

SARGENT & LUNDY
ENGINEERS
CHICAGO

Qualification of Mobil Oil Co. Greases Mobilux
EP-0, EP-1, EP-2 and
Mobilgrease 28

Prepared for Dresden - Units 2 & 3
and Quad Cities - Units 1 & 2
by
Component Qualification Division

Project No. 6896/97-00
February 20, 1989

CQD-042827
Rev. 00

8903280241 890309
PDR ADOCK 05000237
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REV.	DESCRIPTION	RESPONSIBILITY	SECTIONS	DATE
00	Original Issue	PREPARED BY: <i>Boris Pikelny</i>		2-17-89
		REVIEWER COMMENTS & SIGNATURE :		
		<i>Boris Pikelny - no comments, preliminary report</i>	Test Report	2-17-89
		REVIEWER COMMENTS & SIGNATURE :		
		<i>No comments E. Kalchauer</i>		2-20-89
		APPROVED BY: <i>Jinnappan</i>		2-20-89
		PREPARED BY:		
		REVIEWER COMMENTS & SIGNATURE :		
		REVIEWER COMMENTS & SIGNATURE :		
		APPROVED BY:		
		PREPARED BY:		
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		REVIEWER COMMENTS & SIGNATURE :		
		REVIEWER COMMENTS & SIGNATURE :		
		APPROVED BY:		

ISSUE SUMMARY

COMPONENT
QUALIFICATION
DIVISION

SARGENT & LUNDY
ENGINEERS

PROJ. NO. : 6896/97-00
CQD - 042827

1.0 PURPOSE

The purpose of this analysis is to environmentally qualify Mobil Oil Corporation's Mobilux EPO, EP1 and EP2 and Mobil grease 28 for use in Limatorque actuators at the Dresden and Quad Cities Nuclear Power Generating Stations.

2.0 REFERENCES

1. Wyle Report #17019-01, Nuclear Environmental Qualification Test Program on Mobil Greases for Limatorque Actuators, dated 02-08-89, Preliminary Report.
2. CQD-017511, CQD-017504, CQD-017510, CQD-017512 and CQD-017509, Environmental Qualification of Limatorque Actuators, Dresden - Units 2 & 3.
3. CQD-017515, CQD-017517, CQD-017514, CQD-017516 and CQD-017513, Environmental Qualification of Limatorque Actuators, Quad Cities - Units 1 & 2.
4. CQD-015890, Environmental Qualification of Mobil Greases, Dresden - Units 2 & 3.
5. CQD-015891, Environmental Qualification of Mobil Greases, Quad Cities - Units 1 & 2.
6. Letter from (D. K. Yoshida) Nutech to (Z. J. Boxer) CECO, dated 12-02-88.
7. EPRI Document No. NP-4916, "Lubrication Guide."
8. EPRI Document No. NP-4735, "Radiation Effect on Lubricants."

3.0 EQUIPMENT DESCRIPTION, LOCATION AND FUNCTION

Per References 4 and 5, Limitorque valve actuators at Dresden and Quad Cities use two types of lubricants:

- Mobilux EP Greases for actuator main gear box
- Mobil grease 28 for actuator Limitswitch gear box.

Per References 2 and 3, the following are the EQ actuators, their location in the plant, environmental conditions and operability requirements:

QUAD CITIES LIMITORQUE ACTUATORS

TAG NUMBER	LOCATION	NORMAL / ACCIDENT TEMP.	OPERATING TIME	NORMAL # / ACCIDENT RADIATION	UNIT 2	ENVIRONMENTAL ZONE (UNIT 1)
MO-1-1402-4A,B	Torus	NA/135	10 minutes	7.9E03/1.1E05	✓	2
MO-1-2301-35	HPCI Room	NA/230	1 hour	<1.0E04/<1.0E04	✓	7
MO-1-2301-36	HPCI Room	NA/230	1 hour	<1.0E04/<1.0E04	✓	7
MO-1-1001-7A-D	NE/SE Corner Room	NA/114	Continuous	<1.0E04/3.0E06	✓	6, 5
MO-1-1001-16A,B	NE/SE Corner Room	NA/114	Continuous	<1.0E04/2.3E06	✓	6, 5
MO-1-1001-18A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1001-19A,B	NE/SE Corner Room	NA/114	Continuous	<1.0E04/1.5E06	✓	6, 5
MO-1-1001-28A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1001-34A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1001-36A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1001-37A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1001-47	HP Heater Bay	NA/120	40 Seconds	4.1E05/<1.0E04	✓	10*
MO-1-1001-4A,B	NE/SE Corner Room	NA/114	Continuous	<1.0E04/1.3E06	✓	6.5
MO-1-185A,B	NE/SE Corner Room	NA/114	Continuous	<1.0E04/1.3E06	✓	6.5
MO-1/2-7507A	(Zone 37)	NA/104	Continuous	<1.0E04/2.3E05	✓	37
MO-1-1201-5	RWCU HX Room	NA/218	30 Seconds	1.2E06/<1.0E04	✓	22
MO-1-3702	Torus	NA/135	10 Minutes	7.9E03/1.1E05	✓	2
MO-1-3703	Torus	NA/135	10 Minutes	7.9E03/1.1E05	✓	2
MO-2-1001-34A	Torus	NA/135	Continuous	7.3E03/1.1E07	✓	2
MO-1-1001-63	Drywell	150/334	30 Days	1.4E06/1.0E08	✓	28 Note 1
MO-1-1301-16	Drywell	150/334	10 Minutes	2.0E06/3.3E05	✓	9
MO-1-3706	Drywell	150/334	10 Minutes	3.2E05/3.3E05	✓	1
MO-1-2301-4	Drywell	150/334	1 Hour	2.0E06/<1.0E04	✓	9
MO-1-220-1	Drywell	150/334	35 Seconds	3.2E05/<1.0E04	✓	9
MO-2-1001-34B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1-1402A,B	(Zone 27, 21)	NA/104	12 Days	<1.0E04/3.9E05	✓	27, 21
MO-1-1402-25A,B	(Zone 27, 21)	NA/104	12 Days	<1.0E04/3.9E05	✓	27, 21
MO-1-1402-38A,B	Torus	NA/135	12 Days	7.9E03/8.9E06	✓	2
MO-1-1001-5A,B	NE/SE Corner Room	NA/114	Continuous	<1.0E04/2.3E06	✓	6, 5
MO-1-1001-23A,B	(Zone 13, 21)	NA/104	Continuous	<1.0E04/9.6E05	✓	13, 21
MO-1-1001-26A,B	(Zone 13,21)	NA/104	Continuous	<1.0E04/96E05	✓	13,21
MO-1-1001-29A,B	Torus	NA/135	Continuous	7.9E03/1.1E07	✓	2
MO-1/2-7504A,B	(Zone 37)	NA/104	Continuous	<1.0E04/1.6E06	✓	37
MO-1/2-7505A,B	(Zone 37)	NA/104	Continuous	<1.0E04/1.3E06	✓	37
MO-1/2-7507B	(Zone 37)	NA/104	Continuous	<1.0E04/2.3E05	✓	37
MO-1-202-5A,B	Drywell	150/334	2 Minutes	3.2E05/6.7E04	✓	9
MO-1-2301-5	Torus	NA/285	1 Hour	7.9E03/<1.0E04	✓	2
MO-1-2301-8	Steam Tunnel	150/304	10 Minutes	4.1E05/<1.0E04	✓	10
MO-1-220-2	Steam Tunnel	150/304	35 Seconds	4.1E05/<1.0E04	✓	10
MO-1-1001-60	Steam Tunnel	150/304	<1 Minute	4.1E05/<1.0E04	✓	10
MO-1-1301-17	Steam Tunnel	150/304	10 Minutes	3.1E05/2.0E04	✓	10
MO-1-1201-2	Drywell	150/334	40 Seconds	3.2E05/2.2E04	✓	9
MO-1-1201-2	Drywell	150/334	30 Seconds	3.2E05/<1.0E04	✓	9

Note 1 The equipment will be removed from EQ program per Mr. M. Sievert (Quad Cities) and Mr. Wylie (Bechtel).

DRESDEN LIM: TORQUE ACTUATORS

TAG NUMBER	LOCATION	NORMAL / ACCIDENT TEMP.	OPERATING TIME	NORMAL * / ACCIDENT RADIATION	UNIT 3	ENVIRONMENTAL ZONE (UNIT 1)
MO-2-1402-24A,B	(Zone 28, 26)	NA/104	12 Days	<1.0E04/4.7E05	✓	28, 26
MO-2-1402-25A,B	(Zone 28, 26)	NA/104	12 Days	<1.0E04/4.9E05 <1.0E04/4.7E05 <1.0E04/5.2E05	✓	28, 26
MO-2-1402-28A,B	Torus	NA/135	12 Days	7.9E03/8.9E06	✓	2
MO-2-2301-35	HPCI Room	NA/230	1 Hour	<1.0E04/<1.0E04	✓	6
MO-2-1501-11A,B	SE/SW Corner Room	NA/114	Continuous	<1.0E04/2.1E06	✓	5, 4
MO-2-1501-21A,B	Torus	NA/135	Continuous	<1.0E04/1.7E06	✓	10, 14
MO-2-1501-27A,B	(Zone 11, 24)	NA/104	Continuous	<1.0E04/1.4E06	✓	11, 24
MO-2-1501-28A,B	(Zone 11, 24)	NA/104	Continuous	<1.0E04/1.1E06 <1.0E04/9.6E05	✓	11, 24
MO-2-1501-32A,B	SE/SW Corner Room	NA/114	Continuous	<1.0E04/2.3E06	✓	5, 4
MO-2/3-7504A,B	(Zone 30)	NA/120	Continuous	<1.0E04/3.3E06		30
MO-2/3-7505A,B	(Zone 30)	NA/120	Continuous	<1.0E04/3.3E06		30
MO-2/3-7507A,B	(Zone 30)	NA/120	Continuous	<1.0E04/2.9E05		30
MO-2-1201-2,3	(Zone 22)	NA/250	<30 Seconds	1.2E06/<1.0E04	✓	22
MO-2-1201-1	Drywell	150/334	30 Seconds	3.2E05/1.7E04		8
MO-2-1201-1A	Drywell	150/334	<30 Seconds	3.2E05/1.7E04	✓	8
MO-2-3706	Drywell	150/334	30 Seconds	3.2E05/1.7E04	✓	1
MO-2-220-1	Drywell	150/334	<35 Seconds	3.2E05/<1.0E04	✓	8
MO-2-1501-3A,B	SE/SW Corner Room	NA/114	Continuous	<1.0E04/4.4E06	✓	5, 4
MO-2-2301-4	Drywell	150/334	1 Hour	2.0E06/<1.0E04	✓	32
MO-2-202-7A,B	Drywell	150/334	2 Minutes	3.2E05/6.7E04		1
MO-2-202-5A,B	Drywell	150/334	2 Minutes	3.2E05/6.7E04	✓	8
MO-2-2301-5	Torus	NA/262	1 Hour	7.2E03/<1.0E04	✓	2
MO-2-2301-8	Steam Tunnel	150/304	1 Minute	4.1E05/<1.0E04	✓	9
MO-2-220-2	Steam Tunnel	150/304	<35 Seconds	4.1E05/<1.0E04	✓	9
MO-2-205-2-4	RWCU Pipeway	NA/250	<1 Minute	1.2E06/<1.0E04	✓	22
MO-2-1301-2	Steam Tunnel	150/304	<30 Seconds	4.1E05/<1.0E04	✓	33
MO-2-1301-3	Steam Tunnel	NA/304	<30 Seconds	<1.0E04/<1.0E04	✓	25*
MO-3-2301-3a	Torus	NA/262	1 Hour	7.9E03/<1.0E04		2
MO-2-1001-1A,B	Drywell	150/334	<40 Seconds	3.2E05/2.2E04		8
MO-2-1301-1	Drywell	150/334	<30 Seconds	2.0E06/1.7E04	✓	32
MO-2-1301-4	Drywell	150/334	<30 Seconds	3.2E05/1.7E04	✓	8
MO-3-1001-1A	Drywell	150/334	<40 Seconds	3.2E05/2.2E04		8
MO-3-1201-1	Drywell	150/334	<30 Seconds	3.2E05/1.7E04		8
MO-3-1001-1B	Drywell	150/334	<40 Seconds	3.2E05/2.2E04		8

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Hence, the worst case environment for the subject greases is as summarized below:

<u>Parameter</u>	<u>Normal Service</u>	<u>LOCA/HELB</u>
Temperature (°F)	150°F	349°F - 0 to 30 min 287°F - 30 - 70 min
Pressure	14.7 psia	70 psia
Humidity	20 - 90%	100%
Spray	-	Demineralized Water
Radiation	2.0E06 Rads	1.1E07 Rads

4.0 SIMILARITY ANALYSIS

Mobilux EP-0, EP-1, and EP-2 are used in Limitorque operators at Dredsen and Quad Cities stations. Per Reference 1, only EP-1 and EP-2 were tested to the postulated environmental conditions. Mobilux EP-0 is qualified by material similarity to the tested EP-1 and EP-2 formulations. Per Mobil Oil Corporation Product Data Sheets, all three greases have the same base oil thickening agents and additives. Typically the composition is as given below:

<u>CHARACTERISTIC</u>	<u>MOBILUX EP0</u>	<u>MOBILUX EP1</u>	<u>MOBILUX EP2</u>
NLGI No.	0	1	2
Structure	smooth	smooth	smooth
Soap Type	Unleaded Lithium 12 Hydroxystearate		
Color	Medium brown	Medium brown	Medium brown
Penetration at 77°F (25°C)			
Unworked, min-max.	350-390	305-345	260-300
Worked 60 strokes, min-max.	355-385	310-340	265-295
Dropping Point, min °F (C)	340 (171)	340 (171)	350 (171)
Mineral Oil %	92	89	87
Viscosity of Oil			
SUS at 100°F	900	900	900

SUS at 210°F	70/80	70/80	70/80
cSt at 40°C	170	170	170
cSt at 100°C	13.0/16.0	23.0/26.0	13.0/16.0
Timken OK Load. min.lb (kg)	40 (18)	40 (18)	40 (18)
Rust Test ASTM D 1743	Pass	Pass	Pass
Bomb Oxidation Stability #PSI Drop max.	10	10	10

The degradation of greases depend largely upon their base oil, gelling agents and additives. Since all three have the same ingredients, and vary only in the amount of additives the effect of environmental factors on the overall property of the products can be considered almost the same when subjected to the same environmental conditions. Both EP-0 and EP-1 have the same viscosity, dropping point, and performance characteristics which show that the products should perform similarly when subject to postulated environmental conditions. The presence of varying composition of additives do not affect the thermal and radiation tolerance of the base oil. Hence, the testing performed on EP-1 and EP-2 can be extended for the qualification of EP-0

5.0 PERFORMANCE REQUIREMENTS/ACCEPTANCE CRITERIA

The ability of Limitorque actuators, packed with the subject greases, to provide torque and/or thrust required to actuate simulated valve load to either the open or closed position constitutes the acceptance criteria. The actuators performance will be judged by the stroke timing and by the value of the motor current.

6.0 QUALIFICATION JUSTIFICATION

Qualification of the subject greases is based upon the type testing performed to simulate actual environmental conditions. The test data presented in Reference 1 report is evaluated against the performance and environmental requirements. The test sequence is as follows:

- Penetration and Dropping Point Tests (ASTM D-217/D-566) and Mobil Oil Co infrared (IR) Test

- Normal Radiation Exposure
- Thermal Aging
- Accident Radiation Exposure
- Penetration, Dropping Point and IR Tests
- Cyclic Aging
- DBE Simulation Test
- Penetration, Dropping Point and IR Tests.

6.1 Penetration, Dropping Point and Mobil IR Test

- ASTM D-217 - Cone penetration of lubricating grease - Measurement of the grease consistency by penetration of a standard cone.
- ASTM D-566 - Dropping point of lubricating greases - Measurement of the dropping point of the grease as an indication of the maximum temperature that it can be exposed to without liquification or oil separation.
- The tests were performed on grease samples in both unworked and worked conditions. At least 60 strokes were given prior to performing worked test.
- IR testing was performed on worked samples at Mobil Oil Corporation. (Results of IR testing are not currently included in Reference 1).

6.2 Normal Radiation Exposure

The greases were placed into static containers and irradiated to a level of 2.2E06 rads gamma air equivalent which envelops the required radiation dose during normal service operation.

6.3 Thermal Aging

Per Reference 1, Section 10, the samples of greases were thermally aged at 250°F for 100 days.

6.4 Accident Radiation Exposure

The grease samples were irradiated to a level of 1.1E07 rads at a rate of 1.0E06 rads/hr using a Co-60 source. This meets the plant's requirement for 40 years plus accident.

6.5 Cycle Aging

After thermal aging, radiation and the ASTM tests, the grease samples were placed in each of three Limatorque actuators. The Mobilux EPO, EP1 and EP2 were used in the main gear case and Mobil Grease 28 was used in the Limitswitch gear case. The actuators were then cycle tested to simulate at least 120 full stroke and return cycles.

6.6 Accident Simulation

After cycle aging, the actuators were placed in an environmental chamber and subjected to an accident test simulating the 70 minute DBA requirement as given below:

349°F	for	30 minutes
287°F	for	40 minutes

The Limatorque actuators (including lubricants) inside drywell are required to remain operable for up to one hour after any DBA. The worst

case peak temperature during any DBA for which the lubricants are required to be qualified is 334⁰F in the drywell. This value has been enveloped by the test with a margin of 15⁰F.

The actuators outside drywell are required to remain operable for up to one year after any DBA. The only harsh parameter during a LOCA is radiation. The HELB parameter for these actuators is less severe than that of the inside drywell actuators and; therefore, is enveloped by the test.

6.7 Pressure

The peak pressure during the accident test was 71 psia. This pressure exceeds the postulated worst case pressure of 62 psia in the drywell. Pressure qualification is; therefore, considered acceptable.

6.8 Humidity

During the accident test, the actuators with greases were subjected to steam/100% RH environment for 70 minutes, which simulated the actual installation requirement.

6.9 Demineralized Water Spray

The spray requirement for Dresden and Quad Cities Stations is demineralized water spray and is manually initiated. During the accident test, a demineralized water spray was initiated after 30 minutes into the test and continued for the remaining 40 minutes of the test. The spray rate used was 0.15 gpm/ft².

6.10 Submergency

There are no submergence requirements for the Limatorque actuators (with lubricants) at Dresden and Quad Cities.

6.11 Performance Evaluation

The actuators, lubricated with thermally aged and irradiated greases, were cycled for 120 full cycles before the accident simulation test. The values of motor current and the timing of each stroke were recorded (Appendix VI of Reference 1). The actuators cycling was performed at a constant calculated load (Appendix IV of Reference 1).

6.12 The Greases Life Evaluation

In the calculation (provided with Reference 6), the activation energy values were determined for each type of grease at temperatures ranging from 155°F to 265°F. These calculations are based on the oxidation testing performed in accordance with ASTM D942 by Mobil Oil Corporation. Since the activation energy values vary as temperatures vary, it is not practical to use Arrhenius formula for determination of qualified life of the greases.

Reference 7 (Page 9) and Reference 8 (Page 505) indicate that the aging of lubricants follows to the 10°C rule which states that life doubles with every 10°C temperature decrease.

With thermal aging at 250°F for 100 days, the qualified life of the greases, based on 10°C rule, will be at least 8 years at 150°F. This value of grease life corresponds to the greases' life curves limits provided on Pages 8, 9 and 10 of Reference 6.

7.0 CONCLUSION

The preliminary test report (Reference 1) and its evaluation indicate that the tested greases met the acceptance criteria and are qualified to the intent of NUREG-0588 with a qualified life of at least 8 years.