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(54) **METHOD AND APPARATUS FOR  
MONITORING AND ON-DEMAND  
LUBRICATING OF INDUSTRIAL VALVES**

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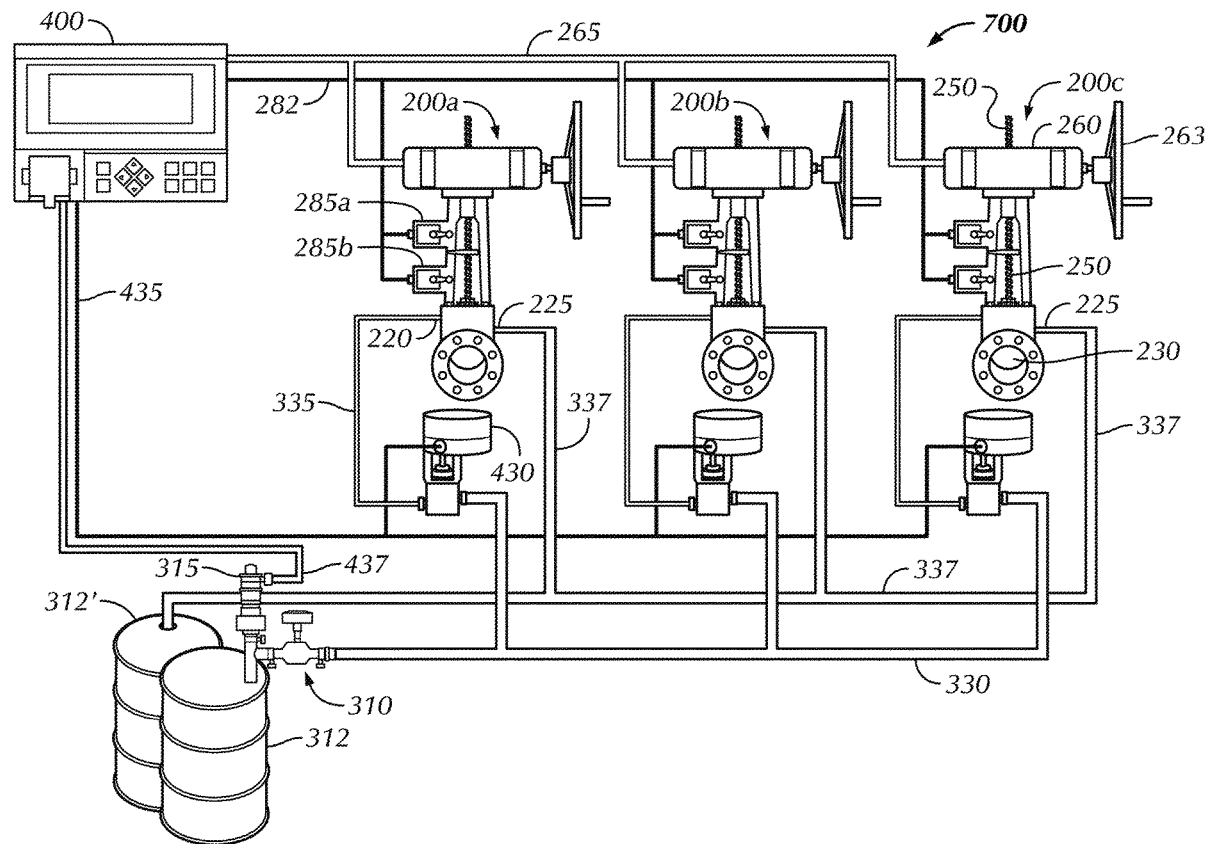
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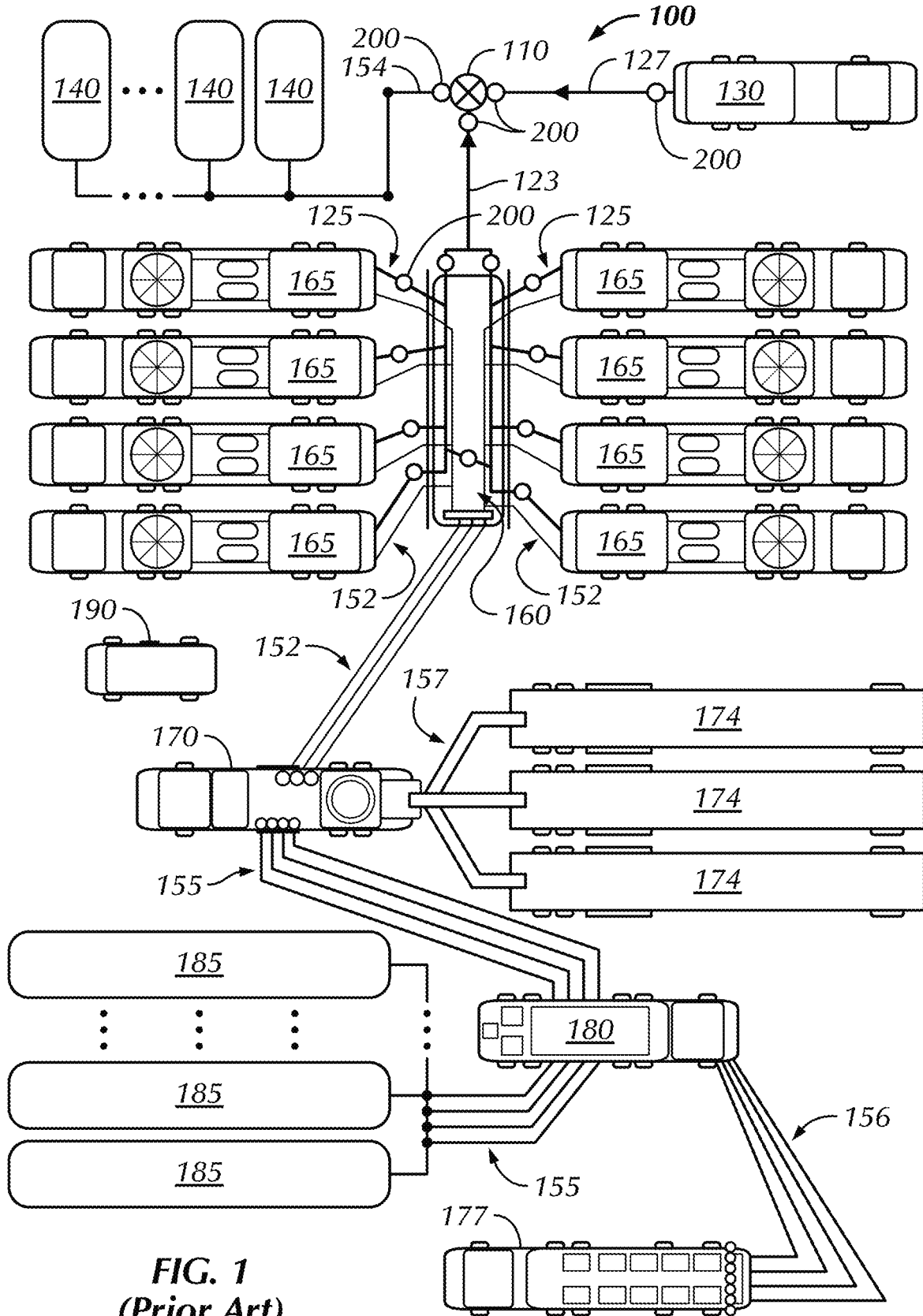
(57) **ABSTRACT**

A method of monitoring industrial valve actuation and maintaining an industrial valve by lubricating it on-demand and in coordination with in-service valve operations through an automated system eliminating downtime and/or exposure of personnel to hazardous environments through centralized lubricant supply and spent fluid collections.

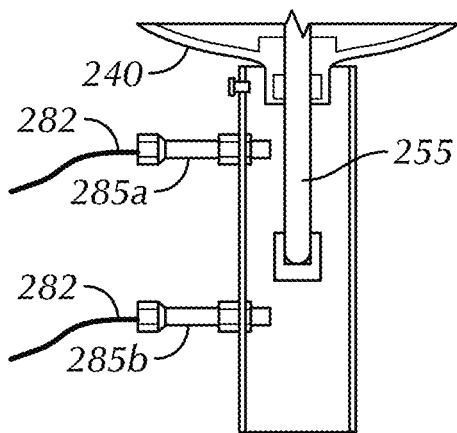
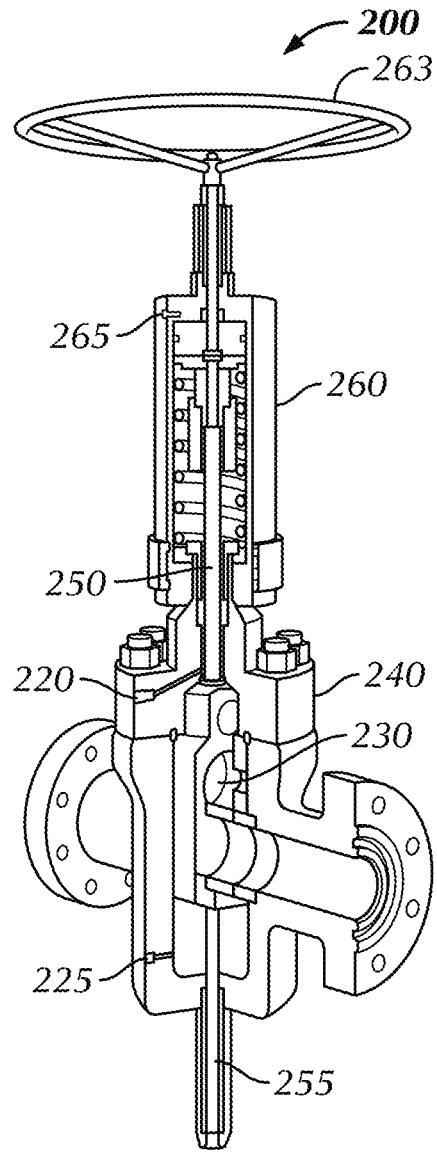
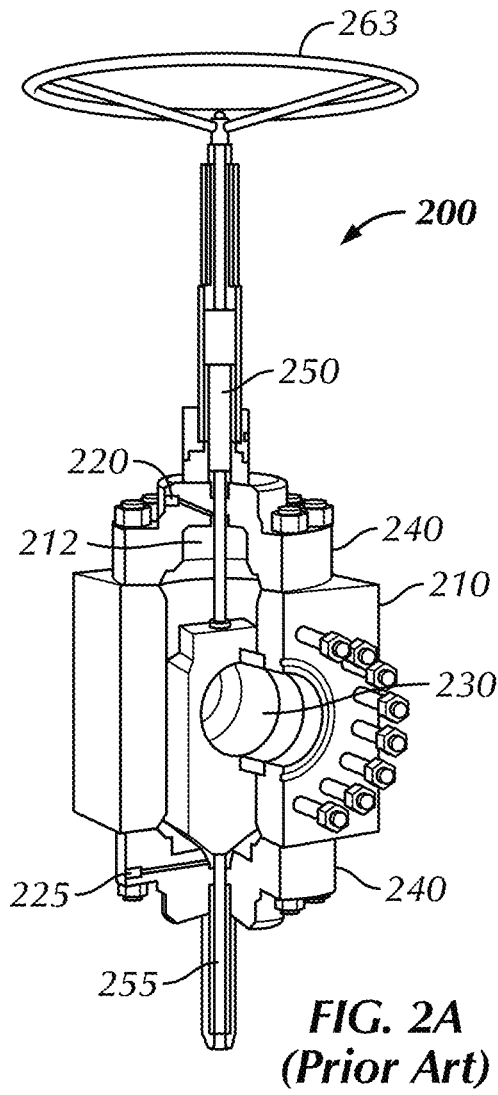
**Related U.S. Application Data**

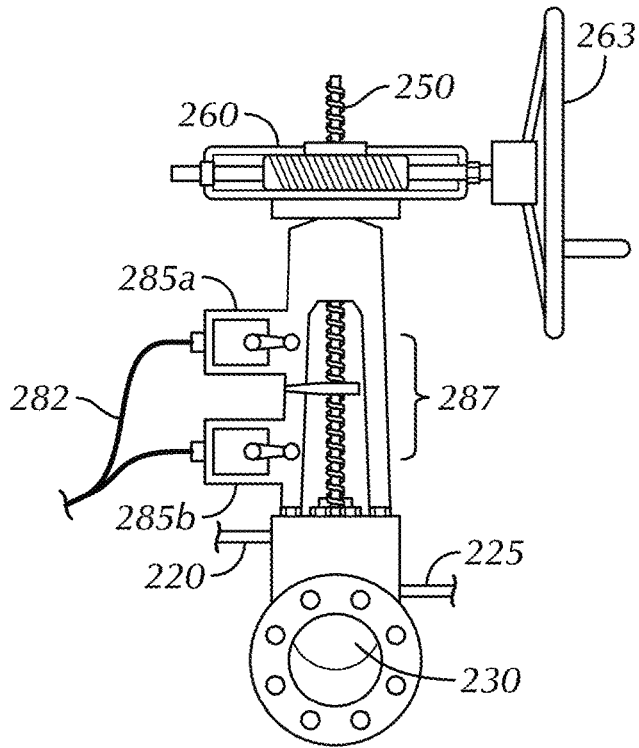
(60) Provisional application No. 62/825,342, filed on Mar. 28, 2019.



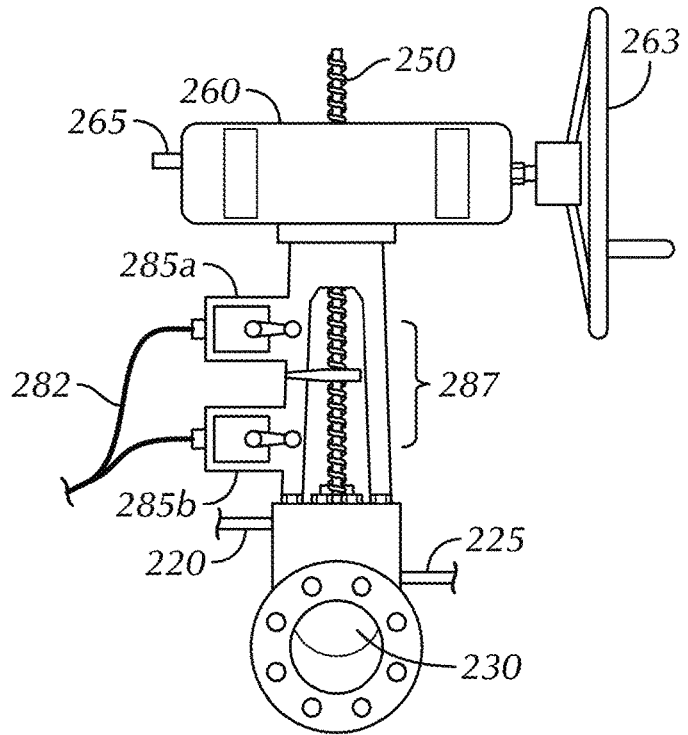


**FIG. 1**  
**(Prior Art)**

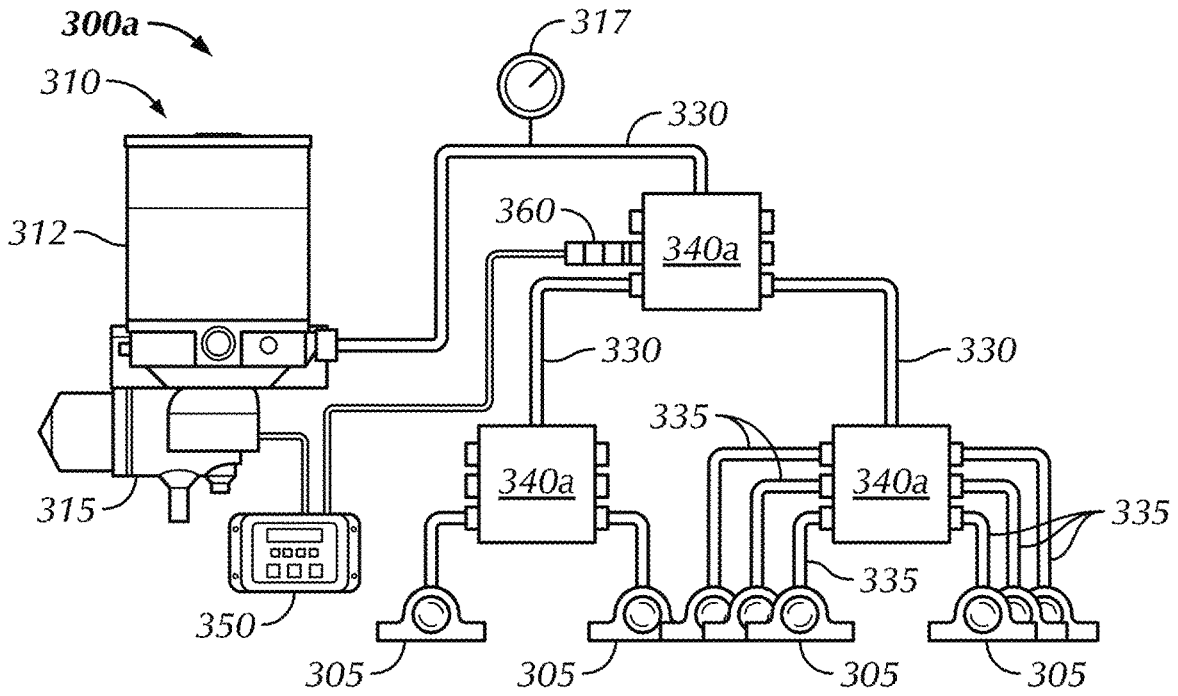




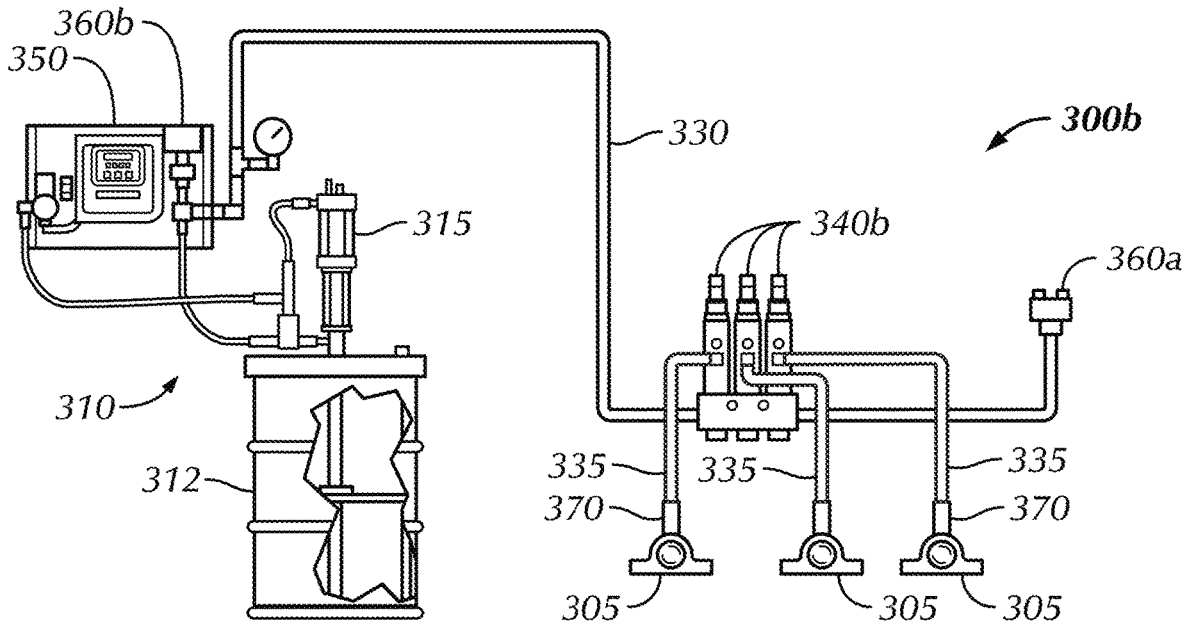
**FIG. 2D**  
**(Prior Art)**



**FIG. 2E**  
**(Prior Art)**



**FIG. 3A**  
**(Prior Art)**



**FIG. 3B**  
**(Prior Art)**

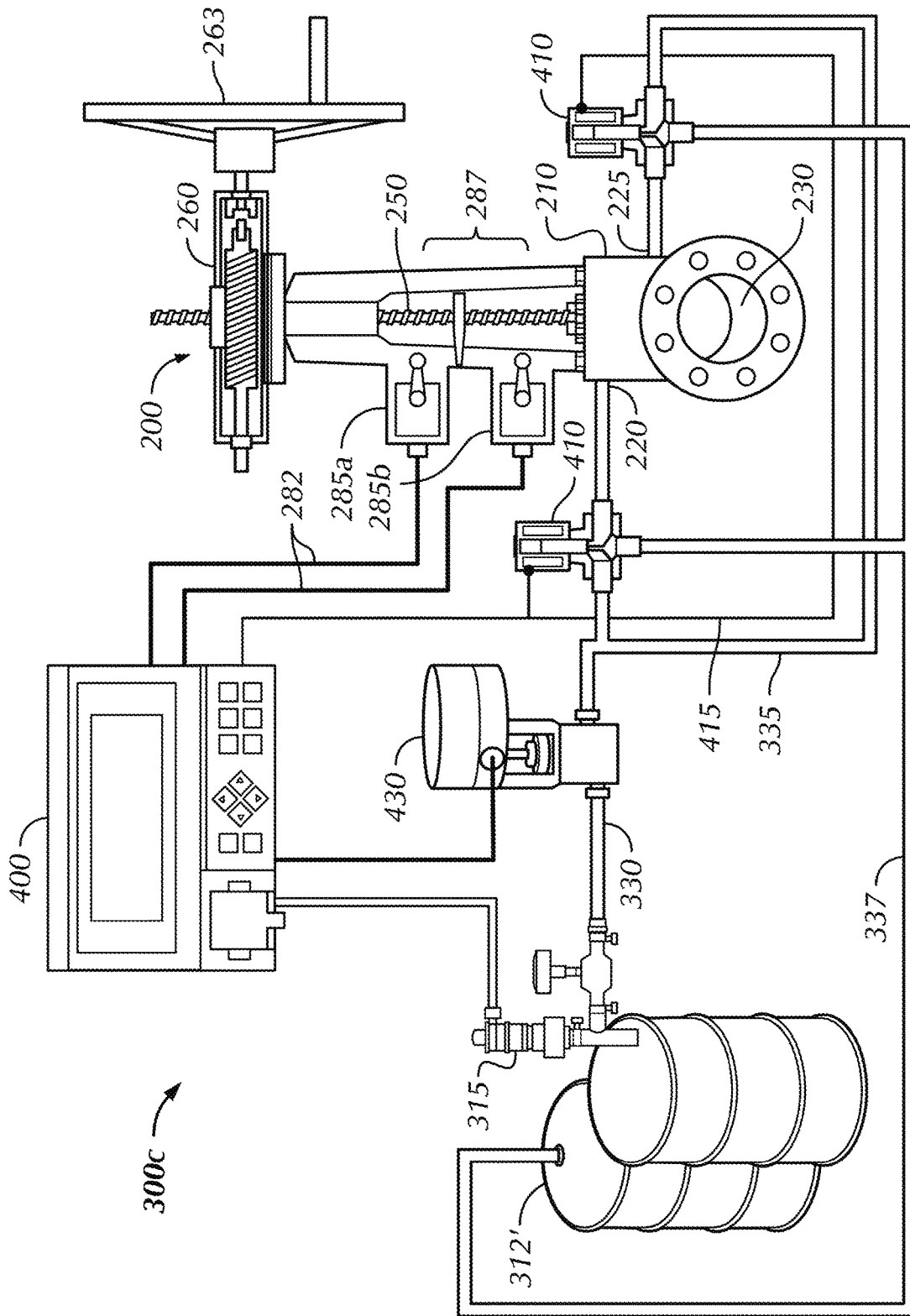


FIG. 4

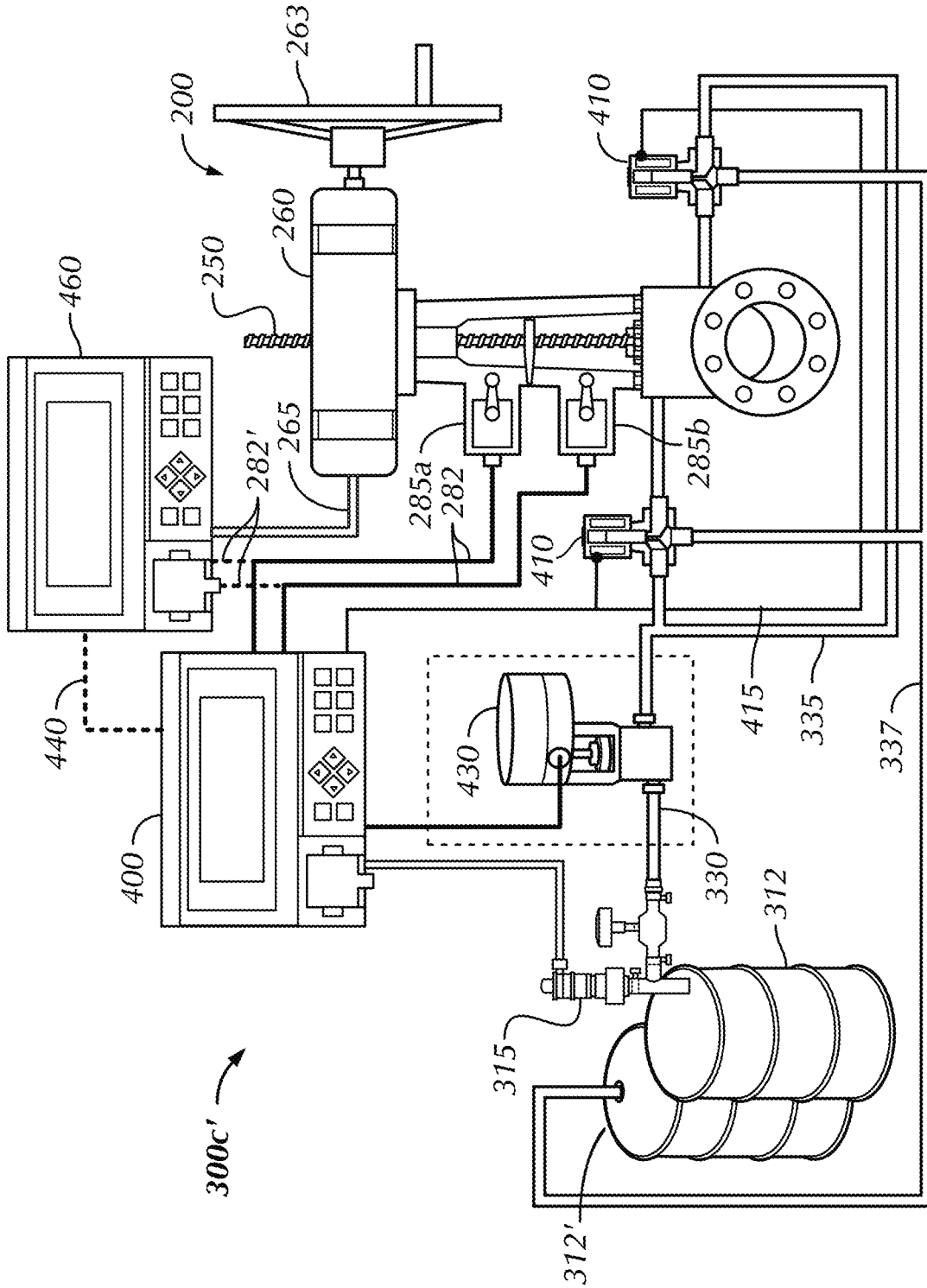


FIG. 5

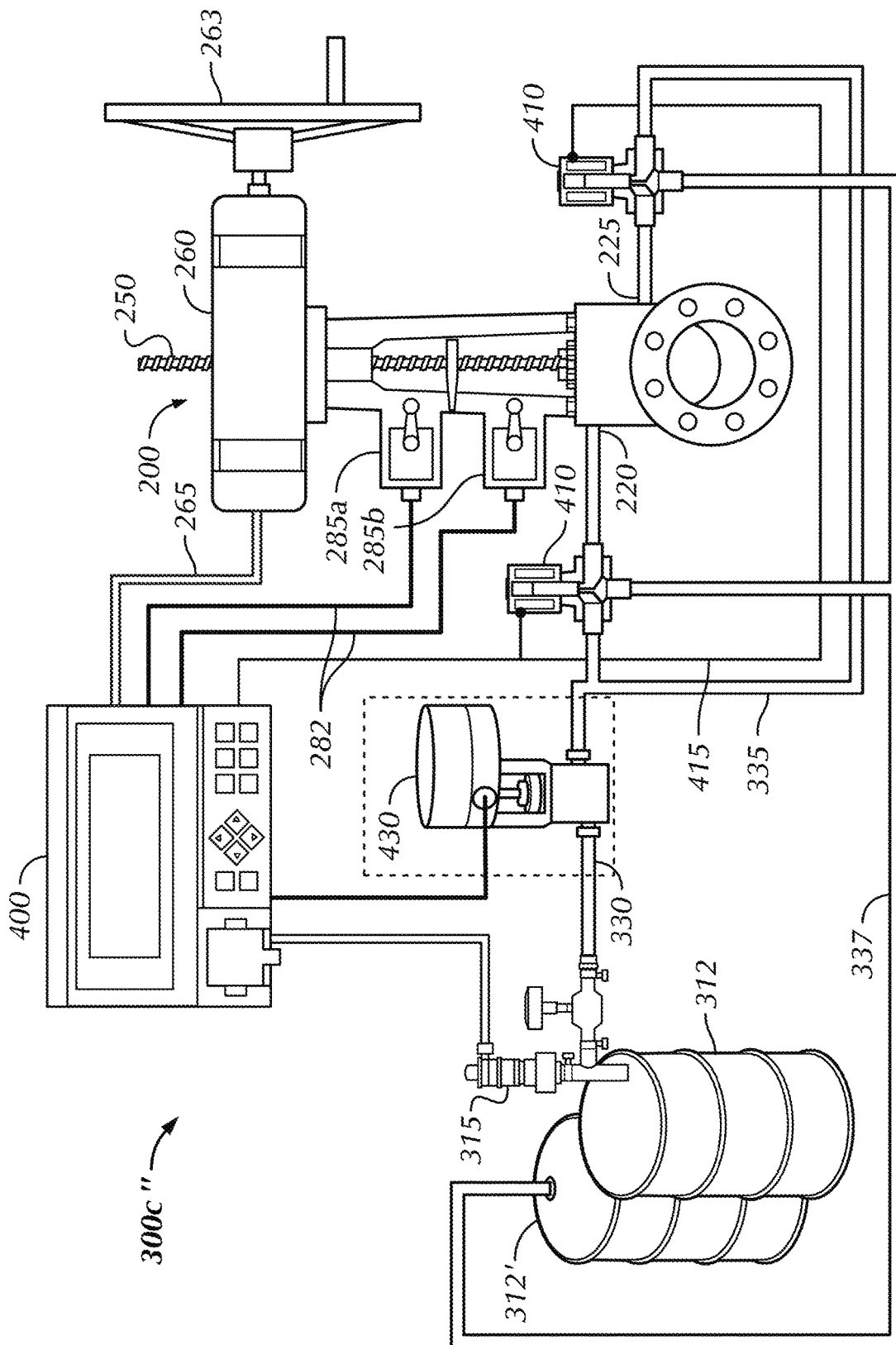


FIG. 6



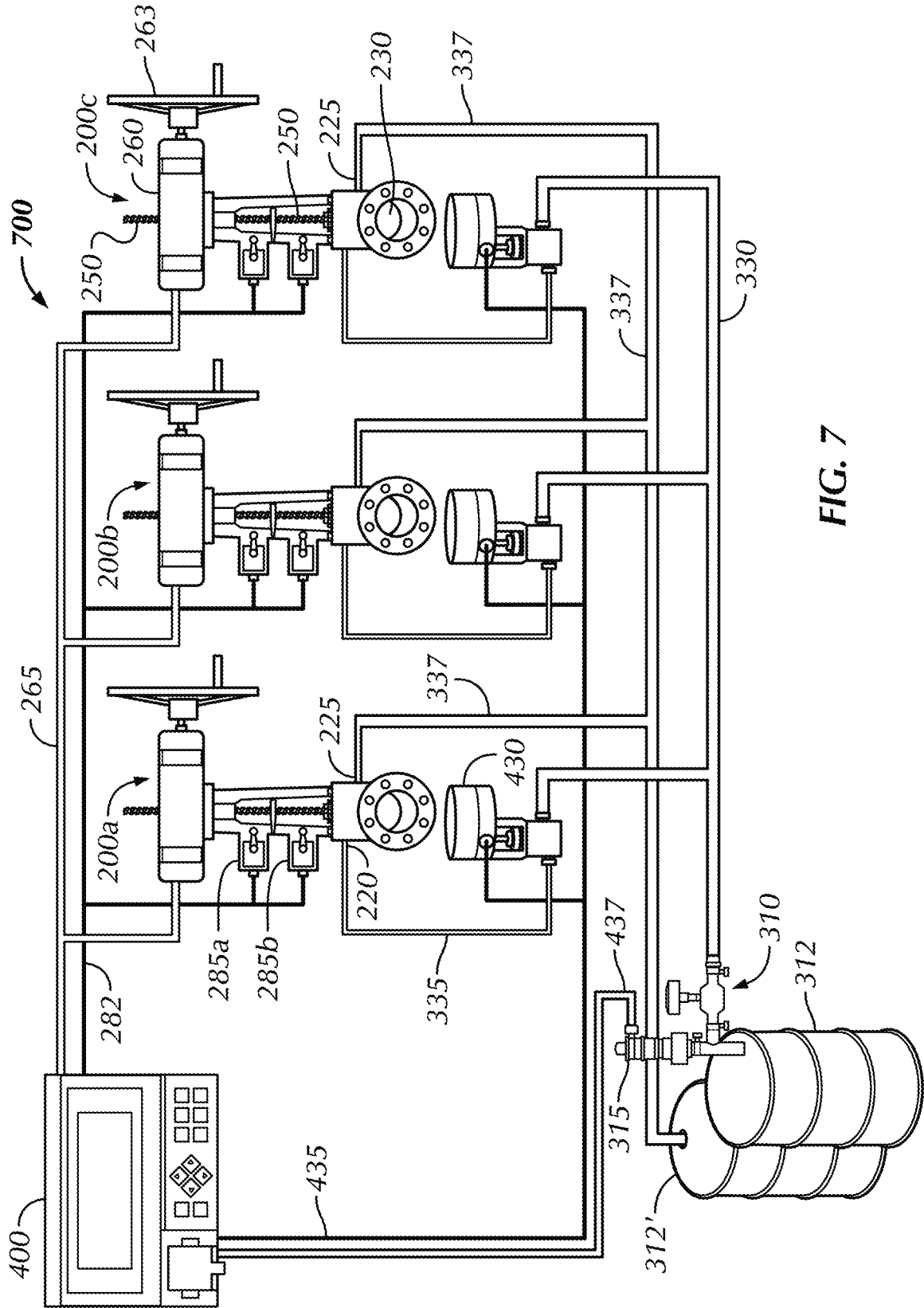


FIG. 7

## METHOD AND APPARATUS FOR MONITORING AND ON-DEMAND LUBRICATING OF INDUSTRIAL VALVES

### BACKGROUND OF THE INVENTION

#### Cross-Reference to Related Applications

**[0001]** This application claims priority under 35 U.S.C. § 119(e) from co-pending U.S. Provisional Patent Application No. 62/825,342, by Jason Pitcher, “Method and Apparatus for Automatically Greasing Valves” filed Mar. 28, 2019, which, by this statement, is incorporated herein by reference for all purposes.

### FIELD OF THE INVENTION

**[0002]** The invention relates generally to maintenance of valves for control of fluid flow. More particularly, the invention relates to automatic preventative maintenance greasing, or lubricating, of industrial valves in-service through coordination with regular operational valve operations.

### BACKGROUND OF THE INVENTION

**[0003]** Many industrial operations are dependent on the ability to control the flow of fluids. Valves are commonly used to control passage through pipes and hoses as well as in/out of equipment, vessels, etc. Valves regulate the flow of gasses, liquids, slurries, or loose materials (hereinafter collectively referenced as fluids) through an aperture or conduit such as a hose, tube, or pipe (hereinafter collectively referenced as pipe or line), by opening, closing, or otherwise interrupting the path of flow.

**[0004]** Valves are manufactured by assembling multiple mechanical parts, primarily comprising: the body (an outer shell), trim (a combination of replaceable wetted parts), stem, bonnet (body end cap), and an actuating mechanism for applying a motive force (usually to a gate via the stem). Valves may be bifurcated into small bore sizes, generally 2 inches or less; and commercial/industrial valves, above 2 inches in diameter (generally designated as ‘Large Bore’).

**[0005]** Valves may be operated, or actuated, via rotating a stem with levers, and/or wheels (collectively called the valve ‘operator’). These are referred to as ‘manual valves.’ Valves may also be actuated via electromechanical devices (‘actuators’) that may be electric, pneumatic, hydraulic, gas over oil, etc. and are collectively designated as ‘actuated valves,’ which may optionally include a secondary manual operator for safety.

**[0006]** A valve controls fluid flow and pressure by: stopping and starting fluid flow; varying fluid flow quantities, commonly referenced as ‘throttling’; directing fluid flow directions, ‘switching’; regulating downstream pressure; and/or relieving excessive pressures or ‘venting’. Actuation of a valve may be through manual, hydraulic, pneumatic, or electric application of motive forces. Examples of common types include the ball valve, butterfly valve, globe valve, gate valve, plug valve, diaphragm valve, reducing valve, needle valve, check valve, and safety/relief valve.

**[0007]** The force applied may require a quarter rotation of a valve stem as in a ball valve, or require multiple complete revolutions, as in a globe valve. There may also be a need for application of a mechanical leverage system for force amplification in larger scale deployments. For example, a

large wheel operator turning a worm screw against a gear positioning the valve stem in a large bore valve controlling a viscous and/or high-pressure fluid line where the gate may be prone to resist movement.

**[0008]** Each valve type was designed for specific needs. Some valves are capable of throttling, while others can only start and stop flow. Some valve designs work well in corrosive systems, offer fine-control capabilities, and other valves are designed specifically for handling high pressure, caustics, abrasives, or combinations thereof. Each valve type, design, and final embodiment has certain inherent advantages and disadvantages.

**[0009]** There is a vast assortment of valve types to work with the diversity of systems, fluids, and environments in which the valves must operate. Choices for specific applications can be further influenced by past industry experience and knowledge, which is often collected and shared in what is commonly referred to as ‘best practices.’ Consensus between industry members to implement a subset of the ‘best practices’ establishes an industry ‘standard,’ to which compliance is voluntary.

**[0010]** The American Petroleum Institute (API), American Society of Mechanical Engineers (ASME), and NSF International (formerly the “National Sanitation Foundation”) are some of the organizations maintaining standards for valve specifications. Because specifications often depend on industry member consensus and voluntary compliance, the duties and obligations required to comply are often minimized as much as tolerable to society. This can lead to eventual codification of the standards by regulatory agencies, resulting in mandatory compliance requirements with enforcement under penalty of law.

**[0011]** For simplicity in explanation and understanding, references herein will be to API specifications for fluids in the O & G (Oil and Gas industry). Examples presented will focus on exploration and production processes, particularly emphasizing the inhospitable environment (as far as valves are concerned) of high-pressure fracturing operations.

**[0012]** These O & G operations require fracturing fluids, comprised of chemicals, abrasives, and high pressures, to be directed among extensive junctions of equipment and along excessive distances with extensive control exercised throughout to successfully accomplish the intended tasks. Any exclusion should not be construed as non-applicable to the teachings herein, unless specifically designated as such.

**[0013]** The API ‘6A specification’ is the international standard for valves specific to wellhead and Christmas tree equipment, used in the petroleum and natural gas industries. API 6A valves are designed for the demanding environments of onshore and offshore drilling; production, pressure, and temperature extremes; and heavy oil, sour, and subsea applications, including hydraulic fracturing operations incorporating pressure ratings in excess of 20,000 PSI (pounds per square inch).

**[0014]** There are many valve types and designs that can safely accommodate the wide variety of industrial applications. But a gate valve is the type commonly preferred in industrial piping. For simplicity, the discussion herein will be of a hydraulically actuated large bore gate valve (LBGV) unless otherwise indicated in the context. One skilled in the arts will appreciate the applications described herein to other valve types and actuators.

**[0015]** The most significant feature of gate valves is their low obstruction to the fluid flow. Turbulence, like that

caused by globe valves, causes a drop in the fluid's line pressure. When fluid is moving through long lengths of pipe, or when energy is being expended to increase pressure above a threshold level for a particular task, it is important that valve selection does not decrease that pressure. When a gate valve is wide open, the gate, (or wedge) is positioned entirely out of the flow path providing a straight passage through the valve body.

**[0016]** In the O & G industry pipelines are often measured in miles, and it can be necessary to create fluid pressures greater than 5,000 PSI for cycling over a mile down a well bore to flush cuttings, power downhole equipment, or fracture rock formations. Here, a gate valve is the preferred option over all other designs to avoid pressure drop in the lines. However, gate valves should only be used in the fully open or closed positions; never for throttling purposes. Gates in intermediate, partially open, positions allow seals and seats to quickly erode as well as creating noisy chatter that propagates along the line.

**[0017]** But more importantly, partially open gates may allow production fluid exposure to lubricating grease in the valve cavity. Force, heat, and/or chemicals can break down lubricant and washout the valve's body cavity leaving the stem, gate, and seats unlubricated and open to wear. This is especially true in applications like high pressure frac operations where chemicals and proppants are intentionally introduced into the fluid.

**[0018]** Unfortunately, transitioning between the open and closed states means that at least some of the time a gate will be partially open. This requires maintenance in the form of lubrication to avoid more extensive repairs and premature equipment failure. Lubricating/greasing valves helps to reduce operating torque and protects against seizing, assist in proper seating and achieving manufacturer specified performance.

**[0019]** Each valve manufacturer provides grease fittings at key locations on the valve body and provides instructions on valve maintenance. These manufacturer-specified procedures and intervals are based on factors, such as but not limited to: design, construction, materials, life expectancy, and cycling frequency.

**[0020]** But consumers set their maintenance procedure by adjusting the intervals to account for application specific factors, such as: line pressure, valve positioning/uses, fluid type, lubricant type, etc. Each valve manufacturer provides grease fittings, or lubrication ports at key locations on the valve body and provides instructions on valve maintenance.

**[0021]** For exemplary purposes, a theoretical valve has a grease fitting protected by a grease fitting cap located on the bonnet flange for body cavity lubrication, and another grease fitting on the bearing cap for thrust bearing lubrication. The manufacturer recommends body cavity lubrication every ten operating cycles, or monthly, whichever comes first.

**[0022]** Lubrication reduces friction between moving parts by substituting fluid friction for solid friction. Reducing friction reduces the amount of energy that is dissipated as heat and the amount of energy required to perform mechanical actions. Lubrication is a matter of vital importance throughout industry. Automated lubrication systems exist to reduce the need for someone to constantly run around the equipment with an oil can or grease gun in hand.

**[0023]** Automated lubrication systems supply a continuous flow of lubricant to bearings, shafts, pulleys, gears, etc. using different methods ranging from gravity fed wicks

dripping oil, or spinning gears splashing oil around a gear chamber, to pumps forcing lubricant under pressure into mechanical parts in measured quantities. Centralized lubrication systems dispense lubricant from a supply reservoir by pumping it to divider valves or metering injectors.

**[0024]** Metering injectors are sized to fill with fluid, and when triggered, inject the quantity of fluid into its connected lubrication point. Divider valves disperse lubricant received at frequent intervals directly to each covered point, dividing the total quantity according to set ratios. Sizing of the injectors, or configuration of the divider ratios can be adjusted along with the frequency of the intervals ensuring proper lubrication of continuously operating equipment.

**[0025]** While sufficient for continuously operating machinery that can be lubricated at regular intervals, or joints that can be lubricated intermittently, these methods do not work for valves which require specific positions during lubrication, may require cycling, and may require injection pressure monitoring. Additionally, continuous lubricators typically dispense lubricant in quantities measuring less than a cubic inch at pressures around 1,500 PSI. Valves require larger quantities of lubricant, holding approximately 1-2 pounds of grease per inch of bore size, possibly requiring injection at pressures more than 2,000 PSI, depending on position and line pressure.

**[0026]** Typical frac operations use as much as 40,000 barrels of water, stored in holding tanks/trucks or a pond. The water is pumped by a Hydration Unit to a Blender truck and is mixed with chemicals supplied by a LAS truck (Liquid Additive System). This creates a 'slime' with the viscosity to suspend proppant, between 1.5-6 million pounds of grit or sand. Sand Kings (trucks or storage units for holding proppant) feed the grit into the Blender for incorporation with the slime to produce frac fluid.

**[0027]** Frac fluid is fed through a manifold sled's, called the 'Missile', low pressure lines to 8-15 High-Pressure Pump trucks. The trucks pressurize the frac fluid and return it to the Missile to be directed down the wellbore. A Back-Pressure truck feeds back pressure to the well annular countering the forces, to ease equipment strain, and containing frac fluid within the well.

**[0028]** The whole operation is monitored, recorded, and directed from a Data Monitoring van/truck to achieve fracking of target rock formations. When spent frac fluid returns through the annular it is directed by return lines to Flowback tanks/ponds for recycling, injection, or disposal.

**[0029]** Large bore gate valves (LBGVs) are common in O & G production and used extensively in hydraulic fracturing operations such as those described above. The required maintenance is dangerous to perform around the high-pressure lines but shutting down operations and relieving line pressure to allow lubrication is a costly option. Downtime must be minimized to meet schedules which typically allow 2-3 days for a job before moving to the next scheduled well.

**[0030]** For a LBGV employed in a typical hydraulic fracturing operation ("frac-op"), lubricant is pumped into a first lubricant port, an injecting port, filling the body cavity and flushing spent lubricant, fluids, and/or contaminants out of a second lubricant port. The lower port may have a back-pressure tool so the new lubricant can approach operating pressure. Alternatively, the second port may be closed first so pressure can be applied through the injecting port. A hand operated grease pump may be sufficient to accomplish

this job. However, lubricant quantity for the body cavity is dependent on the valve's bore size and pressure rating, often requiring over 20 lbs. of grease, more than many hand pumps can deliver.

[0031] A typical frac-job utilizing only a single missile and the accompanying entourage of: sand kings, storage tanks, hydration units, blender trucks, pump trucks, etc. will require a conservative estimate of 50-70 LBGVs to interconnect. These LBGVs will cycle a minimum of once during every frac-op and require maintenance every 4-7 cycles under most company procedures.

[0032] This means that the typical frac-job requiring 20 frac-ops to complete the well, will result in a conservative estimate of 50 valves cycling 20 times with 5 cycles between lubrications, each using a minimum of 25 lbs. of grease, consumes literally more than 2 tons of grease.

$$\frac{50_{\text{valves}} \times 20_{\text{cycles}}}{5_{\text{cycles lubrication}}} \times 25_{\text{lbs of grease lubrication}} = 5,000 \text{ lbs of grease}$$

[0033] What is needed is a way to monitor valve operations and automatically lubricate the valves on-demand in synchronization with their normal operation. This solution would allow preventative maintenance reducing costly downtime and premature equipment failure and reduce the dangerous working environments for maintenance personnel.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0034] FIG. 1 illustrates a typical layout of O & G equipment to contain, mix, pressurize, and inject hydraulic fracturing fluids into a wellbore for hydraulic fracturing operations.

[0035] FIG. 2A illustrates a manually operated large bore gate valve for use in typical O&G operations.

[0036] FIG. 2B illustrates an option for monitoring physical operation of a valve, here through sensing movement of a valve's balancing stem.

[0037] FIG. 2C illustrates an actuated large bore gate valve with secondary manual operation and balancing stem for use in typical O & G operation.

[0038] FIG. 2D illustrates an option for monitoring operation of a manual valve.

[0039] FIG. 2E illustrates an option for monitoring physical operation of an actuated valve with a secondary manual operator.

[0040] FIG. 3A shows a centralized sequential lubrication system for intermittent lubrication of continuous operation devices.

[0041] FIG. 3B shows a centralized parallel lubrication system for intermittent lubrication of continuous operation devices.

[0042] FIG. 4 shows a centralized on-demand lubrication system in accordance with an exemplary embodiment of the innovation.

[0043] FIG. 5 shows a centralized on-demand lubrication system, optionally cooperating with a control system, in accordance with an exemplary embodiment of the innovation.

[0044] FIG. 6 shows a centralized on-demand lubrication system integrated with a valve control system, in accordance with an exemplary embodiment of the innovation.

[0045] FIG. 7 shows a method of on-demand lubrication by a flow control system, in accordance with an exemplary embodiment of the innovation.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0046] The innovation described herein automates valve maintenance by monitoring valve operation and delivering lubricant on-demand according to actual usage and coordinating the lubrication of the valve with in-service valve operations. This avoids downtime caused by taking a valve out-of-service for maintenance or more extensive repairs due to improper maintenance.

[0047] The coordination with in-service valve operations also eliminates effects of unnecessary (i.e. 'maintenance only') valve operations, and ensure maintenance is performed in accordance with company procedure. Additionally, alleviating maintenance personnel from this routine task lowers their exposure to hazards and increases their availability for other tasks.

[0048] Valve operations are monitored by a programmable logic controller that also controls delivery from a lubricant source to the valve. The logic controller delivers lubricant to the valve when operations require, and the valve is in a condition to accept the lubricant. The requirements for accepting, and proper condition to accept, lubricant is dictated by the specific valve and application environment.

[0049] In one embodiment the valve may be a plug valve which may be lubricated in a full open or full close position but must be pressure monitored to avoid over pressurization and possible damage. In another embodiment, such as a sliding gate valve, the valve may need to be in either a full open or full close position but requires venting during lubricant injection. Such valves often have upper and lower lubrication ports (grease fittings). One skilled in the art will understand grease fittings may be replaced by control valves on lubrication ports to automate the regulation of lubricant or grease flow.

[0050] In one embodiment control valves, connected to lubrication ports, have three states allowing the port to be: closed, connected to a lubricant supply, or vented. In another embodiment a control valve may be throttled to control lubricant delivery. In another embodiment throttling may be accomplished by control of the pump regulating delivery pressure of the lubricant supply.

[0051] In another embodiment secondary controls may be positioned near the valve and communicate to the controller through the sensor wired communication medium employed by the controller to monitor valve actuation. In another embodiment the sensor communications and optional secondary controls may utilize a wireless communication medium.

[0052] An expansion of the preferred embodiment concerns cleaners and sealants for various valve types. In addition to controlling delivery from a lubricant source, the fluid control equipment and controller may also provide delivery from a secondary reservoir of other fluids such as cleaner. The controller being configured to optionally inject cleaner into a valve, such as a floating ball valve, prior to introducing lubricant/sealant during maintenance to flush debris into the fluid flow. Further specifics should be obvious to one skilled in the arts and is beyond the scope of this application.

**[0053]** Another expansion concerns pressure locking of valves. A valve that traps pressure within the body cavity may experience pressure locking when line pressure decreases. In a pressure locked state, the valve is inoperable until body cavity pressure is relieved. Due to the high pressures involved, the equalizing procedures are considered dangerous, and is usually entrusted to skilled personnel exercising the utmost care.

**[0054]** However, the innovation described here provides all necessary components for safely venting the body cavity through a lubrication access port remotely from a safe distance without risk. It is recommended that safety procedures such as this be configured, as non-standard safety routines, into controller logic for use in such situations.

**[0055]** Another expansion concerns thermal binding of valves. A controller may include a sensor monitoring temperature of the valve body. In conditions of possible thermal binding, such as a temperature change greater than a threshold range occurring since the last valve actuation, the controller being cognizant of possible binding can be configured to “bump” (provide a short burst of motive power) the valve’s actuator to disengage the current limit switch prior to attempting to fully actuate the valve, possibly causing damage to the valve and/or actuator. In the event the limit switch fails to engage, the controller may alert to the situation so personnel can heat the valve body to relieve the thermal binding without damage.

**[0056]** In a typical frac operation, such as that described above, gate valves may require lubricating to prevent seal wear after every 2<sup>nd</sup> or 3<sup>rd</sup> cycling, i.e. moving from full-open to full-close, or vice versa. High pressure in the lines makes it hazardous for personnel to be in the surrounding area. The extensive number of valves complicates tracking maintenance, and any downtime can be very costly.

**[0057]** in this environment, the preferred embodiment monitors valve operation and at prescribed intervals lubricates the valve according to set procedures. In the embodiment presented here, the controller counts valve cycles for each valve and upon exceeding a limit, attempts to lubricate the valve in a manner that is minimally disruptive to service operations. Minimally disruptive may be determined by configuration of the controller, which may be cognizant of operations and have sufficient artificial intelligence to: cycle an unused valve as required, delay a request for valve actuation for a limited period of time, or temporarily postpone a maintenance lubrication. Such controller configuration is beyond the current scope.

**[0058]** When lubrication is needed and the valve is positioned properly, here a gate valve being in a full-open or full-close position, a lubrication port is opened venting spent fluids, the lubricant delivery source supplies lubricant, injecting a specific quantity through another lubrication port, into the valve body, forcing the venting of the spent fluids. The venting lubrication port is closed, and the injecting lubrication port is pressurized as required, then closed, leaving the valve serviced and operational.

**[0059]** In an alternative embodiment the lubricant delivery source is centralized and supplies lubricant at low pressure to a plurality of secondary pumps which pressurize the lubricant for injection into individual valves. In one embodiment the low-pressure lubricant is delivered in large quantity and secondary pumps increase pressure and deliver high-pressure lubricant in a smaller quantity to supply an individual valve, the tended valve. In another embodiment, a

secondary pump may have a local reservoir sized according to the tended valve’s lubricant requirements.

**[0060]** In one embodiment spent fluids are collected during venting from the valve. In such an embodiment, the collection may be centralized such that the venting valves are interconnected and extended for final discharge into a centralized reservoir. In another embodiment, control valves may be used to route one lubrication port to the lubricant supply and another lubrication port to the discharge collection allowing options for more efficient lubrication depending on, for instance, gate position.

**[0061]** In the preferred embodiment, a programmable logic controller (a controller) monitors valve position and determines lubrication needs independent of manual operation or actuation by a second controller. In such an embodiment, sensors provide information to the controller regarding valve operations.

**[0062]** These sensors may be unique to the controller or provide a shared signal to one or more controllers associated with the valve. In another embodiment the second controller may communicate with the first controller. In a different embodiment the first and second controllers may be a single controller to actuate the valve and control the lubrication.

**[0063]** DETAILED DESCRIPTION OF THE DRAWINGS

**[0064]** FIG. 1 illustrates a typical layout of O & G equipment to contain, mix, pressurize, and inject hydraulic fracturing fluids into a wellbore for hydraulic fracturing operations. The configuration of high-pressure hydraulic fracturing equipment (100) injects high-pressure fracturing fluids down a wellbore (110), to cause fracturing of rock formations thousands of feet under the surface.

**[0065]** A pond, a large tank, or several smaller tanker trucks (185), as shown here, supply water to a hydration unit (180) through water lines (155) where it is mixed with a chemical supply (156) from a liquid additive system, commonly referred to as a LAS truck (177), to create a supply of slime (155).

**[0066]** The slime has higher viscosity than water allowing suspension of sand/grit/abrasives known as proppant stored in several sand kings (174). A blender truck (170) mixes the supplied slime (155) with the supply of proppant (157) to create fracturing fluid.

**[0067]** The fracturing fluid is supplied through low pressure lines (152) to a manifold sled, also known as a missile (160) for distribution to a fleet of high pressure fracturing pump trucks (165) which increase the fluid pressure as high as 20,000 PSI, and return the high pressure fluid through high pressure lines (125) to the missile (160) to collectively be injected (123) into the wellbore (110).

**[0068]** The high-pressure fluid is held in the wellbore (110) by balancing annular differential pressure by fluid back pressure (127) generated by a back-pressure truck (130). Completing a frac-op involves closing off high-pressure lines to the wellbore (123 and 127) to allow spent fluid up the wellbore (110) to the return line (154) to the flowback tanks (140) or holding pond.

**[0069]** The entire operation is managed from a data monitoring van (190) which directs composition, pressure, flow, hold, and return of fluids through actuation of many valves (200), only a few of which are depicted here.

**[0070]** FIG. 2A illustrates a manually operated large bore gate valve for use in typical O&G operations. The valve (200) has a valve body (210) encircling a flow path inter-

ruptible/controllable by a gate (230), illustrated here in a full-open position. Other valves may interrupt the flow path in a more controllable manner through the positioning of a plate, disc, diaphragm, plug, or ball depending on the valve design.

[0071] The gate (230) connects to a stem (250), and an optional balancing stem (255) for actuation of the valve, here by a manual actuator (263, a hand wheel). The stems (250 and 255) typically pass through bonnets (240) which provide access to the stems (250 and 255) and gate (230) within the body cavity (212) for extensive rework and heavy maintenance.

[0072] Upper lubrication ports (220) and lower lubrication ports (225), often including grease fittings, allow for the injection of lubricant into the body cavity (212) for preventative maintenance. The lubricant attempts to preserve gate seals, and seats, as well as the gate itself (230).

[0073] FIG. 2B illustrates an option, for monitoring physical operation of a valve, here through sensing movement of a valve's balancing stem. The balancing stem (255) projects through the bottom of the valve body, or lower bonnet (240). Actuation of the valve gate (230, previous FIG.) moves the connected stems (255 here and 250 previous FIG.) changing the signals emitted through sensor wiring (282) by the sensors, shown here as an upper limit sensor (285a) and a lower limit sensor (285b).

[0074] FIG. 2C illustrates an actuated large bore gate valve with secondary manual operation and balancing stem for use in typical 0 & G operation. The valve (200) has a body (210, not indicated) which encircles a flow path interruptible by a gate (230), illustrated here in a full-closed position. Note the gate valve design is best suited for allowing or preventing fluid flow and can be damaged if employed for extensive periods of flow regulation.

[0075] The gate (230) connects to a stem (250) for actuation of the valve by an actuator (260), here a hydraulic actuator (260) with a control line (280, not shown) connected to the hydraulic port (265), and with secondary manual actuation through a manual actuator (263, a hand wheel). The stem (250) is complimented by a balancing stem (255), and passes through an upper bonnet (240) which provide access to the stems (250 and 255) and gate (230) within the body cavity (212, not designated) for extensive rework and heavy maintenance.

[0076] Upper lubrication ports (220) and lower lubrication ports (225), often including grease fittings, allow for the injection of lubricant into the body cavity (212) for preventative maintenance.

[0077] FIG. 2D illustrates an option for monitoring operation of a manual valve. The valve body (210, not designated) has an upper lubrication port (220) and lower lubrication port (225) for lubricating the gate (230) connected to the stem (250). The actuator's (260) motive power, manual operation by rotating the hand wheel (263), moves the stem (250) to activate an upper limit switch (285a) or a lower limit switch (285b), sending a signal by wire (282) to a monitor.

[0078] Deactivating of one switch (285a or 285b) without activating the other switch (285b or 285a) indicates position along the travel (287), indicating the valve is partially engaged. This is an undesired position for a gate valve and may be detected by allowing a maximum time for valve transition, with an optional alarm being raised by the monitor.

[0079] FIG. 2E illustrates an option for monitoring physical operation of an actuated valve with a secondary manual operator. The valve body (210, not designated) has an upper lubrication port (220) and lower lubrication port (225) for lubricating the gate (230) connected to the stem (250). The actuator's (260) motive power control line (265) or optionally manual operation of the hand wheel (263), moves the stem (250) to activate an upper limit switch (285a) or a lower limit switch (285b), sending a signal by wire (282) to a monitor. Deactivating of one switch (285a or 285b) without activating the other switch (285b or 285a) indicates position along the travel (287), indicating partial engagement of the valve.

[0080] FIG. 3A shows a centralized sequential lubrication system for intermittent lubrication of continuous operation devices. This continuous automatic lubrication system cascades rations of lubricant for sequential distribution among a plurality of devices periodically. The intermittent sequential lubrication system (300a) has a pumping unit (310) with a lubricant reservoir (312), a pressure pump (315) and a pressure gauge (317). At regular programmed intervals a timer/controller (350) powers the pumping unit (310) delivering lubricant to the system for one or more cycles as designated by an end-of-cycle indicator (360).

[0081] The pumping unit (310) injects lubricant through supply lines (330) to a metering device (340), here a divider valve or divider (340a). The divider (340a) sequentially delivers metered quantities of lubricant to each of its ports, cascading lubricant of unused ports to increase the quantity delivered to the next sequential port. The ports of the divider (340a) may distribute fluid to supply lines (330) leading to additional dividers (340a) or to delivery lines (335) connected to fittings or bearings/joints/gears (305) serviced by the system.

[0082] FIG. 3B shows a centralized parallel lubrication system for intermittent lubrication of continuous operation devices. This lubrication system meters out measured quantities of lubricant to be simultaneously injected in a plurality of device intermittently. The intermittent parallel lubrication system (300b) has a pumping unit (310) with a lubricant reservoir (312), a pressure pump (315) and a pressure gauge (317, not designated). At regular programmed intervals a timer/controller (350) powers the pumping unit (310) delivering lubricant to the system for one or more cycles as designated by an end-of-cycle indicator (360), which in this case is a pressure sensor (360a) and pressure relief trigger (360b).

[0083] The pumping unit (310) injects lubricant through supply lines (330) to feed metering devices (340), here metering injectors or injectors (340b). The injectors (340b) independently collect and hold specific quantities of lubricant until pressure builds in the supply line (330) triggering the end-of-cycle indicator (360) to release the pressure. The relief of pressure causes all injectors (340b) to each deliver their collected quantity of lubricant through delivery lines (335) connected by fittings (370) to the individual bearings/joints/gears (305) serviced by the system.

[0084] FIG. 4 shows a centralized on-demand lubrication system in accordance with an exemplary embodiment of the innovation. The on-demand lubrication system (300c) has a programmable logic control unit, a controller (400) monitoring actuation of a valve (200), here by a manually powered actuator (260) for positioning of the gate (230) through manipulation of the stem (250).

[0085] As the hand wheel (263) is operated, the gate's (230) travel (287) is indicated by signal lines (282) from the upper limit switch (285a) and/or lower limit switch (285b) positioned on the stem (250) to the controller (400). Once the valve's (200) gate (230) is in the fully open position as indicated by the upper limit sensor (285a), or the fully close position as indicated by the lower limit sensor (285b), lubrication maintenance may occur if needed.

[0086] A solenoid control valve (410), controlled (415) by the controller (400), vents the valve body (210) through one of the lubrication ports (220 or 225), the 'venting port,' to a return line (337) leading to a centralize collection (312'). Though the embodiment here utilizes a solenoid control valve, specifically a solenoid operated directional spool-type control valve, one skilled in the art will appreciate other control options. A pressure pump (315) in a centralized lubricant pump unit (310, not indicated) distributes lubricant through a supply line (330) where an optional secondary pump (430) increases lubricant pressure along a delivery line (335).

[0087] The delivery line (335) may be routed by another solenoid control valve (410) to another lubrication port (225 or 220), the 'injecting port,' to deliver a measured quantity of lubricant in accordance with the valve's (200) specifications. This inflow of pressurized lubricant through the injecting lubrication port simultaneously forces the venting of spent fluids out through the venting lubrication port to the centralized collection (312') through the return line (337).

[0088] One skilled in the art would appreciate that different valve designs may allow for injecting lubricant simultaneous in more than one lubrication port, or that venting may occur through the flow pathway making venting unnecessary. Further, one skilled in the art would appreciate that a measured quantity of lubricant may not be a specific quantity, but an undetermined amount required to achieve a desired pressure change at the lubrication port, which may be detected by monitor of the supply line or delivery lines.

[0089] FIG. 5 shows a centralized on-demand lubrication system, optionally cooperating with a control system, in accordance with an exemplary embodiment of the innovation. This embodiment of an on-demand lubrication system (300c') has a programmable logic control unit, a controller (400) monitoring actuation of the valve (200), controlled by a remote valve controller (460) through motive power (265) to an actuator, here a hydraulic actuator (260) with secondary manual actuation through a hand wheel (263).

[0090] The remote valve controller (460) may optionally communicate (440) with the controller (400), and/or may also monitor actuation of the valve (200) through shared (282') signal lines (282) from the limit switches (285a and 285b). Once the valve (200) is in the fully open position as indicated by movement of the stem (250) to engage the upper limit sensor (285a), or the fully close position as indicated by engagement of the lower limit sensor (285b), lubrication maintenance may occur as needed.

[0091] A solenoid control valve (410), controlled (415) by the lubrication system's controller (400) vents one of the valve's (200) lubrication ports (220 or 225, not indicated), the 'venting port,' to a return line (337) leading to a centralize collection (312'). A pressure pump (315) in a centralized lubricant pump unit (310, not indicated) distributes lubricant from the lubricant reservoir (312) through a supply line (330) where an optional secondary pump (430) may be used to increase lubricant pressure along a delivery

line (335). The secondary pump (430) may also incorporate a local reservoir to prevent starvation of lubricant by other valves in a multi-valve system employing the centralize lubricant supply reservoir (312).

[0092] The delivery line (335) may be routed by another solenoid control valve (410) to another lubrication port (225 or 220, not indicated), the 'injecting port,' to deliver a measured quantity of lubricant in accordance with the valve's (200) specifications. This inflow of pressurized lubricant through the injecting lubrication port simultaneously forces the venting of spent fluids out through the venting lubrication port to the centralized collection (312') through the return line (337), as discussed above.

[0093] In this embodiment the communication (440) between controllers (400 and 460) may allow predictive use of the centralized pressure pump (315) ensuring sufficient pressure for feed lines (330), eliminating the need for separate delivery lines (335) and secondary pumps (430) by ensuring multiple valves (200) will not simultaneously lubricate, over taxing a shared pump unit (310, not designated). Alternatively, communication between multiple lubrication controllers (400) through a central controller (460) may allow problems of simultaneous demands to be mitigated by adjusting logic control accordingly.

[0094] FIG. 6 shows a centralized on-demand lubrication system integrated with a valve control system, in accordance with an exemplary embodiment of the innovation. This embodiment of an on-demand lubrication system (300c'') has a single programmable logic control unit, a controller (400) actuating the valve (200) and monitoring actuation in case of manual actuation.

[0095] The controller (400) monitors signal lines (282) from the limit switches (285a and 285b) to determine lubrication needs, for instance by monitoring the time necessary for an actuator (260) to physically move a valve. Increased time from deactivation of one limit switch (285a or 285b) to activation of the other limit switch (285b or 285a) may indicate a need for maintenance.

[0096] The controller (400) also controls (415) solenoid control valves (410), a pump unit's (310, not indicated) pressure pump (315), and optional secondary pump (430) for distribution (330) and delivery (335) of from a lubricant reservoir (312), and collection (337) to a centralize collection reservoir (312') of spent fluids.

[0097] FIG. 7 shows a method of on-demand lubrication by a flow control system, in accordance with an exemplary embodiment of the innovation. The on-demand automatic lubrication system provides monitoring and analysis for timely high-pressure delivery of lubrication coordinated with in-service valve operations to eliminate downtime or the effect of extraneous valve operations. The flow control system (700) has a programmable logic control unit, a controller (400), monitoring actuation of a plurality of valves (200a -c), and providing motive power (265) to actuators (260) to independently actuate the valves (200a-c).

[0098] Monitoring actuation of the valves (200) through signal lines (282) from the limit switches (285a and 285b) provide information on individual valve usage, and position for purposes of maintenance lubrication. The controller (400) may consider an individual valve's performance, past usage, maintenance history, anticipated usage, etc. to prioritize maintenance lubrications.

[0099] The controller (400) controls (437) a pressure pump (315) of the centralized lubrication pump unit (310)

delivering lubricant at low pressure from a lubricant reservoir (312) in large quantities through a supply line (330) to secondary pump (430) controlled (435) by the same controller. The secondary pump (430) increases lubricant pressure for delivery (335) to a lubricant port (220), the injecting port.

[0100] A second lubricant port (225) is opened to vent fluids, a venting port, allowing the injection of lubricant to force venting of spent fluids/lubricant through the return line (337) to the collection reservoir (312'). Pressure of spent fluids exiting the venting port will gravitate to the unpressurized collection reservoir (312') but may also be aided by additional pumps to assist flow.

[0101] In one embodiment, the secondary pump (430) increases pressure by reducing the volume of the delivered lubricant. In such a system, the "large quantities" of the supply line are dictated by the consumption of a maximum number of secondary pumps (430) to be concurrently supported. In another embodiment, the secondary pumps (430) have local reservoirs for collecting sufficient lubricant required to lubricate a valve (200). In another embodiment, the secondary pump's (430) local reservoir may buffer the lubricant from the supply line. In another embodiment throttling lubricant flow to one or more valves extends the service time in exchange for an increase in concurrent operations.

[0102] One skilled in the art would appreciate the considerations for balancing the large quantities of lubricant in the supply line against the concurrent demands of a plurality of concurrent valve lubrications with or without local reservoirs, and other factors for configuration of the system and its controller (400) for proper limiting and prioritizing of valve lubrications to yield a desired system performance.

[0103] The diagrams in accordance with exemplary embodiments of the present innovation are provided as examples and should not be construed to limit other embodiments within the scope of the innovation. For instance, quantities, distances, and volumes may not be to scale and should not be construed to limit the innovation to the particular proportions. Additionally, some elements illustrated in the singularity may actually be implemented in a plurality, and those illustrated in the plurality could vary in actual count. Some elements illustrated in one form, design, or configuration may vary in detail from that depicted. Further, specific information should be interpreted as illustrative for discussing exemplary embodiments and is not provided to limit the innovation.

[0104] The above discussion is meant to be illustrative of the principles and various embodiments of the present innovation. Numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

What is claimed is:

1. An apparatus for lubricating an industrial valve comprising:

- a lubricant delivery source comprising:
  - a lubricant reservoir,
  - an optional lubricant sensor, and
  - a first pump;
- lubricant tubing;

at least one industrial valve, comprising:

- a valve body encircling a flow path interruptible by,
  - a gate attached to a stem moved by,
  - an actuator to actuate the industrial valve between:
    - an open, first gate position, and
    - a closed, second gate position for controlling the flow path of the industrial valve; and
  - one or more grease fittings for lubrication of the industrial valve; and a controller configured to:
    - monitor actuation of the industrial valve or position of the gate; and
    - selectively deliver lubricant from the lubricant reservoir, through the lubricant tubing, to one or more grease fittings on the valve body.
2. The apparatus as described in claim 1 wherein the lubricant sensor determines the pressure of lubricant delivered.
3. The apparatus as described in claim 1 wherein the lubricant sensor determines the quantity of lubricant delivered.
4. The apparatus as described in claim 1 wherein the controller is further configured to:
  - record actuation of the industrial valve;
  - count movement of the gate from one position to another position, a valve cycle;
  - monitor gate position; or
  - actuate the industrial valve.
5. The apparatus as described in claim 1 wherein selectively pumping lubricant from the lubricant reservoir is responsive to a specific gate position.
6. The apparatus as described in claim 4 wherein selectively pumping lubricant from the lubricant reservoir is:
  - responsive to actuation of the industrial valve, or
  - concurrent with an actuation of the industrial valve.
7. The apparatus as described in claim 1 further comprising:
  - a second pump:
    - receiving lubricant from the lubricant tubing,
    - pressurizing the lubricant, high-pressure lubricant, and
    - delivering the high-pressure lubricant, to
    - the one or more grease fittings for lubrication of the industrial valve.
8. The apparatus as described in claim 1 wherein the controller is further configured to
  - open a second grease fitting, and
  - vent excess fluid from the valve body while pumping lubricant from the lubricant reservoir.
9. The apparatus as described in claim 1 further comprising:
  - one or more control valves,
  - selectively directing high-pressure lubricant to one of the one or more grease fittings of the industrial valve, and
  - directing excess fluid from a second of the one or more grease fittings of the industrial valve to a discharge collection.
10. The apparatus as described in claim 1 the discharge collection further comprising:
  - a discharge reservoir for collecting excess fluid,
  - optional hose connecting the industrial valve to the discharge reservoir.
11. A system for lubricating an industrial valve comprising:
  - monitoring movement of a gate in an industrial valve,
  - controlling a lubrication system to deliver (at high pressure) lubrication,



greasing the industrial valve by pumping lubrication through a grease fitting for, distributing throughout a cavity of the valve by movement of the gate.

**12.** A method of lubricating a valve comprising: monitoring operation of the valve; responsive to the valve operations and position, delivering a prescribed quantity of lubricant to a first grease connection on the valve, while simultaneously venting excessive pressure and collecting discharge from a second grease connection on the valve.

**13.** The method as described in claim 1, wherein the delivering of lubricant is coordinated with regular in-service valve operations.

**14.** The method as described in claim 1, further comprising: monitoring operation of other valves; coordinating delivery of lubricant among the plurality of valves.

**15.** The method as described in claim 1, wherein the delivery of lubricant is further responsive to anticipated future valve operations.

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