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Project Summary

Development and Demonstration of Concepts for Improving Coke-Oven Door Seals: Final Report

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The report discusses the design, laboratory scale tests, construction, and field tests of an improved metal-to-metal seal for coke-oven end doors. Basic features of the seal are: high-strength temperature-resistant steel capable of 3 times the deflection of current seals without permanent deformation; no backup springs and plungers and the attendant requirement for manual inservice adjustments; seal installed to conform to the jamb profile; seal lip height reduced to give 8 times the inplane flexibility; and compatibility with existing coke batteries and door handling machines. Field tests on operating 4 and 6 m batteries proved the soundness of the concept along the straight vertical sides of the door. However, an unforeseen force combination in the four corners resulted in a net force acting to lift the seal corners away from the jamb, resulting in unacceptable leakage at each seal corner. Various schemes were evaluated empirically in an attempt to understand and solve the problem. A modified design to eliminate the problem and reduce fabrication cost is proposed. Inland Steel Company plans to build and test the modified design at its own expense. This was a jointly funded EPA/American Iron and Steel Institute project.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Project Origin

In 1975 Battelle completed a project entitled "Study of Concepts for Minimizing Emissions from Coke-Oven Door Seals." This project was jointly sponsored by the Industrial Environmental Research Laboratory of EPA and the American Iron and Steel Institute (AISI).

The results and recommendations of the 1975 study were accepted by both sponsoring organizations and late in 1976 Battelle was awarded research contracts (with EPA and the AISI) dealing with development/engineering/laboratory evaluation of the recommended, upgraded metal seal. The results of this effort were accepted by the sponsors and funding was made available to complete Phase III of the program which consisted of fabrication and field demonstration of the recommended seal design/material.

This Report

This report summarizes the entire effort to develop an upgraded, retrofittable, metal coke-door seal. "Upgraded" here is defined as having significantly improved performance in emission control and operation.

Not included in this report are results of a major effort to prevent/minimize warpage of coke-oven jambs by changes in the jamb design and materials. This work was, however, reported in the EPA report, "Development and Demonstration of Concepts for Improving Coke-oven Door Seals: Interim Report," EPA-600/2-78-189 (NTIS PB No. 286 628), August 1978.

The Recommended Seal Design/ Material

The recommended seal design was the result of finding a best "fit" as evaluated by a long list of criteria and specifications. In a systematic approach, each criterion had to be considered, but the two major influences on the design were (a) a general specification by the AISI and EPA, and (b) a criterion strongly desired by Battelle researchers.

The major specification was that the new seal be retrofittable, i.e., the new seal would be a replacement for existing seals without modification of the doors or the door-handling equipment. This also meant that the recommended seal had to "handle" or accommodate all (or nearly all) of the jamb and the door warpage problems that exist at operational plants. Seals are attached to doors and the profile congruency of the door with the oven jamb can be poor due to past warpage and heat effects.

The criterion desired by Battelle personnel was that the recommended design/ material should eliminate the need for numerous, manual seal-adjustment devices associated with all existing seals. With about 25,000 coke-oven doors in operation, each with about 20 manual seal-adjustment devices, the theory is that at times workers climbing ladders or scaffolds would adjust 500,000 devices to improve emission control. Battelle researchers were skeptical about the performance of the adjustment devices and the availability of the time and skill to manipulate them.

The general approach to an upgraded seal was to increase the seal flexibility in every way possible while also increasing its strength and heat resistance. This approach resulted in the recommended design shown in Figure 1.

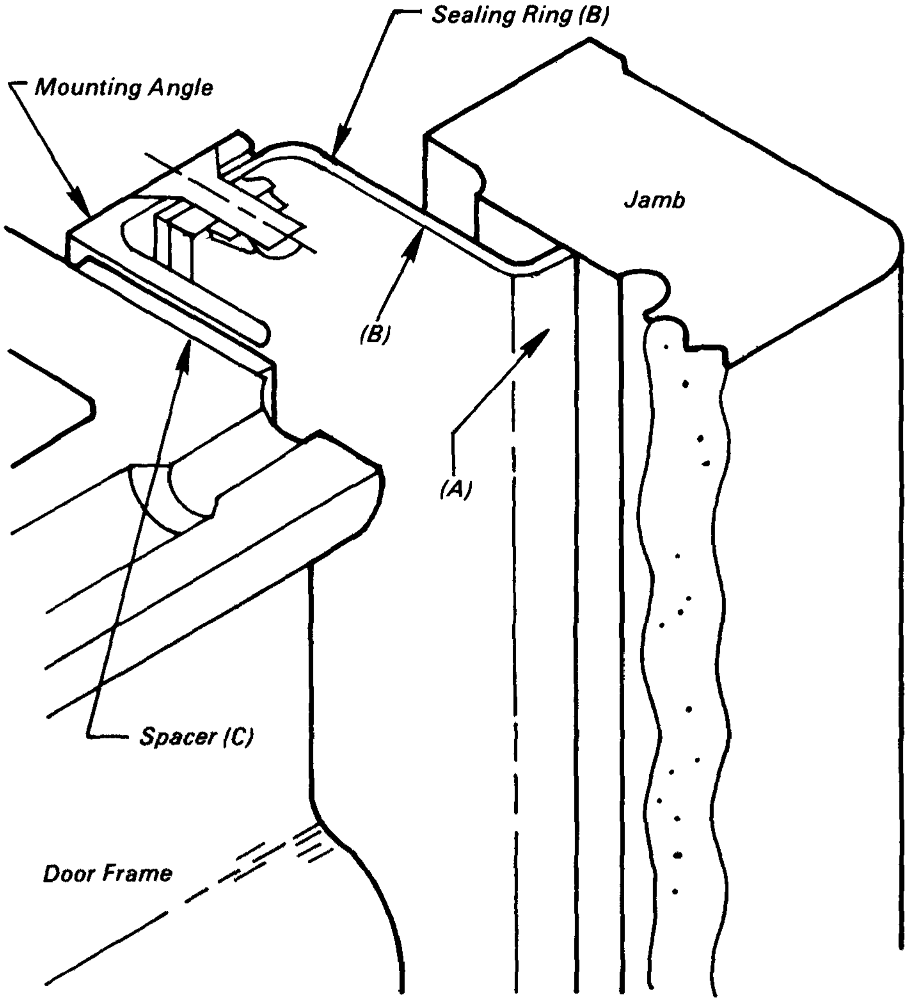

Figure 1. *Cross section of a suggested coke-oven seal.*

The design/material elements leading to increased flexibility and strength are:

1. The height of the contacting edge [(A) in Figure 1] was lowered to a 9.5-mm height (from 19 mm) to increase the flexibility of the edge along the jamb by a factor of 8. This increased flexibility allowed the vertical seal edge to maintain contact with the jamb in spite of curvatures in the jamb surface and the uneven surface of the seal edge.
2. The main spring element [(B) in Figure 1] was switched from 304 stainless or a corrosion-resistant, low alloy steel to a high-strength, high-temperature spring alloy. Battelle recommended that the first demonstration seals be made of age-hardened Inconel X-750. In laboratory tests at 426 °C (800 °F), Inconel X-750 tolerated three times the amount of seal deflection during simulated door latching before plastic distortion by creeping was encountered. Increased seal deflection is desired to (a) absorb minor changes in door and jamb profiles without the need for adjustments, and (b) keep an evenly distributed force pressing the seal edge against the jamb.
3. Changing the width of the spacers [(C) in Figure 1] along the door made it possible (during original seal mounting) to bend the entire seal to make the profile of the seal edge match the general profile of the jamb. This element of flexibility was introduced to make it possible to realign the seal edge and jamb profile in instances where the door and jamb profiles are particularly incongruent.

This design eliminated the need for seal-adjustment devices (and backup springs) pressing in point loading against the outboard side of the seal.

Demonstration Seal Fabrication

Two of the criteria for judging seal designs were (a) whether the design was amenable to mass production methods, and (b) whether the machining during fabrication could be eliminated. For the design presented, Battelle recommended (1) roll forming the seal shape rather than one-at-a-time brake forming, and (2) hydroforming the corners rather than the cut-fit-weld-machine fabrication methods now being used.

Further complications were introduced by (1) the requirement that demonstration seals should be obtained from experienced seal fabricators, rather than jobbing fabrication to different shops; and (2) introduction of a seal-corner design that could be fabricated only in a hydroforming operation.

Eleven months after sending out request for quotation seals, four seals were delivered to the Bethlehem Steel coke plant in Lackawanna, New York.

Results of the Seal Demonstration Efforts

The recommended seal design/material was tested at Bethlehem Steel's coke plant in Lackawanna, New York (6-m Wilputte battery) and at Republic Steel's coke plant in Youngstown, Ohio (4-m Koppers batteries).

At Lackawanna, the usefulness was demonstrated of taking simple measurements of the variation in distance between the jamb and door (along its length) and then installing spacers under the new seal to bring the seal edge into congruency with badly warped jambs. In one instance it was necessary to put a 19-mm (¾-in.) steel bar under the top horizontal portion of the seal to bring the profile of the seal into alignment.

Zero leakage, increased flexibility, and no manual adjustments were demonstrated (for months) along the 6-m vertical sides of the seal, as expected.

However, all four seals put into operation unexpectedly released emissions through gaps at each corner. This problem persisted even after reworking one seal to eliminate variations in the flatness of the seal edge. It was deduced that the corners were "lifting off" the jamb; i.e., the corners were reacting to forces that act to cause a slight gap at the corners during seal deflection. This lift off effect was confirmed at Republic Steel during tests using a 4-m seal forced against a flat machinist table.

The fact that corners on seals can react counter to a desired pattern was not new—U.S. Steel research personnel had told Battelle about "corner lifting" they had encountered on standard seals. What was obvious was that (a) the design changes made to avoid this potential problem were not successful in full-scale operation, and (b) that Battelle's laboratory work on parts of the seal did not model the reactions in complete seals. Experiments at Republic Steel indicated that the seal lip was not part of the problem and that some method had to be found to relieve the "bunch-up of metal" that occurs during seal deflection in the flat portion of the seal in the corners.

The Modified Seal Design

Project originators did not anticipate that a considerable amount of problem solving would be required after getting the first demonstration results. Although continued analytical work was considered (modelling and strain gauge testing on a full-scale seal), the last emphasis in the project was to consider the range of design changes that could provide an empirical solution to the corner problem. Out of this approach came a modified seal design (not yet tested). This modified design is shown in Figure 2.

The major elements are:

A— a flat strip, cantilever-spring replacement for the formed S-shape used in the original design.

B— a heavy-section, carbon-steel, angle-iron seal holder.

C— a demountable seal-edge angle bolted or welded to the seal element (no machining required).

It is recommended that the spring portion of the seal be made of 17-4 PH stainless steel, rather than Inconel X-750. This lower priced alloy was not included for consideration in the original evaluation because it is difficult to form, but all forming is eliminated in this design. It is expected that this seal can be built by steel companies.

For an empirical approach to a solution of the corner problem, it is suggested

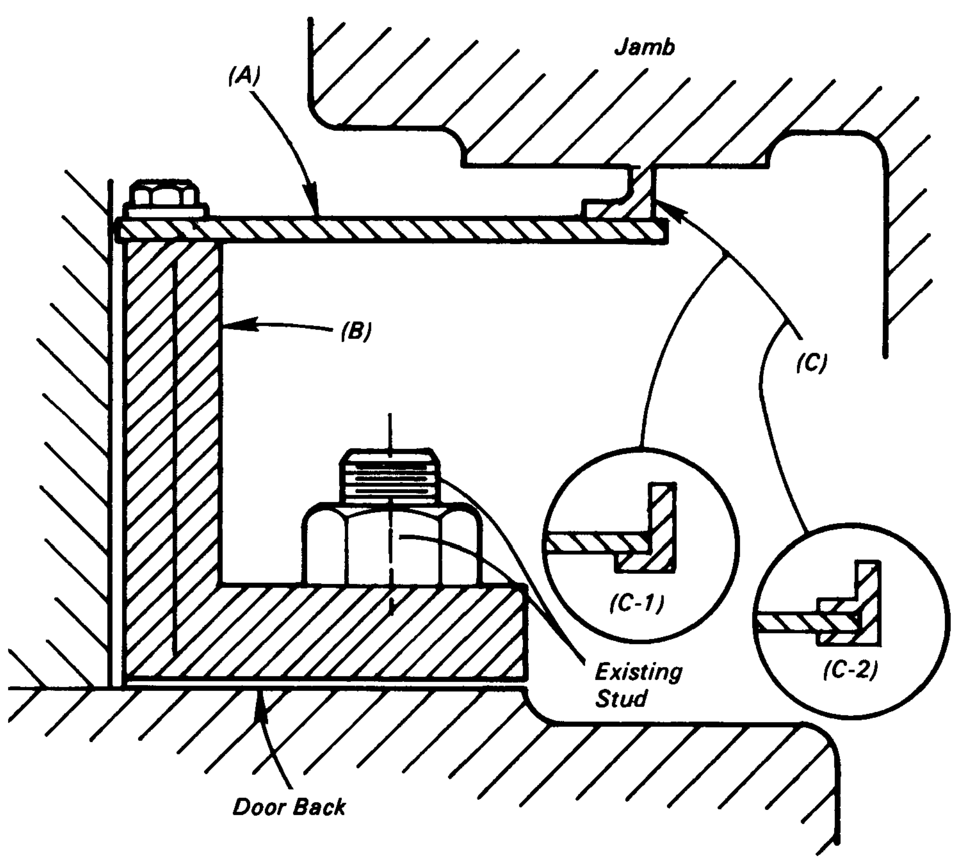

Figure 2. Modified seal design.

that the strips making up the main portion of the seal only be butted at the corners, not welded. This leaves a space or separation in the corner that (a) makes the corner relatively flexible, (b) permits consideration of corner backup (springs) outboard of the corner to force the corner against the jambs, (c) may minimize some of the stress generation in the corners during deflection, and (d) could introduce a built-in emission problem in the corners. To prevent emissions through the spacings, it is suggested that this space be closed with a cover strip (or foil) attached outboard of the corner.

Present Status of the Modified Seal

Inland Steel has volunteered to engineer/fabricate/test and oven-demonstrate one seal of the modified design. At this time, engineering is complete and fabrication is in progress.

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The complete report, entitled "Development and Demonstration of Concepts for Improving Coke-Oven Door Seals: Final Report," (Order No. PB 82-230 913; Cost: $12.00, subject to change) will be available only from:
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