IMPROVED CONTROLS FOR ENHANCED RECOVERY

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ABSTRACT

The increasing emphasis on enhanced oil recovery is producing the need for improved methods of monitoring and controlling the injection process. The economics of injection materials, personnel and equipment reinforce the requirement for efficient management of injection systems.

The application of existing technology in combination with improved hardware and new developments provides the basis for a viable injection control system. The ability to meet the stringent requirements of field control is due in a large part to developments outside the oil industry.

Future improvements and enhancements to injection control and monitoring will be possible through the imaginative application of current and developing technology.

INTRODUCTION

There can be little doubt that the production of oil in the future will depend more and more upon enhanced recovery techniques. With the increase of cost of injection materials, need for more and better data and the requirement for better management of projects, there will arise a need for more and better control methods. The purpose here is to stimulate thinking in the area of measurement and control by considering past procedures, current capabilities and future needs.

MANUAL INJECTION CONTROL

The most widely accepted method of injection control is the use of manually adjusted chokes or valves in combination with either positive displacement or turbine flow meters and pressure gauges to adjust the flow rate into injection wells. The process variables (pressure and flow) are checked periodically and any needed adjustment is made to the choke setting. While this method may be deemed adequate for water flooding, some of its shortcomings may render it unadvisable for enhanced recovery. A brief consideration of the advantages and disadvantages of the manual control system is in order.

ADVANTAGES

1. LOW CAPITAL COST - Only portable pressure and flow measurement equipment are needed.

2. LOW EQUIPMENT MAINTENANCE COST - There are few parts in the system, therefore, a relatively low maintenance cost.

3. EASE OF UNDERSTANDING - Since the system is relatively simple, the training of operators is also simple.

DISADVANTAGES

1. INACCURATE CONTROL - The manual choke does not respond to changes in well conditions or supply system changes.

2. LABOR INTENSIVE - The system requires frequent and time consuming manual checks and adjustments.

3. DATA AVAILABILITY - Operation data must be collected and processed manually. The timeliness and accuracy of operation data can be a problem.

4. NON-CORRECTING FOR SYSTEM INTERACTION - The adjustment of the operation of one well may interact with the operation of one to several other wells.

5. LACK OF SYSTEM FLEXIBILITY - Due to the simple nature of the equipment, it is difficult to obtain different or enhanced performance from the system.

AUTOMATIC CONTROL SYSTEMS

One major factor in employing more sophisticated control methods in water flood operations is the fact that such systems have not been readily available. There have been a number of efforts made to meet one or more of the disadvantages of the manual control system through the use of pressure regulators, and central measurement systems. There are some examples of the use of supervisory control systems to monitor the injection process and to make automatic adjustments. These systems have done much to advance the technology needed to improve control of the injection process. The use of such control and monitoring systems is neither wide spread nor greatly accepted.

SYSTEM REQUIREMENTS

It seems certain that there is currently and will continue to be a need for improved injection monitoring and control methods. Due to the nature of the secondary and enhanced recovery operations, there are a number of very difficult requirements that must be met in order to provide acceptable control performance and economical operation of a control system. Some of these requirements are included in the list below.

1. WIDE RANGE OF PRESSURE REQUIREMENTS - Due to the nature of the formation the injection pressure in one field will vary greatly. The pressure required for the highest pressure well must be supplied and is normally available at the lowest pressure well, causing difficulty in properly sizing control valves and pressure measurement equipment. To make it even more difficult, these pressure requirements may change significantly during the life of the project.

2. WIDE RANGE OF FLOW REQUIREMENTS - Like pressure, the flow rate for wells within a given field may vary greatly and change during the life of the project.

3. AVAILABILITY OF POWER - In some cases, electrical power or low pressure sweet gas is available for supplying power to the control system. However, there are many cases in which there is no power available and the cost to provide conventional power is extremely expensive.

4. HOSTILE INJECTION MEDIA - In many cases, the fluids being injected are highly corrosive and contain relatively large amounts of solid material, creating difficulty in measurement and control.

5. HOSTILE ENVIRONMENT - Any system that is to be generally useful must operate in the subzero cold of Wyoming and Montana, the 100 plus heat and dust of West Texas and New Mexico, the high humidity of the Gulf Coast and corrosive gas in the atmosphere.

6. TRAINING LEVEL OF OPERATING - In most cases, the personnel who are called upon to operate the control equipment have little or no experience with such equipment.

7. HIGH RELIABILITY - Since the process being controlled is important, the control system should be highly reliable.

8. EASY FIELD REPAIR - Even with high reliability, the system will require maintenance and repair from time to time. These functions should not require a high level of training or sophisticated equipment.

9. APPLICATION FLEXIBILITY - There are a wide variety of application requirements to meet the specific needs of a given operator in a given project. The equipment should be adaptable to these needs.

10. FUTURE COMPATIBILITY - In some cases, all the operation requirements are not totally deemed at the time of installation. The system should have the capability to meet future needs without major modifications.

11. INTERFACE ABILITY - In many cases, it will be desirable to interface the well head control system with a supervisory control and data acquisition system. This interfacing should be accomplished with a minimum of difficulty.

12. LOW INITIAL COST - Since there are large numbers of injection wells involved in secondary and enhanced recovery operations, the unit capital investment must be minimized in order to improve the economics of the use of the control system.

13. ACCURATE DATA - Since accurate pressure, rate and volume data are important to the optimum operation of any secondary or enhanced recovery operation, the system should have the capability to obtain this data easily, and with an acceptable degree of accuracy.

14. TEST ABILITY - The ability to reduce the cost and improve the accuracy of steprate and pressure fall off test is an important consideration to the control system.

There are undoubtedly additional requirements for an injection control system, however, if all of the above are met, we are well on the way to establishing a viable operating system.

Current developments in the state of the art in other industries has developed to the point that at least some of the solutions to the problems in injection control are now possible. Everyone is at least aware of the technology explosion in the field of micro processors. There are currently available high reliable solar activated photo voltaic cells for use as power supplies in remote areas. The jelled electrolite battery is a natural companion to the solar panel. Past experience and current developments have established the ball valve as a reliable and economical control element.

The following is a description of an example of the efforts that have been made in one case to meet the requirements for a viable process controller for the oil production industry.

CONTROL ELEMENT

The first consideration in any process control system must be the final control element. Since the entire operation of the process control loop is dependent upon the control element, proper selection control cannot be over emphasized.
In the injection process, the selection of the control element (control valve) is complicated by a number of the requirements stated above. The valve must be capable of producing large pressure drops, be corrosion resistance, be economical to purchase, be economical to operate and repair, and provide accurate control over a wide flow range. These requirements have largely been met by a throttling ball valve. These ball valves have been used successfully for a number of years by a number of operators in injection control operations.

The configuration of the ball valve allows it to be operated by a reversing actuator, giving the capability to modulate the process to a desired level. (See Appendix A, Fig. 8367 for valve sizing.)

The construction of the ball valve allows for quick replacement of the ball and seals, without removing the valve from the line. (See Appendix A, Fig. 8368.)

POWER SUPPLY

Since the ball valve can be actuated by an electrical reversing actuator, the logical choice for power supply is electricity. While there are some problems with electrical power supplies from transcient surges and line regulation, the advantages of general availability, ease of use and dependability generally outweigh the disadvantages. Even though electricity is available in a number of locations, as often than not, there is no power available for well head operations.

Over the past several years, developments in photo voltaic cells (solar panels) have made them a reliable and relatively economical power source for low current operations. Since the solar panel (see Appendix C, 8366 for solar panel sizing) only operates when sunlight is present, it is necessary to provide a storage facility if continuous operation is desired. The gelled electrolite battery is ideal for this application. (See Appendix D for battery sizing information.)

PROCESS MEASUREMENT

The two functions that are of most interest in the injection process are flow and pressure. In order to perform a control function, it is necessary to measure the variable to be controlled.

FLOW MEASUREMENT

Wide application and a long history have established the turbine flow meter as a highly viable fluid flow measuring device. While the turbine meter is not without fault, it does perform well over a large (ten to one) range of flow and provides accurate data. (See Appendix B for turbine flow meter sizing.)

Current developments in vortex shedding and ultrasonic flow meters offer some prospects of alternate means of flow measurement.

Some of the major advantages of the turbine flow meter are: 1) low initial cost; 2) good operational reliability; 3) ease of maintenance; and 4) good turn down ratio.

PRESSURE MEASUREMENT

One of the spin offs of the aerospace industry is the development of relatively low cost, accurate and rugged strain gauge pressure transducers. These transducers have the advantage of operating at low voltages and current. The design and operating characteristics of strain gauge transducers make them very adaptable to the oilfield operation. (See Appendix D for example specifications and description of strain gauge transducers.)

CONTROLLER

Due to the current state of the art of electronics in general, and micro-processors in particular, it is now possible to produce an injection controller that meets current operational requirements and has the flexibility to provide needed expanded capabilities that may be needed in the future.

The basic design features of the controller are the capabilities to interface with other system elements. Of major consideration are: 1) The requirement for use of solar power, which dictates the assurance of low voltage and low current operation; 2) The need to interface with the reversible electric valve actuator; and 3) The ability to accept process measurements from a turbine flow meter and a strain gauge pressure transducer.

The basic logic of the controller is: 1) the comparison of flow rate and pressure to their respective set points and making the decision as to which process is critical (based on high override logic); 2) making the decision as to the magnitude and direction of the correction needed to bring the critical process to set point; and 3) producing a timed control pulse to the control valve.

Auxiliary functions of the controller include: 1) flow volume calculation and accumulation; 2) serial data and information communication; and 3) automatic steprate and pressure fall off testing. (See Appendix E for detailed information on controller.)

CONCLUSIONS

1. The requirements of current and future economics is secondary and enhanced recovery operations require improved measurement and control techniques.

2. There are currently available system elements which provide solutions to many of the current and future problems of measurement and control.

3. There will undoubtedly be a number of advancements in the development of equipment and methods of measurement, control and interfacing.

APPENDIX A

CONTROL VALVE SIZING

To size a control valve it is necessary to know:

1. Flow rate in gal./min. (Q)
2. Pressure drop in PSI (Dp)
3. Specific gravity of fluid (G)

The Cv for a valve is a coefficient expressing the valve capacity at a given position.

To obtain Cv for noncompressible fluids the following equation may be used.

$$Cv = \frac{Q \times G}{Dp}$$

The normal units of flow in injection operations are barrels per day rather than gallons per minute. To convert between BPD and GPM, use the following conversion factors:

1 GPM = 34.28 BPD
1 BPD = 0.0292 GPM

To reduce the pressure drop across the control valve and therefore allow the valve to operate at more favorable conditions, a hand valve in the flow loop to take part of the pressure drop may be used. It should be remembered that while the hand valve will take part of the pressure drop during operation, the control valve will have the full system differential pressure across it in shut-in conditions.

APPENDIX B

TURBINE FLOW METER SIZING
FIGURE 6

METER SIZE	GPM	BPD	PULSES/GAL.
1/2"	.75 - 7.5	25 - 250	13,000
3/4"	2 - 15	65 - 500	3,000
1"	5 - 50	170 - 1700	920
1 1/2"	15 - 180	500 - 6000	330
2"	40 - 400	1300 - 13,000	55

APPENDIX C
SOLAR PANEL SIZING

Solar panel sizing is accomplished by determining the load and the solar energy available and providing a system that is capable of supporting the load.

The 200CM system with no computer interface, process transmitters, or downhole pressure support requirements requires an average of 75 mA (based on 1000 valve actuations per day). The 200CM system with computer interface, process transmitters and downhole pressure requires an average of 100 mA.

Using the equation:

$$\text{Panel Output} = \frac{\text{Current drain X 24 hr.} + 33.3\%}{\text{Equivalent sun hours per day*}}$$

$$\text{Panel Output} = \frac{\text{100 mA X 24 hr.} + 33.3\%}{\text{4.5 sun hr./day}}$$

$$\text{Panel Output} = \frac{\text{3199 mA hr./day}}{\text{4.5 sun hr. / day}}$$

Panel Output = 711 mA

The standard commercial solar panel nearest 711 mA is 750 mA

*Average sun hour per day data from SOLEREX CORP.

APPENDIX D

STORAGE BATTERY SIZING

Battery sizing is accomplished by determining the power requirements of the load and the unpowered operational requirements of the system. Using the example above, assume that it is desirable to operate the system, without charging for a period of several hours.

Using the equation:

$$\text{Battery Capacity} = \frac{\text{Days X 24 hr./day X Load}}{.90^{*}}$$

$$\text{Battery Capacity} = \frac{\text{2 days X 24 hr./day X 100 mA}}{.90}$$

$$\text{Battery Capacity} = \frac{\text{4800 mA Hrs}}{.90} = \text{5333 mA Hrs.}$$

The nearest commercial battery to 5333 mA hr. is 5000 mA hr.

* The battery capacity is derated to 90% of its' capacity to provide for aging of the battery.

The above example assumes that the solar panel is disconnected with the battery at full charge. If, however, the solar panel were disconnected at first light in the morning the battery would be at approximately 72% charge or 3600 mA hr.

To calculate the runtime to low battery shutdown use the equation:

$$\text{Operation Hrs.} = \frac{\text{Battery charge - 500 mA hr.}}{\text{Load}}$$

$$\text{Operation Hrs.} = \frac{\text{3600 mA hr.- 500 mA hr.}}{\text{100 mA}}$$

Operation Hrs. = 31 Hr. (31 hr./ 24 hr./day = 1.3 days)

APPENDIX E

INJECTION CONTROLLER

DESCRIPTION

The 200CM Series Set Point Controller is specifically designed to fill the need for a simple, economical, flexible and reliable process controller for use in a field environment. The use of micro-processor logic allows the operator inputs to be entered through a front panel key pad. All process and controller operating information is presented through a large four digit LCD display.

The 200CM Series Controller may use a low cost ball valve for the process control element. The entire system may be powered with 117VAC, 12VDC or solar panels.

OPERATION

The 200CM Series Controller is a dual input, high override controller which accepts two process signals. The controller compares the process signals to their respective set points and selects the process which is the highest, (with respect to its set point) for control. The controller produces a control pulse, of the proper magnitude and direction to cause the control valve to drive the process toward set point. The duration of the control pulse is proportional to the magnitude of the error between process and set point. When the error becomes less than a preset amount of process range, no control pulses are issued.

Should battery power be lost, the control valve will be left in the last position. The operator will be advised of a power failure by a blank display.

To adjust process set points, controller gains and transducer scaling factors, the operator or technician uses the front key pad to enter desired values. (Operation is similar to a calculator.) In order to read, press: 0) Pressure 1) Pressure Set Point 2) Pressure Gain 3) Pressure Scale Factor 4) Rate 5) Rate Set Point 6) Rate Gain 7) Turbine Meter Cal Factor 8) Volume.

The installation and operation of the 200CM are straight forward and simple, requiring no special equipment or training.

The use of Micro-Processor logic allows a very low parts count with high reliability. In the event service on the electronics is required, the entire electronic section of the controller is removed as a unit. This feature facilitates easy field repair by replacement and allows the entire set of electronics to be removed for repair.

APPLICATIONS

The 200CM Series Controller is ideal for the control of fluid injection in secondary or enhanced recovery operations. The ability to select automatically between pressure and flow rate control allows extreme flexibility in the injection operation.

The 200CM Series Controller may be used in pressure, level, flow or temperature control applications, employing either single or dual process inputs. The application flexibility allows application in control of gas producing wells, central battery operations, water flood station applications, etc.

SPECIFICATIONS

Power:	750 mw
Accuracy:	+ or - .5%
Resolution:	1 part in 255
Display	4 digit LCD
Key Pad:	16 key
Temperature:	0 to 70 C
Enclosure:	10" x 12" x 6" PVC