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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius	lb/ft^3	pound per cubic foot
ft^2	square foot	min	minute
gal	gallon	psig	pound per square inch, gauge
h	hour	s	second
in	inch		
lb	pound (mass)		

EVALUATION OF SAFETY SHUTOFF VALVE SYSTEM ON METHANE GAS PIPELINES UNDER MINE FIRE CONDITIONS

By Patrick A. Kinek,[1] Thomas E. Marshall,[2] and Gerald L. Finfinger[3]

ABSTRACT

The purpose of this investigation was to evaluate the integrity of the existing shutoff valves and actuators used under high-temperature conditions in the Bureau of Mines' horizontal borehole methane drainage pipeline system and to determine the potential for improvement in the system.

In the field tests, both fire-safe ball valves and standard brass ball valves were initially subjected to a 30-min pan fire without thermal protection. Neither valve could maintain line pressure beyond 11 min in a fire that reached temperatures between 500° and 700° C.

Based on the test results, it was concluded that the brass ball valve used in the Bureau's methane drainage pipeline system can be retrofitted with an inexpensive "fire bag" to substantially increase its integrity under mine fire conditions.

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INTRODUCTION

Methane gas is an inherent safety hazard in underground coal mining. In response to this hazard, the Bureau of Mines instituted a methane drainage program that has undertaken numerous improvements over the years (1-3).[4] A major objective of these improvements has been in the area of the pipeline safety system. This system consists of numerous fail-safe mechanisms that control drainage of methane gas under normal and emergency conditions. One emergency condition for which the system had not been tested was its behavior when subjected to a mine fire. Although the occurrence of a mine fire in the life of a mine is very infrequent, the effects of mine fires can be dramatically worsened by gas leaks from underground methane gas pipelines.

The Bureau and the Mine Safety and Health Administration (MSHA) are concerned about this fire hazard because the implementation of methane drainage programs in U.S. coal mines will increase as gassier mines are worked. Although only a handful of drainage programs currently exist, one mine with a methane drainage operation has already had a fire that resulted in extensive property damage (4).

At the request of MSHA, the Bureau undertook the present investigation to determine the integrity of the existing shutoff valves and actuators used in its methane drainage pipeline system when subjected to high temperatures such as those encountered in a mine fire, and to study the potential for improvement in the system.

ACKNOWLEDGMENTS

The cooperation and efforts of members of the Fire and Explosions Group, Bureau of Mines, Pittsburgh Research Center, are greatly appreciated. In particular, Charles P. Lazzara, Supervisory Research Chemist, and Frank Perzak, Research Chemist, were instrumental in the initial investigation of valve manufacturing and insulation techniques. The authors would also like to thank Frank Perzak for his effort in setting up and monitoring the fire tests at Lake Lynn Laboratories.

SURVEY OF VALVE MANUFACTURERS

The investigation began with an inquiry to determine whether any ball valve manufacturer or commercial testing company did any high-temperature performance design and testing on ball valves used to regulate gas. It was found that all high-temperature ball valve designs assumed that a liquid was being regulated (usually a petroleum product), and that all performance criteria (leakage rates) during testing of valves were based upon the regulation of a test liquid (water). It appeared that previous to the Bureau inquiry, no one had ever asked for a ball valve that would regulate gas under fire conditions. The basis for the industry's current design of fire-safe valves is the ability of a liquid under pressure to create a "bubble seal" between the ball and the valve body after the Teflon[5] seat has burned away. Since a single gas phase does not have this property, existing fire-safe valves are not applicable to the methane drainage system.

One manufacturer suggested the use of either ball valves with seats, seals, and body parts made out of expensive materials (i.e., graphite, stainless steel, etc.) or more expensive, custom-designed wafer valves. However, both of these solutions would have meant an 8- to 10-fold increase over the cost of the presently used valves. Accordingly, it was decided to see if the present ball valve or a more expensive, fire-safe ball valve could be insulated from the high temperatures resulting from a mine fire.

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[4] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

[5] Reference to specific products does not imply endorsement by the Bureau of Mines.

INVESTIGATION OF INSULATION TECHNIQUES

The insulation technique had to be (1) relatively inexpensive, (2) easily retrofitted, and (3) accessible when valve maintenance was required. Only two insulation techniques are currently being used in the valve and actuator industry. The first technique is the application of a thin coating of epoxy-based substance which during a fire swells up and chars (an intumescence), forming an insulation barrier. However, its use was not recommended because of the temperatures and duration of the type of fire under consideration and because of expense.

The alternative available insulation technique was a "fire bag" made from inexpensive ceramic fiber and fiberglass (Kaowool, \$1.70/ft^2).[6] A 2-in-thick, 8-lb/ft^3-density material was used. The fiberous material is wrapped in an inexpensive, fire-resistant jacket (\$0.80/ft^2), having a silicon rubber coating with a fiberglass base that provides a weather-resistant barrier. The total cost of materials used to construct the "fire bag" (1 ft^2 of Kaowool, 2 ft^2 of fire-resistant jacket material, and two hose clamps) was approximately \$6. This more than satisfied the first specification of low relative cost.

The second requirement was that the insulation technique had to be easily retrofitted. The "fire bag" was measured and cut in the field with a tape measure and a simple utility knife. Approximately 10 to 15 min was required to construct it. Since all the valve-actuator components in a mine would be identical, the same pattern can be used for all the valves.

The third requirement of valve accessibility was achieved as the fire-resistant jacket can be easily removed and replaced by loosening the two hose clamps.

FIELD TESTS OF BALL VALVES

Field tests were conducted at the Bureau's Lake Lynn Laboratory. A series of pan fire tests was performed on the ball valves, using kerosene as the bulk fuel and heptane as the starter fuel. The test set up consisted of two 10-ft sections of 2-in-diam, standard, schedule 40 steel pipe connected to either end of the ball valve. The ends of the pipe were supported, so that the valve was suspended over the fire pan (fig. 1). One pipe section was sealed and pressurized with nitrogen gas. The nitrogen gas leakage rate was monitored with a pressure gauge and a flow meter. Three thermocouples were used to monitor the temperature of the fire, the outside valve body temperature, and the internal temperature of the valve body around the Teflon seat (fig. 2). The pressure gauge, flow meter, and elapsed time were continuously monitored with a video camera. Thermocouple temperatures were monitored using strip chart recorders and a microprocessor.

Two ball valves were initially tested without an actuator or any thermal protection: a fire-safe valve and the brass valve currently used by the Bureau. The fire-safe ball valve was constructed of stainless steel with a Teflon seat and an asbestos stem seal. The Bureau valve has a brass body with a Teflon seat and a Teflon stem seal; its cost is about one-fourth that of the fire-safe valve.

For each test the valves were turned to the closed position so that nitrogen gas could fill the pipeline. A line pressure of 20 psig was put on the valves to simulate the low pressures observed in a shutoff methane drainage pipeline. Line pressure in a shutoff methane drainage pipeline can reach in situ gas pressures well in excess of 20 psig if allowed to build for 24 h or more. However, in a mine fire emergency, shutoff valves at the collars of the holes would be closed as soon as the fire was detected by the pipeline safety system or by mine personnel. Thus, during the subsequent critical minutes of the early life of the fire, line pressure would remain low.

[6] Prices for equipment are based on July 1984 data.

FIGURE 1. - Test setup for temperature durability evaluations.

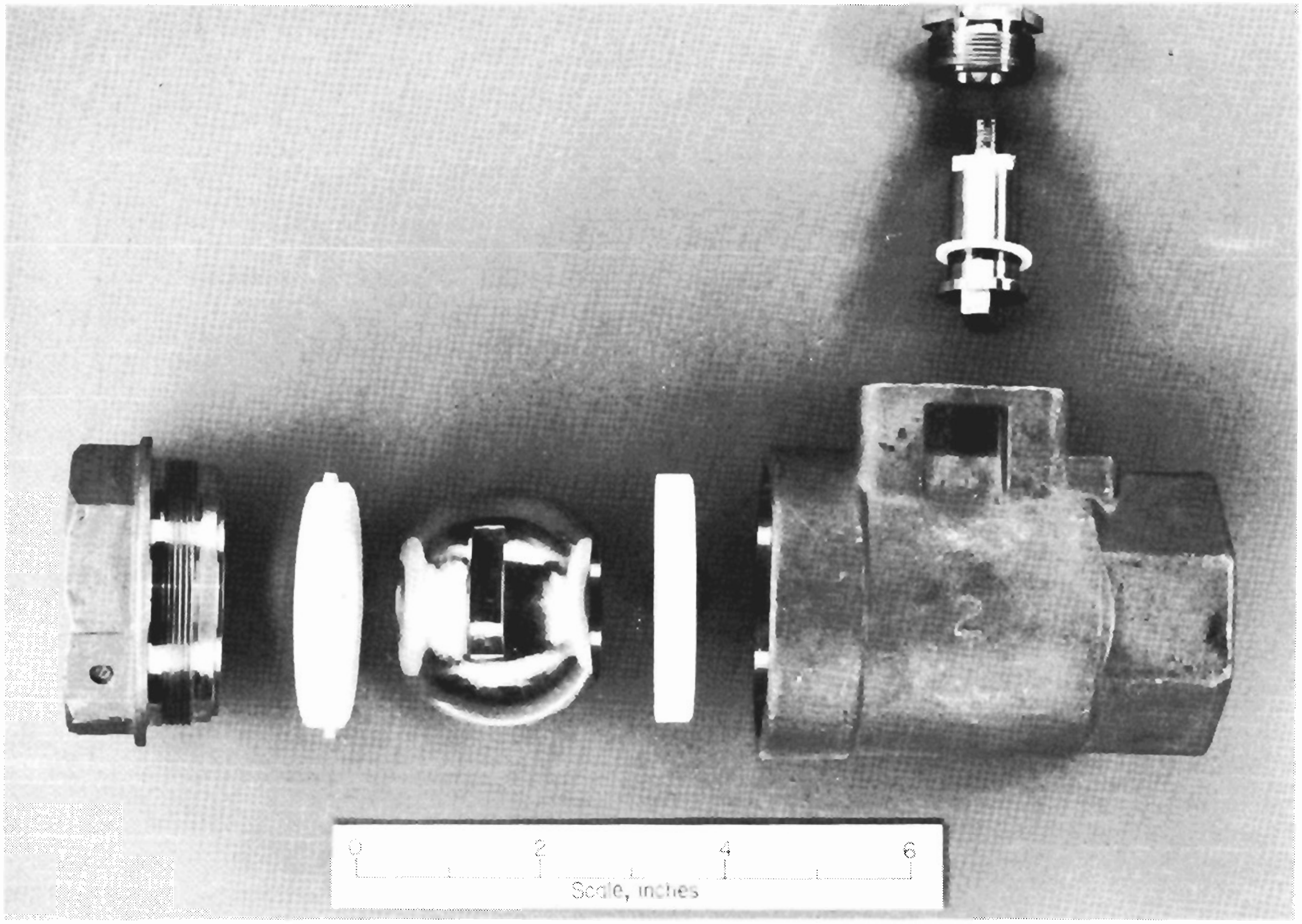

FIGURE 2. - Components of brass valve.

Initially, in each test, a pan fire using 15 gal of kerosene was ignited under the unprotected valve, producing temperatures of 500° to 700° C over a 30-min period. Both valves recorded an internal temperature of 500° to 550° C on the seats at 11 min (fig. 3); this is the temperature range in which Teflon polymer begins decomposing extensively. Not surprisingly, for tests with both valves the flow meter began rising after approximately 11 min, indicating a leak in the system through the valve.

An important observation was that the inexpensive brass valve performed as well as the more expensive fire-safe valve. Low line pressure and the absence of a liquid medium rendered the fire-safe valve as ineffective at high temperatures as the brass valve. Given this finding, it was decided to use only the brass valve for the "fire bag" tests.

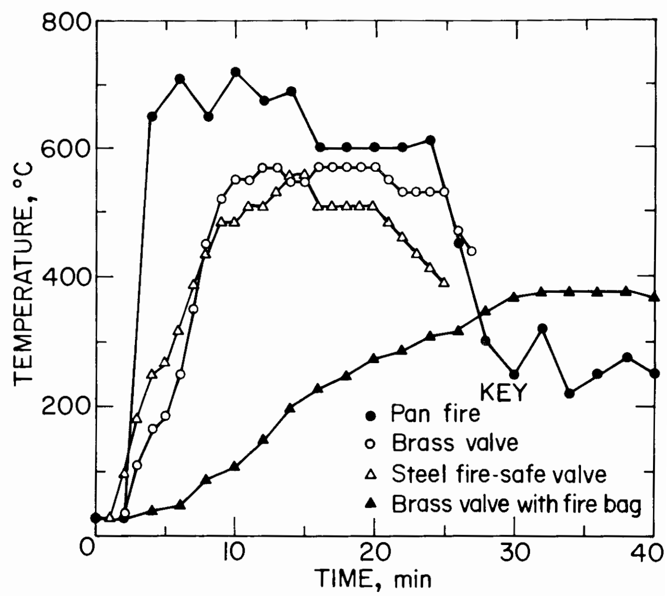

FIGURE 3. - Results of fire test.

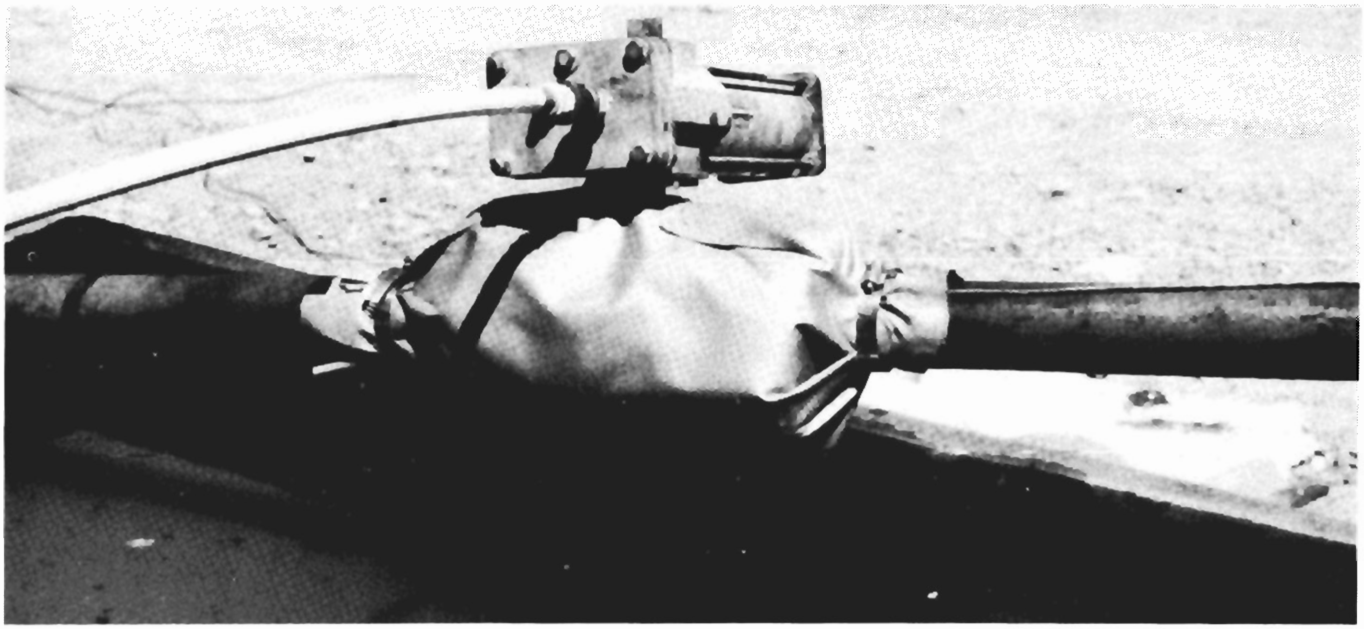

FIGURE 4. - Closeup of a brass valve protected with a "fire bag."

FIELD TEST OF THE "FIRE BAG"

A complete shutoff valve system was constructed for the "fire bag" tests. An air actuator was attached to the normally closed brass valve, and 60 psig of air was applied to the actuator through 1/2-in PVC pipe to keep the valve open (fig. 4). The initial reason that PVC pipe was chosen to carry air to the actuators was that it is inexpensive and would break easily if there were a roof fall on the pipeline (1). Line pressure would drop once the pipe was broken, causing all valves in the system to move to the closed position and thus halting methane gas flow. Given the fact that the PVC pipe being used had a low melting point, it could also serve as a fire warning mechanism. The same series of shutoff events would occur once the PVC pipe burned through as when the pipe was broken by a roof fall.

Once the shutoff valve system was constructed, the valve was wrapped in the "fire bag." Twenty gallons of kerosene was used for these tests to extend the life of the fire from 30 min to 40 min. The kerosene was ignited, and after 20 s the PVC pipe burst, confirming its effectiveness as a fire warning mechanism. As a result, air pressure on the actuator was released, causing the valve to close and stopping the flow of nitrogen gas. After 40 min of fire exposure at temperatures between 500° and 700° C, the ball valve seat and stem seal were still intact and maintaining line pressure. The internal temperature on the Teflon seat was only 380° C at the end of the 40-min period (fig. 3), as compared with 550° C after 11 min without the "fire bag" (fig. 3).

CONCLUSIONS

The results of the investigation indicate that the ball valves now used in the Bureau's methane drainage pipeline system can be retrofitted with an inexpensive "fire bag" to substantially increase the system's short-term integrity under mine fire conditions. It was also established that the more expensive fire-safe ball valves are no more effective at sealing a low-pressure gas line under high-temperature conditions than a thermally unprotected brass ball valve.

It was also found that normal 1/2-in PVC pipe can function not only as a roof fall warning system, but also, because of its low melting point, as a fire warning system for methane gas pipeline.

REFERENCES

1. Tongue, D. W., D. D. Schuster, R. Niedbala, and D. M. Bondurant. Design and Recommended Specifications for a Safe Methane Gas Piping System (contract J0155145, Energy Applications Inc.). BuMines OFR 109-76, 1976, 97 pp.; NTIS PB 259 340/AS.

2. Prosser, L. J., G. L. Finfinger, and J. Cervik. Methane Drainage Study Using an Underground Pipeline, Marianna Mine 58. BuMines RI 8577, 1981, 29 pp.

3. Irani, M. C., F. F. Kapsch, P. W. Jeran, and S. J. Pepperney. A Fail-Safe Control System for a Mine Methane Pipeline. BuMines RI 8424, 1980, 11 pp.

4. Mann, F. C., J. V. Bowman, and W. W. Hulvey. Report of Investigation (Underground Coal Mine). Mine Fire and Explosion, VP-5 Mine (ID No. 44-03795), VP-5 Mining Company, Vansant, Buchanan County, Virginia. Mine Safety and Health Administration, Apr. 15, 1982, 14 pp.