ and Dia-El Perfluor™), tetrafluoroethylene propylene elastomer (TFE/P elastomer Aflas™), and Camlast™ (proprietary elastomer formulation). Materials were evaluated as sealing elements in a steam environment up to 600° F and 5000psi.

Phase II - Selection of candidate materials was based on performance in the screening tests, cost, produceability, and ability to bond to metal components in the finished product. Using this selection criteria, the following three elastomer compounds were selected for full scale fabrication:

Camlast. GT-2 - An EPDM based compound.
Camlast. GT-3 - An EPDM based compound.
Camlast. HT-2 - A high temperature oil resistant proprietary formulation.

Rubber to metal bonding systems and molding techniques for each candidate material were developed during this phase. Ram packers, top seals, bonnet seals, and connecting rod seals for use in a Cameron 13-5/8"-10,000 psi U type ram BOP were fabricated from each candidate material. Ram packers were molded using special top and bottom plates designed to prevent elastomer extrusion at elevated temperatures. See photograph 1 for details of plate design.

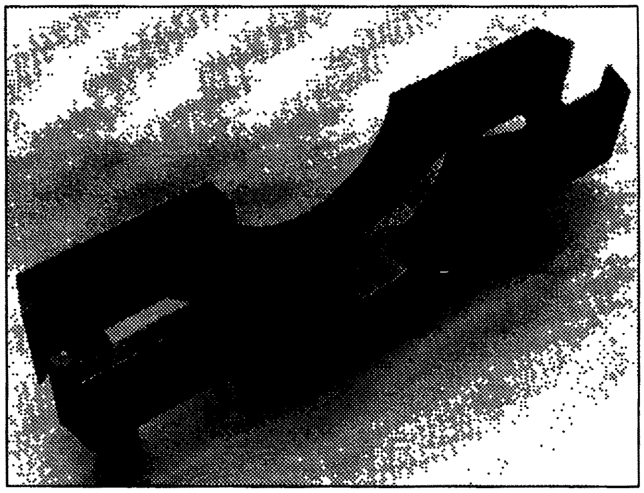
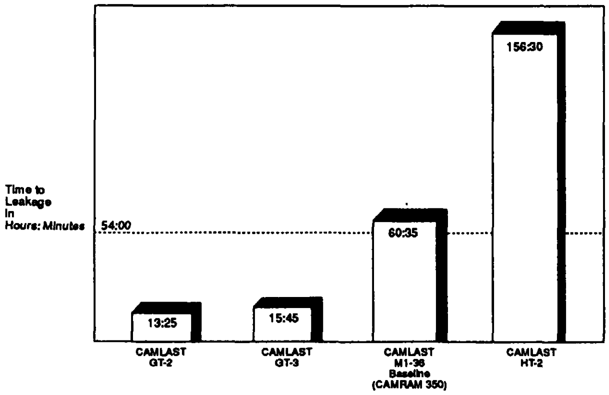


Photo 1: Lipped Plate Design for CAMRAM™ Packer

Phase III - Full scale laboratory evaluation of candidate materials was carried out in a specially modified Cameron 13-5/8"-10,000 psi U ram type BOP. Photograph 2 shows this modified ram type BOP.

Photo 2: 13-5/8" - 10,000 'U' type blowout preveter with insulation jacket installed and electric oil heater connected.

The goal in this phase of testing was to determine if candidate elastomeric components could operate for a minimum of 54 hours at 425° F without leakage. The test cycle consisted of two hours of thermal conditioning at 425° F with the BOP rams in the retracted position. After two hours of thermal conditioning, the rams were closed around a mandrel simulating drill pipe and the wellbore pressure increased to 3000 psi. The 3000 psi pressure was held for 15 minutes and BOP monitored for leakage. No leakage was permitted. The thermal conditioning and pressure test cycles were continued until leakage occurred. In addition to the three elastomeric materials selected in Phase II, BOP components made from Camlast™. compound M1-36 were also include in the test as a baseline high temperature material. Camlast compound M1-36 is used in the fabrication of commercially available Camram™. 350 high temperature packers and top seals used in oil and gas drilling. Figure 3 bar chart shows the results of the full scale laboratory test.



RESULTS OF FULL SCALE LABORATORY TESTING
RELATIVE LIFE - RAM PACKERS/TOP SEALS
425°F/3000 PSI STEAM/HOT WATER
FIGURE 3

Prior to starting the full scale laboratory testing, we had anticipated that both of the EPDM based compounds would offer superior high temperature performance. However this was not the case. Apparently at 425° F and 3000 psi applied pressure, the EPDM compounds do not possess sufficient physical strength to resist extrusion and materials loss in critical sealing area on the packers and top seals. Based on results of the full scale laboratory testing, BOP components made with the following materials were selected for field testing on an operating geothermal well:

Camlast™ HT-2 (high temperature/oil resistant)
Camlast™ GT-3(EPDM based)
Camlast™ M1-36 (high temperature/oil resistant)

PHASE IV TESTING - OPERATING GEOTHERMAL WELL, LARDERELLO, ITALY

Full scale testing of BOP components on an operating geothermal well occurred from November 1990 to April 1991 at ENEL's Secolo #1 well in the vicinity of Larderello, Italy. Photographs 3 and 4 show an overall view of ENEL's test facility. Secolo #1 produces up to 40 tons of steam per hour at 428° F (220° C) at a pressure of 6 bars (88 psi). The steam flow has a pH of 6.54 and contains 3.49% CO2 and 3.7 ppm H2S (hydrogen sulfide gas).

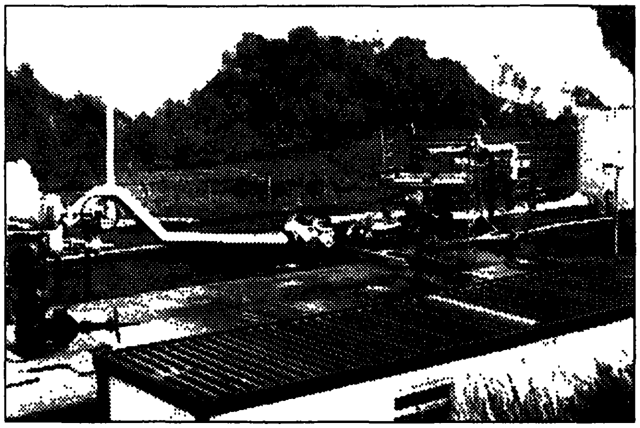


Photo 3: ENEL's Secolo #1 test facility.

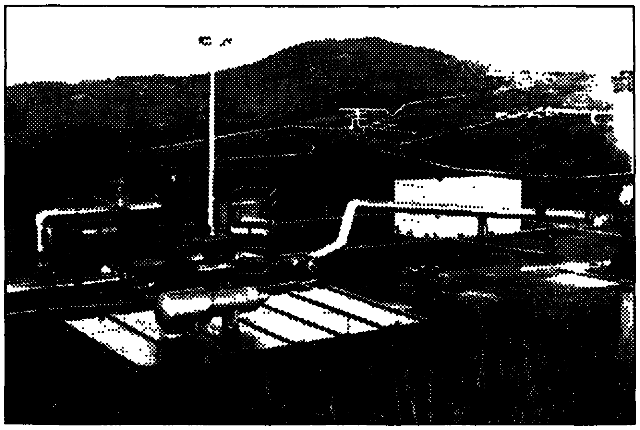
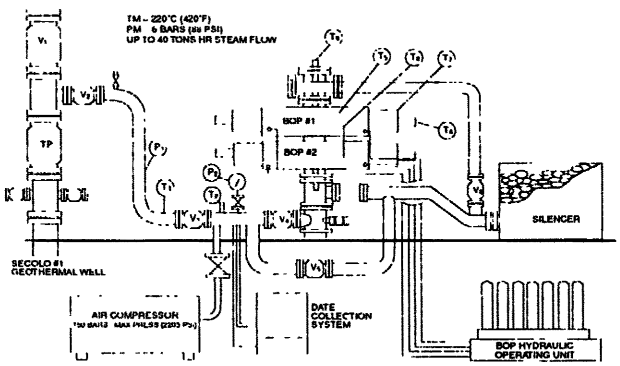


Photo 4: Another view of ENEL's #1 test facility.

The blowout preventers were provide by ENEL and consisted of a double Cameron 13-5/8"-5000 psi U type ram BOP. Because the well pressure was only 88 psi, a supplemental pressurization system was used during the 15 minute pressurization portion of the testing. An air compressor was used during pressure testing to boost the test pressure to 1800 psi. Figure 4 shows a schematic of ENEL's Geothermal Test Facility. The test BOP was fully instrumented and testing was conducted on a 24 hour per basis. The lower BOP cavity was fitted with blind packers and the upper cavity was fitted with 5" pipe packers. The 5" pipe packers were closed on a 5" mandrel during pressure testing to simulated 5" drill pipe. During the two hour thermal conditioning phase of the test cycle, BOP ram blocks were retracted to permit unrestricted steam flow through the BOP. At this time the front faces of the ram packers were exposed to the flowing steam.

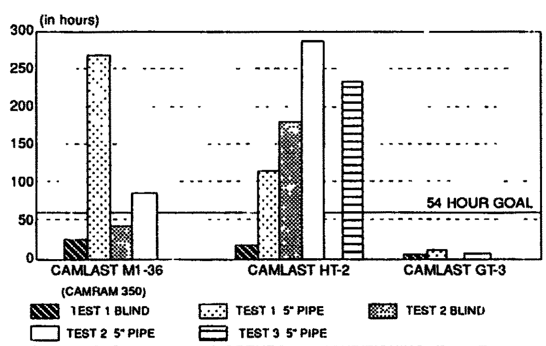


SCEMATIC OF ENEL GEOTHERMAL TEST FACILITY
FIGURE 4

RESULTS FROM GEOTHERMAL WELL TESTING

Figure 5 bar chart graphically shows the results of the geothermal well testing of the three candidate elastomeric materials. Of the high temperature elastomeric components involved in this test program, no failures were noted with the bonnet seals and connecting rod seals. When leakage did occur, it was generally confined to the packer-top seal interface located on the side of the ram block.

TEST RESULTS - GEOTHERMAL TEST SITE
LARDERELLO, ITALY - SECOLO #1 WELL



TEST CYCLE - TWO HOURS OF THERMAL CONDITIONING AT 425°F
15 MINUTE PRESSURE TEST AT 1800 psi
FIGURE 5

The EPDM based elastomer (Camram™ GT-3) ram packers and top seals did not achieve the 54 hour test goal. In the first series of tests, blind packers made of Camlast™ GT-3 completed only two pressure tests after four hours of thermal conditioning. Pipe packers (5") completed four pressure tests after nine hours of thermal conditioning. A follow-on test of blind packers completed four pressure tests after eight hours of thermal conditioning. None of the packers and top seals made of the EPDM based elastomer Camlast. GT-3 were able to achieve the 54 hour test goal. This testing duplicated our previous full scale laboratory testing. Leakage was a result of elastomer loss at the packer-top seal interface on the side of the ram blocks. See photograph 5 and 6 for details of the failure area for blind and 5" pipe packers made with Camlast™ GT-3. Bonnet seals and connecting rod seals made from the EPDM based elastomer were in satisfactory condition after the nine and eight hour thermal conditioning periods and pressure tests.

Photo 5: CAMLAST GT3, Test 1: Blind ram packer after 2 test cycles

Photo 6: CAMLAST GT3, Test 2: Pipe ram packer after 4 test cycles

The next series of tests involved our baseline material, Camlast™ elastomer compound M1-36 used in the fabrication of Camram™ 350 packers and top seals intended for high temperature oil and gas service. In the first test run, the blind packers completed 11 pressure tests after

25 hours of thermal conditioning. The 5" pipe packers were able to complete 117 pressure tests after 267 hours of thermal conditioning and exceed our 54 hour test goal. by a significant margin. In the second test run the blind packers completed 4 pressure tests after 16 hours of thermal conditioning. The 5" pipe packers completed 54 pressure tests after 115 hours of thermal conditioning. Only the 5" pipe packers were able to exceed the 54 hour test goal. Uncontrolled leakage (failure) in all cases was a result of excessive elastomer loss in the area of the packer top seal interface on the sides of the ram blocks. See photograph 7 and 8 for details of mode of failure Camram™ 350 blind and 5" pipe packers made using Camlast™ compound M1-36. Connecting rod seals and bonnet seals made from Camlast™ compound M1-36 did not leak during the testing.

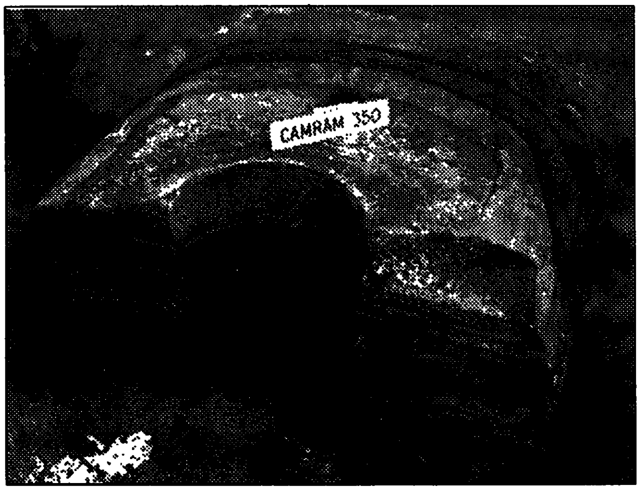


Photo 7: CAMRAM 350, Test 1: Pipe ram packer after 117 test cycles

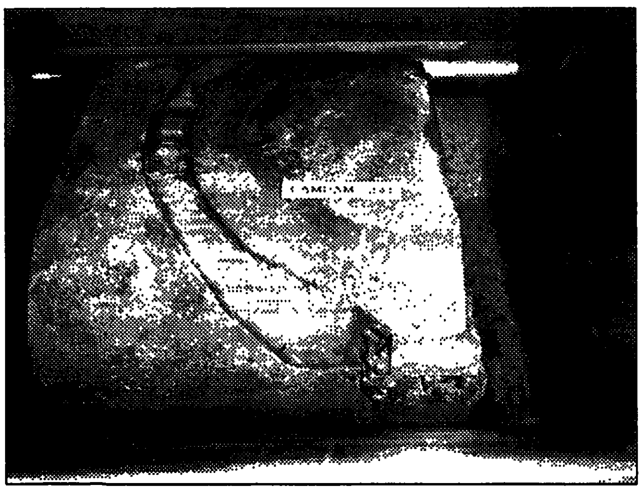


Photo 8: CAMRAM 350, Test 1: Blind ram packer after 11 test cycles

Final testing involved ram BOP components fabricated using Camlast™ HT-2 elastomer. In the first test, blind packers completed 19 pressure tests after 41 hours of thermal conditioning. The 5" pipe packers completed 41 pressure tests after 86 hours of thermal conditioning. In the second test run blind packers completed 87 pressure tests after 180 hours of thermal conditioning. The 5" pipe packers in this test completed 98 pressure tests in 288 hours of thermal conditioning. The third and final test involved the 5" pipe packer only. In this test 110 pressure tests were completed after 236 hours of thermal conditioning. In all cases, leakage (uncontrolled) was a result of excessive elastomer loss in the area of the packer-top seal interface on the side of the ram blocks. Photographs 9 and 10 show typical failure mode for blind and 5" pipe packers made with Camlast HT-2 elastomer. The bonnet seals and connecting rod seals made of Camlast. HT-2 did not leak during any of the above three tests.

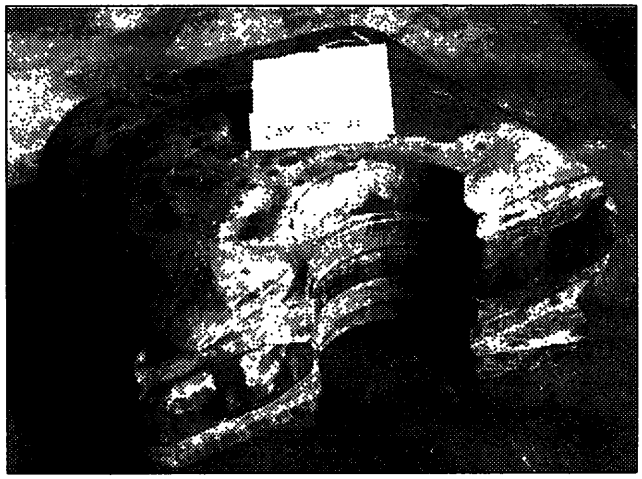


Photo 9: CAMLAST HT2, Test 2: Pipe ram packer after 98 test cycles

Photo 10: CAMLAST HT2, Test 2: Blind ram packer after 87 test cycles

The blowout preventer hydraulic operating systems did not contain any special high temperature seals, just the normal nitrile elastomer and polyester elastomer seals. BOP temperatures were monitored throughout the test program. The temperatures which were monitored were

1- the outside surface of the BOP (T_6)
2- the bonnet seal area (T_7)
3- ram packer temperature (T_9). This temperature was measured through the inside of the operating piston rod.

BOP outside surface temperatures (T_6) ranged from 128° C (262° F) to 161° C (322° F) with ambient air temperature ranging from 2° C (36° F) to 10° C (50° F). Under these same ambient temperature conditions, the temperature in the bonnet seal area ranged from 80° C (176° F) to 137° C (279° F).

The BOP inlet temperature (TR_2) ranged from 195° C (383° F) to 218° C (424° F).

CONCLUSIONS

Results of the on site testing at ENEL's Secolo #1 geothermal well indicated the best material developed and tested in this test program was Camlast™ HT-2. Both blind packers and 5" pipe packers were able to surpass the 54 hour test goal. The testing also provided us with information on an area for improvement, the interface between the top seal and ram packer. We have taken action to increase the elastomer mass in the interface area. Improved packer and top seals made with Camlast HT-2 (COT Material Specification 1066) have been provided to ENEL for follow on testing and evaluation. Testing is scheduled to be completed by the end of 1995. Cooper Oil Tool has designated ram packers and top seal made with Camlast™ HT-2 elastomer as Camram. GT/CO_2. These high temperature packers and top seal for Cameron U type ram BOPs are available from Cooper Oil Tool on a special order basis.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the cooperation and efforts of Ing. Paulo Magneschi of ENEL, Larderello Italy, and T.F. Griffin and C.C. Raines of Cooper Elastomer Technology (formerly Cameron Elastomer Technology) in the accomplishment of this project. In addition I would like to thank ENEL (Italy) for their support in this development effort.

REFERENCES

Vicic, J. C. , 1984, Testing of Polymers for Oil and Gas Applications, Energy Rubber Group, September 27, 1984, Houston Texas.

Parker, B. G. and Raines, C. C. , 1990, Development of Geothermal Capable Elastomers for Use in Ram Type Blowout Preventers, Geothermal Resources Council Transactions, Vol 14, Part I, August 1990.