Improving Plant Operations

Retrofit of Waste-to-Energy Stoker Controls to Improve Combustion and Availability

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ABSTRACT

This paper discusses the retrofit of the stoker grate hydraulic system and controls at Montenay's Montgomery County Pennsylvania Waste-to-Energy Facility. Since commencing operations in 1991, the stoker grate system was plagued with operational disruptions caused by fusion of its moving grates. The existing hydraulic system was designed to control the movement of waste on the grate sections by maintaining constant velocity stoker grate movement and varying the length of time the grates were dormant between cycles of grate movement. The purpose of the retrofit was to improve grate operations by replacing the existing hydraulic system with a system capable of providing continuous stoker movement at variable velocities, eliminating the dormant cycle of the grate movement.

Background

Montenay Energy Resources of Montgomery County operates a modern mass-burn waste-to-energy facility located in Pennsylvania. The Facility was constructed in 1991 with two 608 ton per day boilers manufactured by Steinmuller, GmbH.

The Steinmuller design incorporates 10 independently controlled, stoker type, moving grates which control the rate of flow and combustion of municipal solid waste. The original stoker grate control system utilized a series of fixed displacement pump-sets that moved the individual grate hydraulic cylinders at a constant rate of speed. The movement of waste was controlled by varying a standby timer at the end of each grate stroke (Table 1). This control resulted in an inconsistent movement of fuel in the furnace. This type of control also caused the grate sections to remain dormant for standby periods up to 5 min., which in turn caused the grates to become susceptible to fusing in place due to weldments (Fig. 1). Weldments frequently occurred when small quantities of iron-core material, such as the steel belt in a tire, were exposed to excessive temperatures resulting from the combustion of high heating value waste. The iron material would melt and fuse/embed to the surface of the grate casting, thus obstructing the movement of the opposing bar. A small weldment of approximately ½ in. in diameter was capable of seizing a grate section 10 ft. by 10 ft. in size, which would force a shutdown of the affected boiler.
<table>
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<th>Grate Section</th>
<th>Movement Duration (seconds)</th>
<th>Standby time (Min.)</th>
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<td>137</td>
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Table 1– Original Stoker Movement Cycles

Figure 1 - Stoker Grate Movement and Weldment Overview

New Concept
In late 2002, a modification to the method in which the stoker operated was developed. The approach was simply to make modifications to the stoker controls and equipment, eliminating the dormant standby period in which grate sections remained motionless. This method of operation was replaced with a method in which movement varies in velocity such that the rate of movement of waste is virtually constant. The result would be a more consistent even flow of fuel, thus stabilizing furnace combustion conditions. This concept allowed the grate to remain in motion, eliminating the periods in which the grate was dormant, thereby reducing the possibility of weldments which were causing the grate sections to seize.

The proposed system would continuously move the grates at variable speeds to ensure a constant and continuous flow of fuel on the grates. The basic theory and cycle timings of the original control system would be maintained, thus maintaining the original design throughput and capacity. Instead of the stoker section moving for a fixed period of time and then remaining motionless for variable periods of time set by the boiler master control program, the stoker section would continuously move at a variable rate of speed.

Overview of Existing System Design

Hydraulic Pump Sets
The existing system design utilized 6.3 L/min fixed displacement pumps that were not capable of restricted hydraulic flow. The pumps were designed to displace a fixed volume of hydraulic fluid per revolution of the pump. If the output flow was restricted, the discharge pressure of the pump would continue to increase until pump damage occurred. The pump sets were designed in a stacked formation in which six (6) pumps were connected together and driven by a single motor. (Fig. 2)

Figure 2 Existing Hydraulic Pump Set

This pump/motor design did not allow utilization of variable frequency drives to regulate the output of the pump. A variable frequency drive would vary the flow rate of all 6 pumps simultaneously. Each grate section must be able to move independently at varying rates.
Hydraulic Control Valves
Each fixed displacement pump was individually connected to a series of pressure relief valves and a directional control valve (Fig. 3) with an open spool center for free flow return to the reservoir when the stoker grate section was not moving (directional valve not energized) to prevent damage to the pump. The directional control valve, when energized, would direct hydraulic fluid from the pump to either the forward (extend) or the backward (retract) side of the hydraulic cylinder depending on which side of the valve was energized. Two pressure relief valves regulated the normal and maximum pressure that the hydraulic cylinders and the stoker carriage would be exposed. The design allowed the lower pressure relief valve to be manually isolated momentarily, permitting a higher pressure to be delivered to the cylinder in an attempt to free a stuck stoker grate seized by a weldment. This process was successful only about 5% of the time it was attempted.

The Controls
The directional control valves were automated using an Allen Bradley PLC 5 programmable logic controller (Fig. 4). The PLC received a demand signal from the boiler master control system which monitored the boiler performance with regard to steam flow production and furnace temperature.

If the steam flow and furnace temperature were below the set-point, the boiler master controls would call for an increase in fuel feed and a corresponding increase in stoker movement. This was accomplished by decreasing the duration of the standby cycle for the individual stoker sections, thus increasing the number of times the stoker section moved.

If the steam flow and furnace temperature were above the set-point, the boiler master control would call for a decrease in fuel feed and a corresponding decrease in stoker movement. This was accomplished by increasing the standby duration for the individual stoker sections, thus decreasing the number of times the stoker section moved, slowing down the combustion process.
The PLC was operated to indirectly monitor the performance of the stoker grate hydraulic cylinders via timers. With the use of fixed displacement pumps, the cylinders moved at a fixed rate of speed, so the movement was capable of being monitored based on time. Each time the individual section was called to move, a timer was started to monitor the duration of the movement. When the cylinder reached the end of its stroke, hydraulic pressure would increase until the pressure relief valve would open, allowing the hydraulic fluid to return to the reservoir. A pressure switch was used as feedback to the PLC when this condition occurred. This feedback would stop the timer. The timer was then compared to the performance standard. If the timer exceeded the standard (e.g., cylinder taking too long to reach full movement), an alarm annunciated to warn of a weak pump output, or faulty cylinder seals; if the timer failed to reach the standard (cylinder reaching maximum pressure too soon), an alarm was annunciated to signify a short stroking cylinder (this condition was most often caused by a grate weldment).

This configuration eliminated the need for numerous limit switches that would have been required to ensure the correct (full) movement of the cylinders. This full movement is critical in the proper flow of fuel on the stoker grate.

Figure 4. – Allen Bradley PLC Control

The Hydraulic Cylinders
The existing system utilized a 1:1 ratio hydraulic cylinder (Fig. 5) on each stoker section. This cylinder is designed with equal volume on both the forward (extended) and the backward (retracted) positions and has a volume of 2.67 liters. With the use of the 6.3 L/min fixed displacement pumps, the cylinder completed each cycle in approximately 26 seconds.

Figure 5 – Typical Stoker Grate Drive Cylinder

Concept Design
The concept to eliminate dormant cycles of the stoker grate required the ability to individually vary the volume of hydraulic fluid that is directed to each stoker grate hydraulic cylinder. All existing cycle times (movement plus standby time) were to be maintained in the new design so that fuel feed and capacity would not be affected. Based on the hydraulic cylinder volume and the required movement cycle times, the hydraulic flow rate had to be controlled between 3.02 L/min. and 0.0085 L/min. This corresponds to a movement cycle of 53 seconds to 313 seconds. As
previously mentioned the existing pumps were not capable of restricted flow and would require replacement.

**Pump Selection**
With the need to vary hydraulic flow to multiple valves at various flow rates, the required pump had to be capable of pumping with a closed discharge (dead-headed) without damage and must be capable of self-regulating output flow. A variable displacement axial piston pump (Fig. 6) was selected to provide this performance. The pump self regulates flow based on discharge pressure setting: as flow demand increases, a small pressure drop occurs due to the release of pressurized fluid. The pump senses the drop in discharge pressure and instantaneously increases the hydraulic output to maintain proper discharge pressure. Due to the pump's ability to self-regulate output flow from full flow capacity down to zero output flow, one large pump is capable of replacing 5 of the original fixed displacement pumps.

![Figure 6 - Variable Displacement Hydraulic Pump](image)

**Control Valve Selection**
The next component that required replacement was the directional control valves. The new valves were required to precisely control the flow of hydraulic fluid from the pump to the associated stoker grate hydraulic cylinder under constantly varying hydraulic work loads (back-pressure) in order to control the rate of movement of the stoker grate section. The valve would be controlled by the PLC through a variable voltage output card. Ideally the selected valve would be capable of such precise hydraulic flow control and repeatability, such that the existing controls and alarms for stroke length could be adapted into the new system, thus eliminating the need for additional limit switches or instrumentation.

**Component Testing**
The components were selected based on discussions with a local hydraulics supplier and review of available technical performance data. This available data showed the general capability of the components individually but did not supply sufficient information to ensure the success of the project. It was decided that a smaller scale performance test was required to simulate and verify the performance of all of the components assembled into a system. A test station was assembled to enable offline performance verification of the system and to collect the necessary valve performance data. This data was required to create the PLC control logic that would control the movement of the stoker. The test station (Fig 7) was connected to a spare stoker hydraulic cylinder to record actual cylinder stroke movements at various voltage inputs to the control valve. A PLC test program was developed to repeatedly stroke the hydraulic cylinder back and forth at input voltage increments of 0.01 volts. Each voltage step was repeated 50 times and the performance data was automatically logged for performance and repeatability assessment.
The pump performed as expected, maintaining hydraulic pressure throughout the full range of hydraulic flow. The first control valve tested was a proportional directional control valve that did not incorporate any valve spool position feedback. The valve was capable of controlling hydraulic flow to the cylinder but did not provide the accuracy and repeatability required for the application. The second control valve tested was also a proportional directional control valve, except this valve was designed with an electronic spool feedback signal which through onboard electronics ensured that the valve spool moved to the correct position relative to the input voltage signal.

The second valve tested exhibited improved repeatability, although when the control valve was reversed with the same input signal, the reverse movement velocity did not match the corresponding forward movement velocity. Both types of proportional directional valves did not meet the performance characteristics required to properly control the stoker movements. Without the demonstration tests the project would not have been successful.

New Control Valve Configuration

Following the failure of the proportional directional control valves initially specified for the project, a slightly different control concept was developed. This concept utilized a proportional flow control valve with a built-in pressure compensator (non-directional design), a custom manifold to distribute hydraulic fluid, and reuse of the existing directional control valves. This design utilized the same flow control valve for both movement directions ensuring consistent movement. The valve/manifold combination utilized a stacked design capable of being mounted onto the existing system manifold and piping configuration. This design aided in minimizing the conversion costs. The new design was tested with the same test program previously utilized. The results were positive, with the average standard deviation throughout the range of the valve being less than 0.15 seconds over the 50 test strokes used to performance test the hydraulic controls.

Online Performance Testing

The valve performance data collected was utilized to write the PLC control logic required to incorporate the new system design into the existing stoker grate control system. The test system was then temporarily connected to one of the stoker grate sections on an operating boiler through the use of temporary hydraulic hoses. The existing system remained intact in the event that poor control resulted. The test section performed as expected with stroke cycles identical to the previous system, except that the standby time of the previous system was now replaced with continuous movement.

It was decided to expand the test station to allow the temporary control of 8 of the 10 boiler stoker sections for a true performance test before investing money in a capital upgrade of the existing system. The test station was connected to the 8 sections of the boiler stoker in April 2005, during a scheduled shutdown. During the shutdown, four
(4) grate sections were refurbished with new grate shoes. Historically, equipping a grate section with new shoes resulted in the increased frequency of stuck grate shoes. The clean and smooth metal surfaces increased the likelihood of molten metal adhering to the surface.

Following startup of the unit with the eight (8) sections controlled by the continuous grate controls, there were no further instances of binding caused by metal fusion on the grate.

Two weeks later the second unit was shutdown and the same grate replacement process was performed, only this time the unit was not connected to the continuous moving grate controls. Upon startup, this unit had five (5) occurrences of stuck grate sections within 1 ½ weeks, three (3) of which required shutdown for repair. It was concluded that the modified hydraulic control system was successful in reducing/eliminating the occurrence of stuck grates. The plans were finalized to complete a full conversion of hydraulic controls on both units to incorporate the continuous moving grate control technology. The final design incorporated redundant pump/motor sets and a similar power consumption profile as the original system. This conversion was successfully completed in March 2006.

Conclusion
Historically since 1991, the frequency of a binding or stuck grate section was about once every 5 weeks, with an increase in occurrences immediately after replacing a grate section. Since the first test section was put into operation in 2004, there has not been any occurrence of a binding grate section using the continuous moving grate controls. Additionally, a significant improvement in combustion stability was noted. This is attributed to the improved consistency in the movement and feeding of waste during the combustion process.

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Solid Waste Resource Recovery Project
Units 1 & 2
Montgomery County, Pennsylvania
Two 162,000 lbs/hr - 600 psig operating 750F
Fired by Bulk Refuse 608 Tons/Day Capacity Each
Steinmuller - Gummersbach, Germany