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Tschabold

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[54] **LUBRICATION SYSTEM FOR GRINDING MILL OR THE LIKE**

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[73] Assignee: **Allis Chalmers Corporation**, Milwaukee, Wis.

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[52] **U.S. Cl.**...............**184/6.4,** 241/DIG. 20, 308/122

[51] **Int. Cl.**..**F16n 29/02**

[58] **Field of Search** .....184/6.1, 6.3, 6, 6.4; 241/176, 241/285, DIG. 20; 308/122, 73

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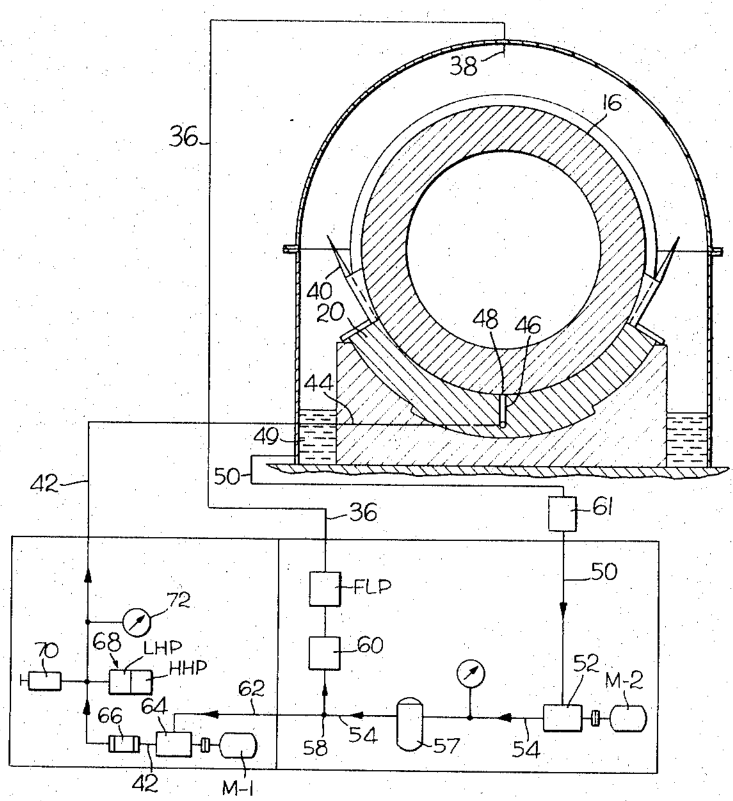
Attorney—Robert C. Sullivan et al.

[57] **ABSTRACT**

In combination with a grinding mill or the like having a trunnion supported by a stationary bearing structure to define a "free bearing" which permits axial contraction of the grinding mill during the cooling-off period after mill shutdown, a high pressure lubrication system including a high pressure pump for applying hydrostatic pressure to the "free bearing" during the mill cooling-off period whereby to "float" the trunnion in the stationary bearing structure, and timing means activated upon shutdown of the grinding mill to automatically provide "on-off" cycling of the high pressure lubricating pump.

8 Claims, 5 Drawing Figures



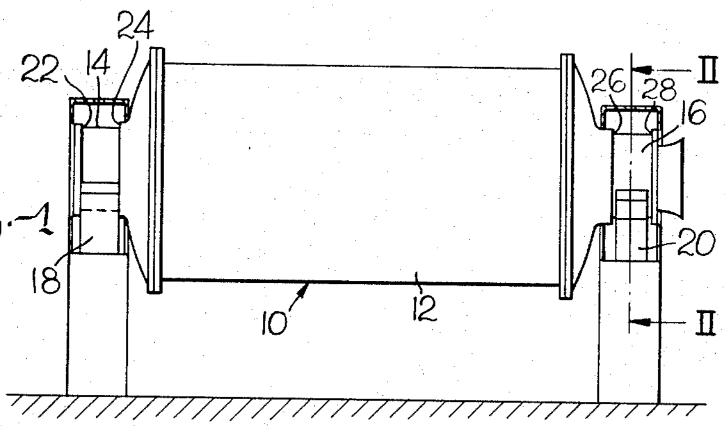

24
22
14
26
28
II
16
20
18
10
12
II

Fig. 1

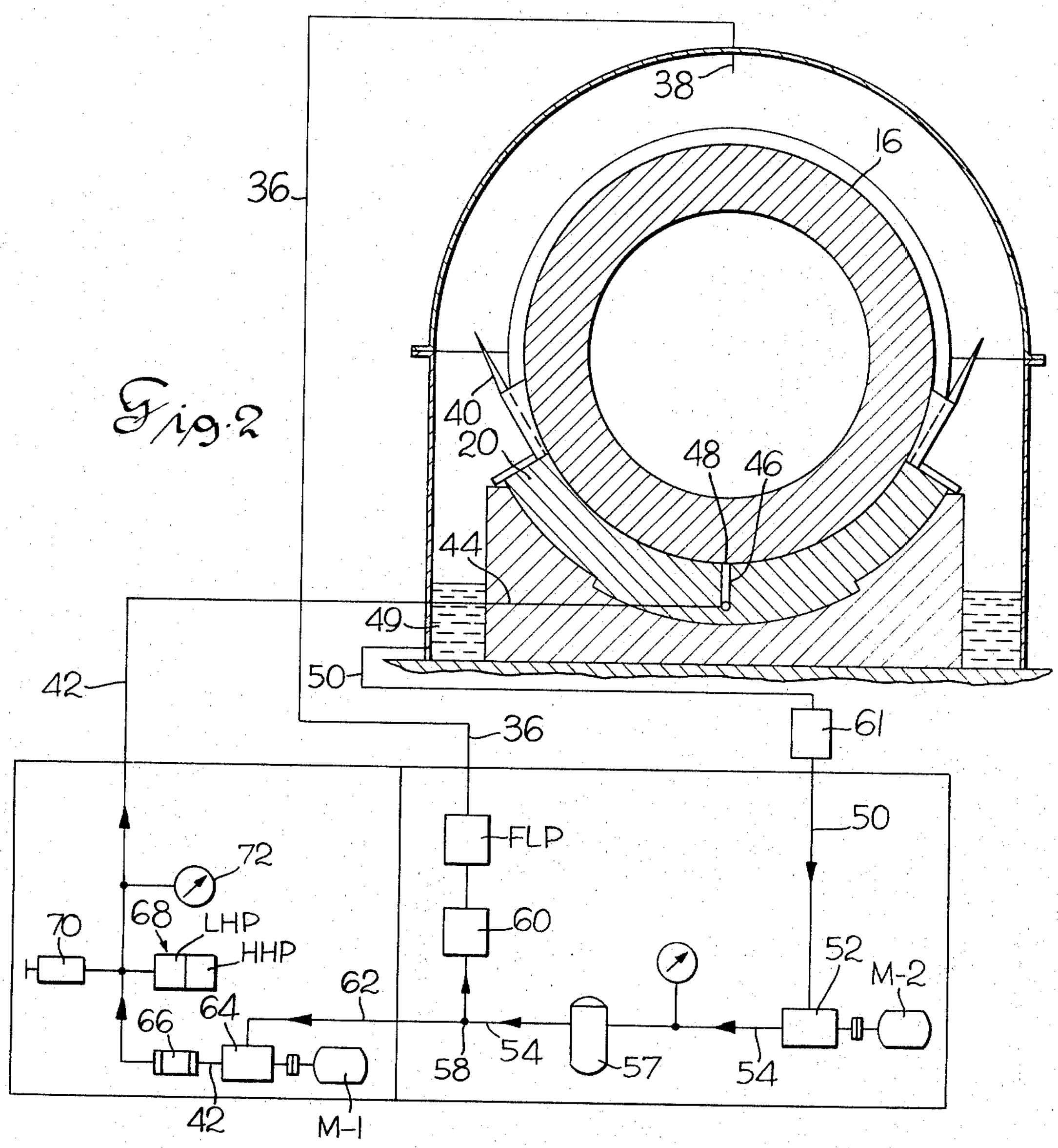

38
16
36
40
20
48
46
44
49
50
42
36
61
50
FLP
72
60
70
68
LHP
HHP
52
M-2
62
66
64
58
54
57
54
42
M-1

Fig. 2

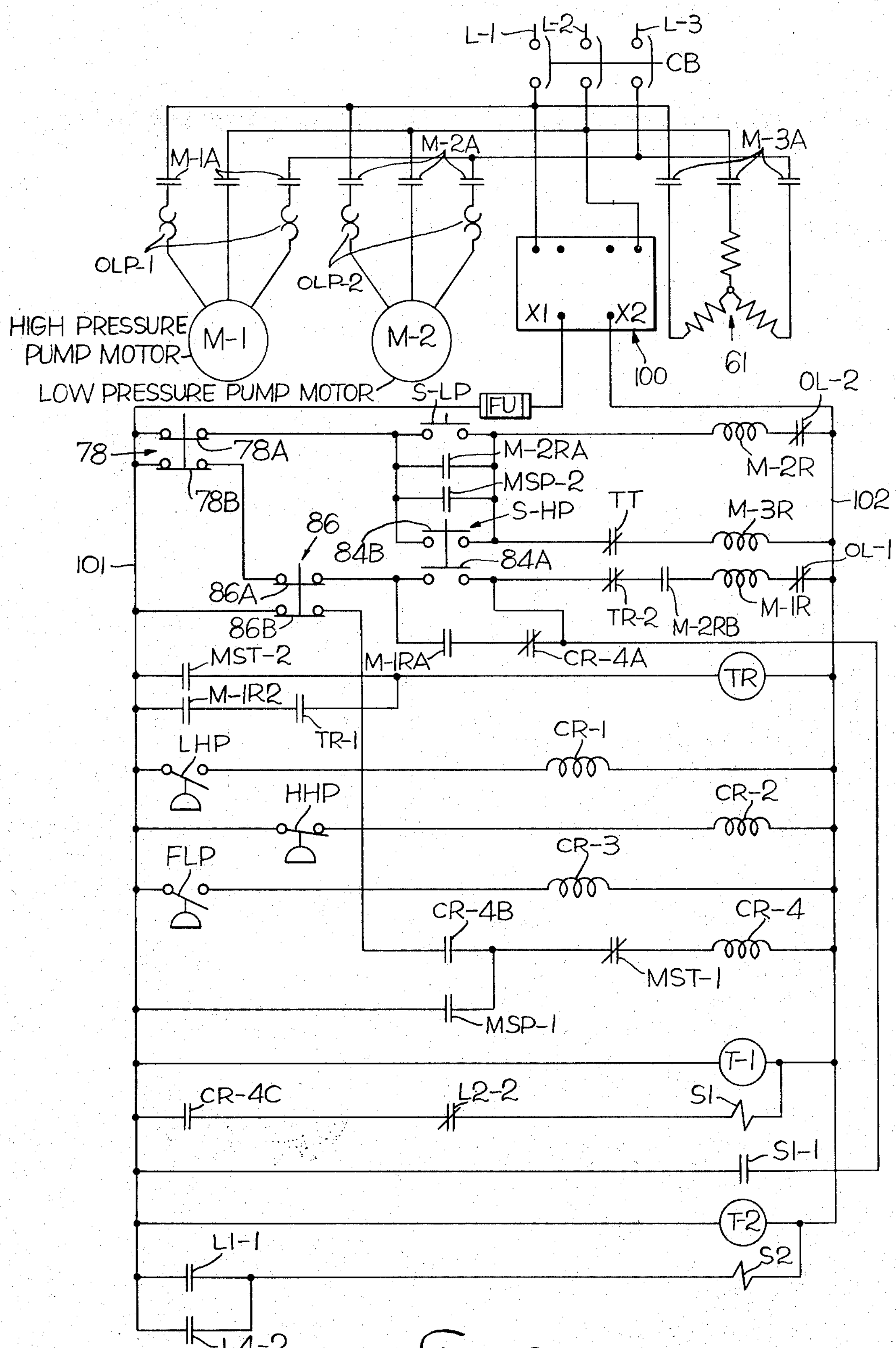

L-1
L-2
L-3
CB
M-1A
M-2A
M-3A
OLP-1
OLP-2
HIGH PRESSURE PUMP MOTOR
M-1
M-2
LOW PRESSURE PUMP MOTOR
X1
X2
100
61
S-LP
FU
OL-2
78
78A
78B
M-2RA
M-2R
MSP-2
S-HP
TT
M-3R
102
86
84B
84A
OL-1
101
86A
86B
TR-2
M-2RB
M-1R
M-1RA
CR-4A
MST-2
TR
M-1R2
TR-1
LHP
CR-1
HHP
CR-2
FLP
CR-3
CR-4B
CR-4
MST-1
MSP-1
T-1
CR-4C
L2-2
S1
S1-1
T-2
L1-1
S2
L4-2

Fig.3

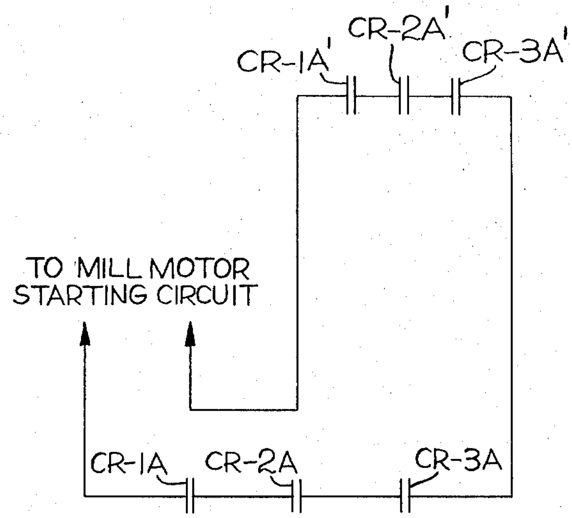

CR-1A'
CR-2A'
CR-3A'
TO MILL MOTOR STARTING CIRCUIT
CR-1A
CR-2A
CR-3A

Fig. 4

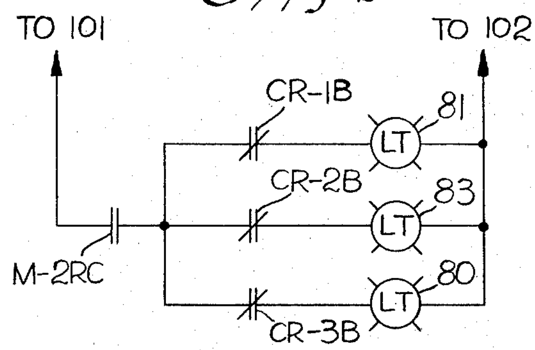

TO 101
TO 102
CR-1B
81
LT
CR-2B
83
LT
M-2RC
80
LT
CR-3B

Fig. 5

LUBRICATION SYSTEM FOR GRINDING MILL OR THE LIKE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a lubrication system for rotary drums of the type having bearing journals integral therewith, such as grinding mills having integral trunnions which are supported for rotation by stationary bearings at opposite ends of the grinding mill.

The invention will be described as embodied in a lubricating system for a grinding mill but it will be understood that the invention is applicable to lubrication systems for analogous rotating machinery.

2. Description of the Prior Art

Grinding mills are conventionally provided with trunnions extending from opposite ends of the rotary grinding mill drum and adapted to be supported for rotation by stationary bearings. Such trunnions are generally supported by the stationary bearing only beneath the lower surface portion of the rotating trunnion, with the trunnions being open and uncovered on the upper peripheral surface thereof.

The bearing arrangement at one end of the grinding mill structure has generally been known in the art as the "held bearing" since the rotating journal at the "held" end includes peripheral flanges which are closely spaced relative to the opposite axial ends of the stationary bearing thereby permitting only a very small axial movement of the rotatable journal or trunnion relative to the stationary bearing structure at the "held" bearing. The bearing structure at the opposite end of the grinding mill is known as the "free bearing" since the peripheral flanges on the rotatable journal member are spaced from the corresponding axial ends of the stationary bearing by a greater distance than in the case of the "held" bearing. Thus, the "free" bearing will permit free axial contraction of the mill during the mill "off" period when the mill is cooling to ambient temperature after shutdown.

During the operation of a grinding mill, the mill heats up due to the frictional forces inside the mill produced by the grinding operation. Heat is also generated at the trunnion and stationary bearing structure. As a result of this heat the grinding mill expands in length while in operation and contracts in length during the cooling-off period after shutdown.

It has been well known in the prior art to apply high pressure lubrication which may be of the order of magnitude of 1500–2500 pounds per square inch, for example, beneath the surface of the journal or trunnion, particularly at the "free" bearing end of the grinding mill, whereby to apply hydrostatic lubrication beneath the trunnion of the mill at shutdown. This high pressure hydrostatic lubrication "floats" the trunnion in the bearing to permit free axial contraction of the mill as the mill cools down after shutdown, preventing metal-to-metal contact between the trunnion and the stationary bearing which would cause scoring of the metal bearing surfaces if the high pressure lubricant were absent.

It has been known in the prior art to provide a control arrangement which automatically turns on the high pressure lubricating system to apply the hydrostatic lubrication at the "free" bearing as just described upon mill shutdown. However, such control systems of the

prior art depended upon a manual shutoff operation by the operator, and the high pressure lubrication system would continue to operate until manually shut off by the operator. Sometimes, the operator would fail to shut off the high pressure lubricant pump in accordance with operating instructions with the result that the high pressure lubricating pump would run for an excessively long time after the mill had cooled down after shutdown.

This excessive length of operation of the high pressure lubricant pump without shutdown thereof would frequently result in mechanical failure of the pump. In addition to the continuous operation of the pump as a cause of pump failure, a contributing factor to the pump failure may be the fact that the high pressure lubricant being pumped may contain certain small size contaminants which it is impractical from a cost or commercial standpoint to attempt to filter out but which ultimately may cause damage to the high pressure pump, particularly when the high pressure pump is operated for excessive lengths of time. In accordance with the present invention, the contaminant problem may still exist but is reduced in seriousness due to the fact that the time element of the duty cycle of the high pressure pump after mill shut-down has been greatly reduced to provide an acceptable pump life.

It has also been known in the prior art to instruct the operators of such grinding mills or the like after shutdown of the mill to periodically turn on the high pressure lubricating system at the "free" bearing for short periods during the mill shutdown while the mill is cooling off. However, experience has proven that such instructions are frequently not adhered to by operating personnel.

STATEMENT OF THE INVENTION

Accordingly, it is an object of the present invention to provide an automatic lubricating system for grinding mills or the like in which a cycling on-off operation of the high pressure lubrication system is initiated automatically upon shutdown of the grinding mill or the like whereby to insure a continuous and adequate supply of high pressure lubricant to the "free" bearing structure of the grinding mill during the cooling-off period after mill shutdown during which the mill is contracting in length.

It is another object of the invention to provide a lubrication system for the "free" bearing of a grinding mill or the like during the cooling-off period after shutdown of the mill, which is more efficient than prior art lubrication systems for this purpose, and which insures a minimum of wear on the high pressure lubricating pump to thereby increase the life of the high pressure lubricating pump.

In achievement of these objectives, there is provided in accordance with an embodiment of this invention the combination with a grinding mill or the like having a trunnion supported by a stationary bearing structure to define a "free bearing" which permits axial contraction of the grinding mill during the cooling-off period after mill shutdown, a high pressure lubrication system including a high pressure pump for applying hydrostatic pressure to the "free bearing" during the mill cooling-off period whereby to "float" the trunnion in the stationary bearing structure, and timing means activated upon shutdown of the grinding mill to automatically provide "on-off" cycling of the high pressure lubricating pump.

Further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view in axial elevation of a grinding mill showing the "held" bearing at one end and the "free" bearing at the other end thereof;

FIG. **2** is a flow diagram of the low pressure and of the high pressure lubricating systems for the trunnion bearing at one end of the grinding mill, combined with a view in vertical section along the line II—II of FIG. **1**;

FIG. **3** is a schematic diagram of the electrical control circuitry for the low pressure and high pressure lubricating systems of FIG. **2**;

FIG. **4** is a schematic circuit diagram of the electrical interlock arrangement between the lubrication control system of FIG. **3** and the motor starting circuit of the grinding mill being lubricated; and

FIG. **5** is a schematic diagram showing the electrical warning circuit controlled by the control circuitry of FIG. **3**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and more particularly to FIG. **1**, there is shown a rotary grinding mill generally indicated at **10** comprising a rotary drum **12**, a feed trunnion **14** at one end of the mill and a discharge trunnion **16** at the opposite end of the grinding mill. Mill **10** is rotatably driven by suitable drive means, not shown. The trunnions **14** and **16** are supported for rotation by stationary bearing structures **18** and **20**, respectively. It will be noted that the inlet or feed trunnion **14** is provided with a pair of axially spaced peripheral flanges **22** and **24** which are respectively contiguous the opposite axial ends of the stationary bearing structure **18**. The clearance between each of the respective peripheral flanges **22** and **24** with respect to the facing surface of the corresponding end wall of the stationary bearing structure **18** is very small and is of such value as to substantially prevent any axial movement of trunnion **14** relative to stationary bearing structure **18**. Thus, the trunnion or journal **14** and the associated stationary bearing **18** referred to in the art as the "held" bearing.

On the other hand, the peripheral flanges **26** and **28** of discharge trunnion **16** are spaced from the corresponding end faces of the stationary bearing structure **20** by an axial distance such as to permit some degree of axial movement such as 0.4–1.0 inch, for example, of trunnion **16** relative to the stationary bearing structure **20** during the axial contraction of the mill in the cooling-off period after shutdown. Hence, the trunnion or journal **16** and the associated stationary bearing structure **20** are referred to in the art as the "free" bearing.

It will be noted (see FIG. **2**) that the respective trunnions **14** and **16** are supported beneath only a part of the peripheral extent of the under surface of the respective trunnions **14** and **16**, such as 120°, with the major portion of the peripheral surface including the upper peripheral surface of the respective trunnion members being uncovered and open.

A separate low pressure lubricating system and a separate high pressure lubricating system including separate low pressure and high pressure pumps and separate electrical control circuits therefor are provided for the bearing structures at each end of the grinding mill. In general, the lubricating systems at the two ends of the mill are essentially duplicates of each other, insofar as piping, pumps, and high pressure and low pressure flow circuits are concerned. The system at the "free" bearing **16–20** differs from the system at the "held" bearing **14–18** principally in that the on-off cycling system and cycling control circuit used for the high pressure lubrication system at the "free" bearing after mill shutdown is not employed at the "held" bearing **14–18**. Instead, at the "held" bearing the low pressure and high pressure lubrication pump systems are operated at shutdown of the mill for a predetermined length of time, such as 15 minutes, and then shut off permanently until the mill is being prepared for restarting.

The low pressure and high pressure lubrication systems at the "free" bearing **16–20** will be described, it being understood that much of this descriptive matter also applies to the low pressure and high pressure lubrication systems at the "held" bearing structure **14–18** as qualified by the discussion in the preceding paragraph.

As best seen in FIG. **2**, the low pressure lubricant is supplied to the journal or trunnion **16** by a conduit **36** which extends to an outlet **38** vertically positioned above trunnion **16**. During the operation of the grinding mill, the low pressure lubricant passes outwardly through discharge outlet **38** and falls onto the upper surface of the rotating trunnion **16**, the lubricant then flowing down the surface of the rotating trunnion **16** and into a scoop or wedge **40** contiguous the rotating surface of trunnion **16**, from whence the low pressure lubricating oil is drawn by the rotating trunnion into the interface between the rotating trunnion **16** and the upper or facing surface of the stationary bearing member **20**.

The high pressure lubricant passes through a conduit **42** which is connected to a lateral passage **44** in the stationary bearing structure **20**. The lateral passage **44** communicates with a vertical passage **46** which terminates at an opening **48** through which the high pressure lubricant is admitted at the interface between trunnion member **16** and the stationary bearing structure **20**. The low pressure oil and the high pressure oil both are returned from a common sump **49** by conduit **50** to the inlet of the low pressure pump as will be explained more fully.

The return conduit **50** from the oil sump is connected through a heater **61** to the inlet of low pressure pump **52**, which is driven by low pressure pump motor **M-2**. Pump **52** delivers low pressure oil to conduit **54**. The output conduit **54** from low pressure pump **52** is connected to a filter **57**. The oil flow in conduit **54** of the low pressure system continues past a junction **58** and through a spring biased resistance check valve **60** and thence through a flow switch indicated at FLP. After passing through flow switch FLP, the low pressure oil flows through conduit **36** which delivers the low pressure oil to the upper surface of trunnion **16**. Low pressure pump **52** may typically deliver oil at a pressure such as 50 pounds per square inch at the pump outlet.

An input conduit **62** to high pressure pump **64** is connected to the low pressure line **54** at junction **58**, so that some of the lubricant from the low pressure system will pass through the line **62** to the inlet end of high pressure pump **64**. High pressure pump **64** is driven by an electric motor M–**1**. The function of the resistance check valve **60**, to which reference was previously made, is to provide a sufficient back pressure in the conduits **54** and **62** to ensure that oil from the low pressure system is available at all times to the high pressure lubrication system is and when high pressure pump **64** is started up as will be explained hereinafter. When high pressure pump **64** is operating, the oil is directed from pump **64** at a pressure which may be of the order of magnitude of 1500 to 2500 pounds per square inch, for example. The oil passes from pump **64** through the output line **42** in series with check valve **66** which prevents reverse flow of oil into high pressure pump **64**. A dual pressure switch, generally indicated at **68**, is connected to high pressure line **42** downstream of check valve **66**. Dual pressure switch **68** includes a switch indicated at LHP, which closes a normally open electrical contact when the pressure of the lubricant in the high pressure system reaches a predetermined minimum value (see the electrical schematic diagram of FIG. 3); dual pressure switch **68** also includes a switch designated at HHP which operates a normally closed electrical contact to open position when the pressure in the high pressure conduit **42** rises above a predetermined maximum value (see schematic electrical diagram of FIG. 3). Pressure relief valve **70** is also connected to the high pressure line **42** and a pressure gauge **72** is connected to the high pressure line **42**. As previously explained, conduit **42** delivers the high pressure lubricant to the interface between the trunnion **16** and the stationary bearing **20**.

DESCRIPTION OF ELECTRICAL CIRCUITRY AND OPERATION THEREOF

Referring now to FIG. **3**, it will be seen that the high pressure lubrication pump motor M–**1** and the low pressure pump motor M–**2** are connected to electrical power through a circuit breaker CB. The three power lines L–**1**, L–**2** and L–**3** are connected to high pressure pump motor M–**1** each respectively through a normally open contact M–**1**A, controlled by starting relay coil M–**1**R. Similarly, each of the power lines L–**1**, L–**2** and L–**3** is connected to the low pressure pump motor M–**2** in series with a normally open contact M–**2**A. Overload protective devices OLP–**1** and OLP–**2** are connected in the input power connections to the respective motors M–**1** and M–**2**. In addition, an overload protective device OL–**1** protects relay coil M–**1**R and an overload protective device OL–**2** protects relay coil M–**2**R from excessive control circuit current. Sealing-in contact M–**2**RA is controlled by starter relay coil M–**2**R. Heater **61** is connected to the electrical power lines L–**1**, L–**2** and L–**3** in series with normally open contacts M–**3**A which are controlled by relay coil M–**3**R. The control circuitry is connected across control power lines **101**–**102** which derive electrical power through a protective device or fuse FU from the secondary side of a step-down transformer generally indicated at **100**.

Starting Up Operation of Lubrication System

Assume that the grinding mill or the like is shut down and that is desired to start up the grinding mill. Before starting the grinding mill up it is necessary that the lubrication system be started in operation. Hence, the first step is to manually momentarily close low oil pressure starter button S–LP to initiate operation of the low pressure lubricating system. It will be noted that closure of low pressure system start button S–LP energizes relay coil M–**2**R which is connected across the control power lines **101** and **102** in series with pushbutton contact **78**A of the pump system stop pushbutton **78** and in series with the overload contact OL–**2**. Both the contacts **78**A and OL–**2** are closed at the time of startup of the low pressure system, and hence a circuit is completed to energize relay coil M–**2**R when pushbutton switch S–LP is momentarily closed. The energization of relay coil M–**2**R closes normally open contact M–**2**RA, which is a sealing-in contact for relay coil M–**2**R. Hence relay coil M–**2**R remains energized after the momentarily closed pushbutton S–LP is released to open position.

Energization of relay coil M–**2**R also closes the normally open contacts M–**2**A in the three input power lines to low pressure pump motor M–**2** so that the low pressure pump motor M–**2** begins operation to cause low pressure pump **52** to pump low pressure oil through the low pressure lubrication circuit. Energization of relay coil M–**2**R also closes normally open contact M–**2**RB in the circuit of relay coil M–**1**R which controls the high pressure pump motor as will be explained hereinafter. Thus, the closure of contact M–**2**RB "sets up" the circuit of relay coil M–**1**R to permit energization of relay coil M–**1**R when the start pushbutton S–HP for the high pressure pump circuit is closed.

Energization of relay coil M–**2**R also results in the energization of relay coil M–**3**R which controls heater **61**, since, as seen in FIG. **3**, a circuit is completed through sealing-in contact M–**2**RA and thermostat contact TT which is closed when the oil is at a temperature requiring heating. Thus, relay coil M–**3**R is energized to close normally open contacts M–**3**A in the electrical supply circuit of heater **61** to thereby energize heater **61** to heat the oil to a desired temperature. When the oil reaches a predetermined temperature, the thermostat contact TT opens to deenergize relay coil M–**3**R and thereby open contacts M–**3**A in the electrical input circuit of heater **61**.

When the oil flow in the low pressure lubrication circuit reaches a predetermined minimum flow value, flow switch FLP closes and thereby energizes relay coil CR–**3**. Energization of relay coil CR–**3** closes contact CR–**3**A in the circuit of the mill motor starter (FIG. **4**). It will be noted that the circuit of the mill motor starter is connected in series with normally open contacts CR–**1**A, CR–**2**A, and CR–**3**A, which are associated with the control circuit of the "free" bearing and also in series with corresponding normally open contacts CR–**1**A', CR–**2**A', and CR–**3**A', which are associated with the control circuit for the "held" bearing at the opposite end of the grinding mill or the like. Before the mill motor can be started, all of the normally open contacts just enumerated must be closed. The proper minimum low pressure oil flow condition at the "free" mill bearing will close the contact CR–3A as just described.

Energization of relay coil CR–3 by closure of low pressure oil flow contact FLP also causes opening of normally closed contact CR–3B to deenergize warning signal light **80** (FIG. **5**). When warning signal light **80** is extinguished, it indicates to the operator that the low pressure oil flow condition is satisfactory or normal.

Before starting up the grinding mill, the low pressure lubrication system is always started up first as just described and is permitted to run for a predetermined time for oil heat-up at the discretion of the operator, such as 2 hours, for example, before starting up the high pressure lubrication system, and before starting up the mill.

Before mill start-up, it is necessary to pump up or "-float" the trunnion in the stationary bearing structure, so that when the mill does start to rotate, the trunnion will already be "floating" and there will be sufficient lubricant between the bearing surfaces to prevent any damage to the bearing. If only the low pressure lubrication system were employed at mill start-up, there would be sufficient time lag in the hydrodynamic feed of the lubricant between the bearing surfaces produced by rotation of the trunnion to possibly permit damage to the bearing surfaces. By using the high pressure lubrication system prior to mill start-up and for a short period (such as 5 to 15 minutes) after mill start-up, a supply of lubricant is assured between the rotating trunnion and the stationary bearing without depending on the hydrodynamic lubricating action produced by rotation of the trunnion.

To start the operation of the high pressure lubrication pump system, which is usually done shortly before startup of the grinding mill, the high pressure start pushbutton S–HP is closed to momentarily close contact **84**A. Momentary closure of contact **84**A completes the energization circuit of relay coil M–1R to cause the closing of the contacts M–1A in the energization circuit of high pressure pump motor M–**1**. The energization circuit of relay coil M–1R also includes contact **78**B of pump system stop switch **78**, contact **86**A of high pressure pump system stop switch **86**, contact TR–2 of timing relay TR, normally open contact M–2RB, and normally closed overload contact OL–1. Since all of the contacts just mentioned are closed at the moment that high pressure pump start pushbutton contact **84**A is momentarily moved to closed position, relay coil M–1R is energized as just described and seals itself in through contact M–1RA to complete a sealing-in or holding circuit for relay coil M–1R. The sealing-in or holding circuit for relay coil M–1R also includes normally closed contact CR–4A, controlled by relay CR–4. Contact CR–4A is in its normally closed position when the high pressure lubrication start button is moved to closed position before mill start-up since, as will be explained hereinafter, relay CR–4 can only be energized to open normally closed contact CR–4A by the closing of the mill stop pushbutton.

Since high pressure pump motor M–1 is now operating due to the energization of relay coil M–1R and is driving high pressure pump **64** to pump high pressure oil through the high pressure lubrication circuit, although the mill has not yet been started up in operation, the dual pressure switch **68** will be activated by the high pressure lubricant condition in high pressure line **42** to cause contact LHP indicating normal high pressure condition in the high pressure lubricant line to close. Also assuming that an excessive high pressure condition does not exist in high pressure line **42**, the normally closed contact HHP will remain closed. Relay coil CR–1 will be energized by the closure of pressure switch LHP and relay coil CR–**2** will remain energized by the normally closed condition of pressure switch contact HHP. Energization of relay coil CR–1 closes the normally open contact CR–1A in the circuit of the mill motor starter; and similarly, the energization of relay coil CR–2 closes the normally open contact CR–2A in the circuit of the mill motor starter (See FIG. **4**). As previously explained, contact CR–3A controlled by relay CR–3 of the low pressure control circuit is already closed, and hence all three of the normally opened contacts CR–1A and CR–2A and CR–3A are now closed. Assuming that the corresponding contacts CR–1A', and CR–2A', and CR–3A' at the bearing of the opposite end of the mill and which are respectively responsive to corresponding conditions as those which actuate contacts CR–1A, CR–2A, and CR–3A, are similarly closed at this time, the mill motor can be energized by closure of a pushbutton switch in the mill motor starter circuit, as would be obvious to one skilled in the art, to start up the grinding mill motor (not shown).

From the foregoing it can be seen that an interlock circuit is provided which prevents starting up of the mill motor unless the relay CR–3, which is responsive to normal lubricant flow conditions in the low pressure lubricant flow circuit is energized, and also unless the relays CR–1 and CR–2, which are responsive to proper pressure conditions in the high pressure lubricant system, are energized. Furthermore, proper lubricant flow and pressure conditions must be in effect at both mill bearings before the mill motor starting circuit can be energized.

Energization of relay coils CR–1 and CR–2 will also cause the opening of the normally closed contacts CR–1B and CR–2B, respectively, in the energization circuit of warning signal lights **81** and **83**, respectively, thereby indicating that the pressure conditions in the high pressure lubrication circuit are normal. It will also be noted in FIG. **5** that a normally open contact M–2RC which is operated to closed position by energization of relay coil M–2R of the low pressure pump motor circuit, is connected in series with the parallel-connected contacts CR–1B, CR–2B, and CR–3B in the energization circuit of warning lights **80**, **81**, **83**. Thus, warning lights **80**, **81**, **83** cannot be lighted at all unless low pressure pump M–2 is in operation.

With the high pressure and low pressure lubrication systems in operation as just described, and with the interlock contacts CR–1A, CR–2A, CR–3A, etc. of FIG. **4** closed, the mill may now be started up by the following procedure: close the mill motor "Start" pushbutton which closes appropriate relay means (not shown) to energize the mill drive motor which will remain in operation until the mill motor "Stop" pushbutton is closed to cause interruption of the energization circuit of the mill motor. The mill motor "Start" pushbutton includes normally closed momentary contact MST–1 in the circuit of relay coil CR–4 and normally open momentary contact MST–2 in the circuit of timing relay TR as auxiliary contacts operated by the closure of the mill motor "Start" switch or pushbutton.

Movement of the mill motor start switch to closed position will momentarily open normally closed contact MST–1 to deenergize relay operating coil CR–4 if coil CR–4 is not already deenergized at this time.

Deenergization of operating coil DR–4 will open seal-in contact CR–4B to maintain relay coil CR–4 deenergized after momentary contact MST–1 recloses. Deenergization of relay coil CR–4 will also close normally closed contact CR–4A in the sealing-in circuit of relay M–1R which controls the operation of high pressure lubrication pump motor M–1.

Closure of the mill motor start switch will also momentarily close normally open contact MST–2, which is one of the auxiliary contacts of the mill start switch, to energize timing relay TR. Timing relay TR operates two contacts; namely, a normally open contact TR–1 in the sealing-in circuit of timing relay TR and a normally closed timed contact TR–2 in the energization circuit of relay coil M–1R which controls the operation of high pressure lubrication pump motor M–1.

When timing relay TR is energized by the closure of contact MST–2, timing relay TR seals itself in through the series connection of normally open contact M–1R2 which is closed at this time since control relay M–1R is energized at this moment, and also through normally open sealing in contact TR–1 which has been moved to closed position by the energization of timing relay TR. Timing relay TR is so constructed that after a predetermined energization interval such as 15 minutes, for example, it will open timed contact TR–2 momentarily. This momentary opening of timed contact TR–2 will deenergize relay coil M–1R and cause a dropping out of the sealing-in contact M–1RA which is operated by relay M–1R. Even through timed contact TR–2 is reclosed a short interval after its opening by the deenergization of timing relay TR, reclosure of contact TR–2 will not reenergize the circuit of relay coil M–1R which controls the high pressure lubrication pump since the sealing-in contact M–1RA will still be open, and there will thus be no energization circuit completed for relay coil M–1R.

Timing relay TR may be of the type manufactured by Paragon Electric Company, Inc., 1600 Twelfth Street, Two Rivers, Wisconsin 54241, under the designation of Model 500–132–0, and described in 500 Series-Bulletin 426:5–70" of Paragon Electric Company, Inc. Paragon Electric Company, Inc., is a subsidiary of AMF Incorporated, 261 Madison Avenue, New York, New York 10016.

As a result of the deenergization of relay coil M–1R at the end of the period such as 15 minutes timed by the timing relay TR, the high pressure lubrication pump motor M1 will cease operation and the mill which is now in operation will continue operating but only with the low pressure lubrication pump motor M–2 in operation.

The deenergization of the relay M–1R will also result in the opening of contact M–1R–2 in the sealing-in circuit of the timing relay TR, thereby resulting in the deenergization of timing relay TR. Deenergization of timing relay TR will also result in the opening of the sealing-in contact TR–1, restoring that contact to its normally open position. When relay TR becomes deenergized, he timing contact TR–2 in the circuit of relay coil M–1R reverts to its normally closed position.

DESCRIPTION OF THE OPERATION OF THE CONTROL SYSTEM UPON SHUTDOWN OF THE GRINDING MILL

Assume that it is desired to shut down the grinding mill. The mill motor stop pushbutton (not shown except for contacts in lubrication control circuits) is pushed causing the rotating mill drum **10** to come to a stop and also causing a momentary closing of the normally open auxiliary contacts MSP–1 and MSP–2 which are carried by the mill motor stop pushbutton. Momentary contact MSP–1 is in the circuit of relay coil CR–4, and momentary contact MSP–2 is in the circuit of relay coil M–2R which controls the operation of the low pressure lubrication pump motor M–2.

Momentary closure of mill stop pushbutton contact MSP–1 will energize relay coil CR–4 which will close sealing-in contact CR–4B to seal-in relay coil CR–4 in a circuit which also includes high pressure lubrication pump motor stop pushbutton contact **86B** and normally closed momentary contact MST–1 of the mill motor start pushbutton, both of which are closed at this moment. Closure of auxiliary contact MSP–2 by the closure of the mill motor stop switch will energize relay coil M–2R to thereby energize the low pressure lubrication pump motor M–2 if that motor is not already energized at the time the mill motor stop switch is actuated to closed position. Relay coil M–2R, when energized, will close the following contacts: (1) Normally open contact M–2R–A in the sealing-in circuit of relay M–2R; (2) Normally open contact M–2RB in the circuit of relay M–1R; and (3) Normally open contact M–2RC in the circuit of the warning signal lights (FIG. 5).

Energization of control relay coil CR–4 by the momentary closure of the mill motor stop switch auxiliary contact MSP–1 as previously described will result in the opening of the normally closed contact CR–4A in the sealing-in circuit of relay coil M–1R which controls high pressure lubrication pump motor M–1, with the result that as long as relay coil CR–4 is energized, the energization path of relay coil M–1R from control power lines **101** to **102** must include contact S1–1 associated with timer TM–1.

Energization of relay coil CR–4 will also close normally open contact CR–4C in the circuit of solenoid S–1 associated with timer TM–1. Energization of solenoid S–1 begins the timing operation of timer TM–1. Solenoid S–1 is also in series with normally closed contact L2–2 which is operated by timer TM–2. Energization of solenoid S–1 will instantaneously close normally open contact S1–1 which completes a circuit from control power line **101** to control power line **102** through closed contacts TR–2, M–2RB, relay coil M1–R and normally closed overload contact OL–1 to thereby energize relay coil M–1R which will close contacts M–1A in the energization circuit of the high pressure lubrication pump motor M–1 to thereby start up and cause operation of the high pressure pump motor M–1. Starting up of the high pressure pump motor M–1 will drive high pressure lubrication pump **64** to supply high pressure lubricant in hydrostatic lubricating relation to the free trunnion **16** to thereby "float" the free trunnion while the mill is shut down, permitting the mill to contract as it cools off without metal-to-metal contact between the trunnion and the stationary bearing which supports the trunnion.

The control circuit of FIG. **3** includes timers TM–1 and TM–2. Timer TM–2 includes as components thereof a timing motor T–1, a solenoid S–1, and contacts S1–1 and L1–1. Timer Tm–2 includes as components thereof a timing motor T–2, a solenoid S–2, and contacts L2–2 and L4–2.

At the end of a predetermined time after the energization of solenoid S–1, such as two minutes, timer TM–1 will momentarily close contact L1–1 to energize solenoid S–2 of timer TM–2 to begin the timing action of timer TM–2. Immediately upon the energization of solenoid S–2 of timer TM–2, the solenoid S–2 of timer TM–2 will (1) seal itself in by closure of sealing-in contact L4–2; and (2) will open normally closed contact L2–2 in the circuit of solenoid S–1 of timer TM–1. Opening of contact L2–2 will deenergize solenoid S–1 and permit contact S1–1 in the circuit of relay coil M–1R to open, thereby deenergizing relay coil M–1R and causing high pressure lubrication pump motor M–1 to stop running.

At the end of a predetermined time such as 30 minutes following the shutdown of high pressure lubrication pump motor M–1, timer TM–2 operates to (1) cause contact L2–2 in the circuit of solenoid S–1 of timer TM–1 to revert to its normally closed position to thereby reenergize solenoid S–1; and (2) to reopen sealing-in contact L4–2 to thereby deenergize solenoid S–2 of timer TM–2.

With solenoid S–1 reenergized at the end of the predetermined time such as 30 minutes, contact S1–1 recloses and completes the circuit through relay coil M–1R to again energize high pressure lubrication pump motor M–1 for the predetermined "on" period such as 2 minutes, at the end of which "on" period, timer TM–1 will again momentarily close contact L1–1, in the circuit of solenoid S–2 will result in the reopening of contact L2–2 in the circuit of solenoid S–1 to again result in the opening of the contact S1–1 to again deenergize solenoid M–1R which again results in the shutting down of high pressure pump motor M–1.

The "ON-OFF" cycling of the high pressure pump at the "free bearing" during the cooling-off period after shutdown will provide a sufficiently thick film of oil during the "on" period of the high pressure lubrication pump (such as 2 minutes) to provide a sufficient lubrication film at the interface between the trunnion **16** and the stationary bearing **20** during the "off" period of the pump, for example, 30 minutes. The oil film at the interface is gradually "squeezed" out by the weight of the trunnion, but is replenished during the next "on" period of the high pressure lubrication pump before being diminished below a safe value. The relative lengths of the "on" and "off" times of the cycling operation can be so adjusted as to ensure that there is always a sufficient film of oil at the interface of the trunnion and the stationary bearing during the cooling off period of the grinding mill after shut-down.

Timers TM–1 and TM–2 are commercially available and are manufactured by Paragon Electric Company, Inc., 1600 Twelfth Street, Two Rivers, Wisconsin 54241, U.S.A., a subsidiary of AMF Incorporated, 261 Madison Avenue, New York, New York 10016. Timer TM–1 is MOdel No. 500 and timer TM–2 is Model No. 501, as described in Paragon Electric Company Bulletin No. 426:5–70, and in Paragon Electric Company Catalog No. 497:12–70, Page 10.

The ON-OFF cycle of the high pressure lubrication pump motor M–1 as controlled by timers TM–1 and TM–2, with a predetermined "on" time of motor M–1 such as 2 minutes, and a predetermined "off" time of motor M–1 such as 30 minutes, will continue indefinitely unless interrupted in one of the following ways:

1. By momentarily pushing high pressure lubricating pump stop pushbutton **86**, pushbutton contacts **86A** and **86B** are momentarily opened. The momentary opening of pushbutton contact **86B** of pushbutton **86** deenergizes the circuit of relay coil CR–4, opening up sealing-in contact CR–4B of relay coil CR–4, and also opening contact CR 4C in the circuit of solenoid S–1. Since solenoid S–1 is thus deenergized, contact S1–1 remains open and cannot be cycled alternately to closed and to open position by the action of timers TM–1 and TM–2, as previously explained to energize relay coil M–1R and hence energize high pressure pump motor M–1. The momentary opening of contact **86A** of high pressure pump stop pushbutton **86** also opens the circuit of relay coil M–1R to also cause a dropping out of sealing-in contact M–1RA. Thus, even though normally closed contact CR–4A recloses with the deenergization of relay CR–4, the uncycled energization path of relay M–1R is open due to the opening of sealing-in contact M–1RA. Hence, both the uncycled path and the cycled path of energization of relay coil M–1R have been opened, resulting in deenergization of high pressure lubrication pump motor M–1.

It will be noted that there are two pump stop pushbuttons, namely pump stop pushbutton **78**, which includes contacts **78A** and **78B**, and pump stop pushbutton **86**, which includes contacts **86A** and **86B**. Actuation of pump stop pushbutton **78** to open contacts **78A** and **78B** causes both the high pressure pump motor M–1 and low pressure pump motor M–2 to stop. Actuation of pump stop pushbutton **86** to open contacts **86A** and **86B** causes only high pressure pump motor M–1 to stop.

2. The ON-OFF cycling of high pressure lubrication pump motor M–1 can also be terminated by pushing the mill motor start pushbutton to momentarily open normally closed auxiliary contact MST–1 carried by the mill motor start pushbutton. Opening of contact MST–1 will deenergize relay coil CR–4 and open normally open contact CR–4C in the circuit of solenoid S–1 of timer TM–1. Deenergization of solenoid S–1 by the opening of contact CR–4C will cause cycling contact S1–1 in the energization circuit of relay coil M–1R to remain open, thereby preventing ON-OFF cycling as previously described. Also normally closed contact CR–4A in the circuit of relay coil M–1R will close, permitting sealing-in of coil M–1R when it is energized. However, closure of the mill motor start pushbutton will initiate the energization of timing relay TR, as ex-

plained earlier in the specification, due to the momentary closing of contact MST-2 carried by the mill motor start pushbutton, and timing relay TR will cause high pressure pump motor M-1, if already in operation such that normally open contact M-1R2 is closed, to operate on an uncycled basis for a predetermined time such as 15 minutes, after which it will interrupt the energization circuit of pump motor M-1. If the high pressure pump motor M-1 is not operating with concurrent closure of contact M-1R2 in the circuit of timing relay TR when the mill motor start pushbutton is closed, the mill will not start because the pressure switch interlock contacts CR-1A and CR-2A are not closed in the energization circuit of the mill drive motor.

The following is a recapitulation of the various relays in the lubrication control circuit at the "free" bearing **16–20** and of the contacts which they control:

1. Relay coil M-1R controls the following contacts:
   a. Normally open contacts M-1A in the circuit of high pressure pump motor M-1. Contacts M-1A are operated to closed position by the energization of relay coil M-1R and move to open position when relay coil M-1R is deenergized.
   b. Normally open contacts M-1RA and M-1R2 are respectively moved to closed position by the energization of relay coil M-1R and move to open position when relay coil M-1R is deenergized.
2. Relay Coil M-2R controls the following contacts:
   a. Normally open contacts M-2A of the low pressure pump motor M-2 are operated to closed position by the energization of relay coil M-2R and move to open position when relay coil M-2R is deenergized.
   b. Normally open contacts M-2RA, M-2RB and M-2RC are respectively moved to closed position by the energization of relay coil M-2R and respectively move to open position upon the deenergization of relay coil M-2R.
3. Relay coil M-3R controls normally open contacts M-3A in the circuit of heater **61**. When relay coil M-3R is energized, contacts M-3A move to closed position, and when relay coil M-3R is deenergized, contacts M-3A move to open position.
4. Relay coil CR-1 controls normally open contact CR-1A (FIG. **4**) and normally closed contact CR-1B (FIG. **5**).

When relay coil CR-1 is energized, contact CR-1A closes and contact CR-1B opens, when relay coil CR-1 is deenergized, contact CR-1A opens and contact CR-1B closes.

5. Relay coil CR-2 controls normally open contact CR-2A (FIG. **4**) and normally closed contact CR-2B (FIG. **5**). When relay coil CR-2 is energized, contact CR-2A closes, and contact CR-2B opens when relay coil CR-2 is deenergized, contact CR-2A opens and contact CR-2B closes.
6. Relay coil CR-3 controls normally open contact CR-3A (FIG. **4**) and normally closed contact CR-3B (FIG. **5**). When relay coil CR-3 is energized, contact CR-3A closes and contact CR-3B opens; when relay coil CR-3 is deenergized, contact CR-3A opens and contact CR-3B closes.
7. Relay coil CR-4 controls normally closed contact CR-4A, and normally open contacts CR-4B and CR-4C. When relay coil CR-4 is energized, normally closed contact CR-4A opens and normally open contacts CR-4B and CR-4C close; when relay coil CR-4 is deenergized, normally closed contact CR-4A closes and normally open contacts CR-4B and CR-4C open.

From the foregoing detailed description of the present invention, it has been shown how the objects of the invention have been obtained in a preferred manner. However, modifications and equivalents of the disclosed concepts such as readily occur to those skilled in the art are intended to be included within the scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In combination, a rotary grinding mill mounted for rotation, means for rotating said mill, a trunnion forming part of and rotatable with said grinding mill, stationary bearing means supporting said trunnion for rotation, a lubrication system including a high pressure pump, fluid conduit means connecting the output of said high pressure pump to the interface between said trunnion and said stationary bearing means for applying high pressure lubricant between said trunnion and said bearing means upon mill shutdown whereby to "-float" said trunnion in said bearing means, an electric drive motor in driving relation to said high pressure pump, electrical control circuitry for said lubrication system, and control means forming a part of said electrical control circuitry and being actuated upon shutdown of said grinding mill to cause a cyclic ON-OFF operation of said electric drive motor and thus of said high pressure pump whereby to cyclically pump high pressure lubricant to the interface between said trunnion and said stationary bearing means, said control means including means for controlling said energization of the electric drive motor for said high pressure pump, said means for controlling said energization of said electric drive motor being connected to electric power prior to start-up of the grinding mill and for a predetermined time after start-up of the grinding mill in a normal circuit path, said control means comprising means actuated upon shutdown of the grinding mill for interrupting said normal circuit path and for connecting said means for controlling the energization of said electric drive motor to electrical power through an alternative circuit path and comprising timing means for cyclically and repetitively closing and then interrupting said alternative circuit path whereby to cause said cyclic ON-OFF operation of said high pressure pump.

2. The combination defined in claim **1** in which said lubrication system includes a low pressure pump for applying low pressure lubrication to said trunnion and to said bearing means.

3. The combination defined in claim **2** including conduit means connecting the output of said low pressure pump to the input of said high pressure pump whereby said high pressure pump derives its supply of lubricant from said low pressure pump, and means forming part of said electrical control circuitry for causing said low pressure pump to be in operation whenever said high pressure pump is in operation.

4. The combination defined in claim **1** in which said electrical control circuitry includes additional control means actuatable to stop the cyclic ON-OFF operation of said high pressure pump.

5. A lubrication system for a rotary grinding mill of the type having a trunnion forming a part of and rotatable with said grinding mill and a stationary bearing means supporting said trunnion for rotation, said lubrication system including a high pressure pump, fluid conduit means adapted to connect the output of said high pressure pump to the interface between said trunnion and said stationary bearing means for applying high pressure lubricant between said trunnion and said bearing means upon mill shutdown whereby to "float" said trunnion in said bearing means, an electric drive motor in driving relation to said high pressure pump, electrical control circuitry for said lubrication system, and control means forming a part of said electrical control circuitry and adapted to be actuated upon shutdown of said grinding mill to cause a cyclic ON-OFF operation of said electric drive motor and thus of said high pressure pump whereby to cause said high pressure pump to cyclically pump high pressure lubricant to the interface between said trunnion and said stationary bearing means, said control means including means for controlling the energization of said electric drive motor for said high pressure pump, said means for controlling the energization of said electric drive motor being adapted to be connected to electric power prior to start-up of the grinding mill and for a predetermined time after start-up of the grinding mill in a normal circuit path, said control means comprising means adapted to be actuated upon shutdown of the grinding mill for interrupting said normal circuit path and for connecting said means for controlling the energization of said electric drive motor to electrical power through an alternative circuit path and comprising timing means for cyclically and repetitively closing and then interrupting said alternative circuit path whereby to cause said cyclic ON-OFF operation of said high pressure pump.

6. A lubrication system as defined in claim **5** which includes a low pressure pump adapted to apply low pressure lubrication to said trunnion and to said bearing means.

7. A lubrication system as defined in claim **6** including conduit means connecting the output of said low pressure pump to the input of said high pressure pump whereby said high pressure pump derives its supply of lubricant from said low pressure pump, and means forming part of said electrical control circuitry for causing said low pressure pump to be in operation whenever said high pressure pump is in operation.

8. A lubrication system as defined in claim **5** in which said electrical control circuitry includes additional control means actuatable to stop the cyclic ON-OFF operation of said high pressure pump.

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