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Impingement Baffles to Reduce Emissions from Coke Quenching

In the production of metallurgical coke, the hot, incandescent coke just removed from the ovens must be cooled rapidly for subsequent handling and to prevent it's burning. Cooling is usually carried out in quenching stations by spraying with large quantities of water. The violent evaporation of the water results in a carryover of solid particles and liquid mist up the stack of the quench station and into the atmosphere. A research study was conducted to determine means to reduce the emission of particulates from the quench stations. The results of the study showed that louver-type wooden impingement baffles installed in the stack will significantly reduce emissions without interfering with production operations.

One of the problems of controlling the particulate emissions inherent in steel-industry operations is that associated with the water quenching of hot metallurgical coke which has just been removed from the coking ovens. Coke, one of the basic raw materials of the steel industry, is charged to blast furnaces to provide the heat and carbon necessary for smelting iron ore. An average of over 1300 lb of coke is required for every ton of iron produced in blast furnaces; consequently, hundreds of thousands of tons of hot coke are water-quenched every day.

Coke-Making Process

Coke is made in batches in gas-fired oven batteries where raw coal is charged and heated to about 2000°F for 16–18 hr. The coal is converted to coke as the volatile matter is driven off. Numerous chemicals are later recovered from this volatile matter in coal-chemical plants. When the coking cycle is complete, about 12–14 tons of red-hot coke at approximately 2000°F are pushed from an oven into a special railroad car, which transfers the coke from the oven area to processing operations. The first step in the processing is to quickly quench the hot, incandescent coke with water to prevent it from burning and to reduce the temperature to a point at which the product can be safely handled. The violent evaporation of the water as it contacts the hot coke results in a cloud of steam, shown in Fig. 1, that can carry particles of coke and liquid mist up the stack of the quenching station and into the atmosphere.

The solid particles or "grit" are relatively coarse and tend to drop out in the area of the quench station. In an effort to cope with this problem, U. S. Steel's Applied Research Laboratory and Clairton Works have conducted a research program to determine means to reduce the emissions of particulates from coke-quench stations. This work was conducted at U. S. Steel's coke plant at Clairton, Pa. Other work has been done on this problem, notably in Europe, where several installations are in operation having some type of louver impingement baffles to trap grit particles from coke-quench-tower emissions. However, detailed data on the performance of these systems is lacking and there seem to be wide differences of opinion about their value. For these reasons, U. S. Steel conducted the research study to develop first-hand information on the design and performance of a quench-tower control system. This paper will present the results of our experiences.

Figure 2 is a diagram of a typical quench system. A quench car containing the hot coke is moved into the station and positioned below a system of water sprays. The particular tower used for this investigation is constructed of treated wood and is 100 ft high and 15 ft square in the stack section. During normal operation, about 13 tons of coke are sprayed with about 4000 gal of water for 2 mins. About half of this, or around 2000 gal is evaporated into the atmosphere for every load. The quenching systems are completely closed, and designed so that any water which is not evaporated drains into a sump to be recirculated to the quench sprays. A fresh batch of coke is quenched every 6 or 7 mins.

Literature Survey

As the first step in the investigation, a literature survey was made to determine whether any published material might indicate a solution or guide the course of action. The results showed that relatively little has been reported on the measurement or elimination of carryover from coke-quenching operations. Most of the work reported was British and involved the testing of various types of baffles and grids placed near the top of the quenching towers. No definite conclusions could be drawn regarding the general effectiveness of the devices tried. The survey indicated a need for an improvement in sampling methods to make possible a more quantitative evaluation of the performance of any type of control system installed in a quench tower.

After the literature survey, a test program was set up to include (1) a study of existing conditions of the quench-tower effluent to provide background information and to develop sampling techniques, (2) small-scale tests of various types of devices for particulate removal, and (3) a full-scale

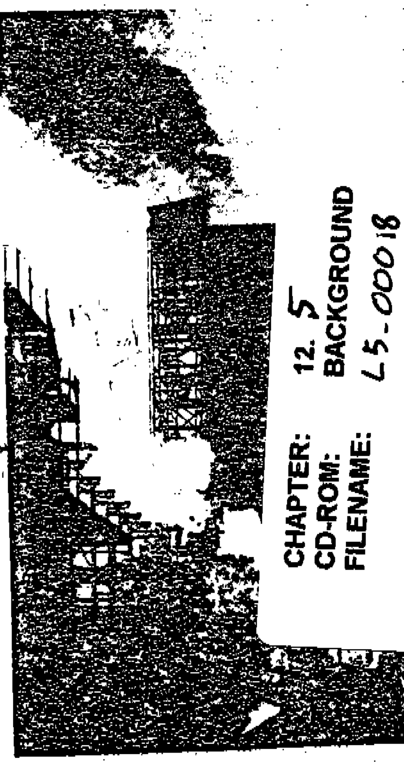

Fig. 1. Coke quench tower.

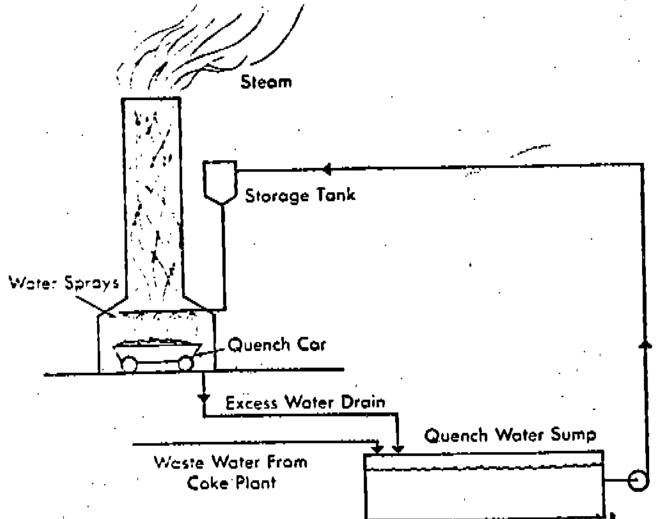

Fig. 2. Typical coke quenching system.

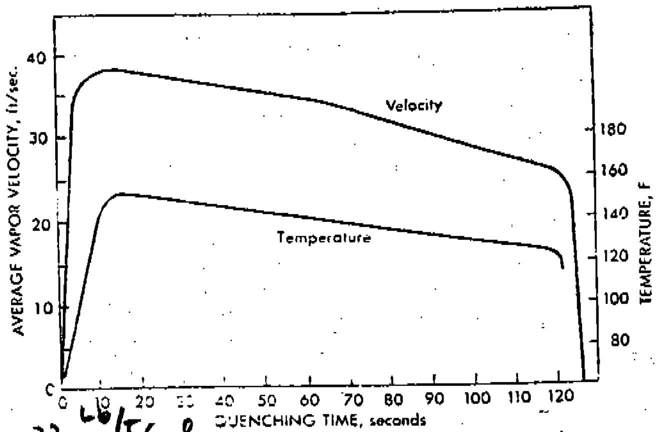

Fig. 3. Quench tower velocity and temperature versus time.

evaluation of the most promising type of device as determined by the small-scale tests.

Existing Conditions

The first phase of the study consisted of determining the existing conditions of quench-tower effluent, including velocity, temperature, and particulate content. All tests were conducted at one of the eight quench towers at the plant at Clairton Works. A stairway was constructed to the top of the tower, with a platform to provide access for testing the emissions at the source. Ground-level fallout tests would have been meaningless because of the interference of emissions from the other quench towers in the area.

Velocity profiles were determined by pitot-tube traverses, and temperatures were measured by thermocouples. In the testing, the cross section of the tower was divided into 16 imaginary equal-area zones, and velocity and temperature measurements were made in the center of each area every 15 sec during a quench period. This procedure was repeated during several quenches to obtain an average profile, which is shown in Fig. 3. The vapor velocity and temperature reach a maximum of about 36 fps and 160°F, respectively during the first 10 sec of the quench. During the remainder of the 2-min quenching period, the velocity and temperature drop steadily to about 24 fps and 130°F. On the basis of the average velocity of 32 fps and temperature of 150°F, a volume of 900,000 cu ft of steam and air are discharged from the tower during each quench.

Several methods of sampling for solids concentration were tried including a ceramic filter, a test cyclone, a demister screen device, and a greased-plate technique. The greased-plate method proved to be the most successful. In this test, a 16-gage stainless-steel plate, 0.1 sq ft in area, was coated with a thin film of temperature- and moisture-resistant grease, and inserted into the tower during the quench period. Solids in the effluent impinging on the plate adhered to the grease, which was then removed for analysis. In the analysis of the samples, the grease was dissolved in hot carbon tetrachloride, the solution was filtered hot, and the separated solids were weighed. Preliminary tests showed that particulate distribution was fairly uniform across the tower cross section; therefore, most tests were then conducted only at a single point of average velocity. It should be noted that the greased-plate sampling technique was intended primarily to provide a relative comparison of the amount of solids emitted before and after a removal device was installed. Although the efficiency of the greased plate in trapping the solids passing a given sample area is not known, it is believed that most of the particles are caught. The average solids emission during a 2-min quench (as calculated from the weight of solids collected on the greased-plate samples) was about 6 lb. As shown in Fig. 4, about 87% of this emission occurs during the first minute of the quench. As the coke is cooled and evaporation becomes less violent, the carryover of particles decreases. Table I is a typical screen analysis of the solids collected in the quench tower. This material is relatively coarse and thus tends to fall out locally instead of being carried long distances as a suspended dust plume.

Small-Scale Test

Any device to reduce the amount of solids emission from coke-quench towers must offer very little resistance to flow and must not act as a condenser for the large volume of steam generated during a quench. Any slight resistance will back the steam up and force it to escape along the bottom of the tower, thus creating interference with ground-level operations. Conceivably, a fan could be provided to draw the tower effluent through a conventional dust collector, but condensation of the steam (which would occur) would negate the requirement that all the plant's waste-contaminated water be disposed of by evaporation.

Therefore, the use of some type of low-resistance impingement removal device appeared to be the only practical approach to reducing the emissions. To determine the most promising device for a full-scale trial, we first conducted several small-scale tests on various devices. These were installed in a 2-ft square section of duct suspended in the quench tower. The results of these tests showed that although a 2-in-thick stainless-steel wire-mesh demister screen had a lower initial pressure drop for a given flow than did the wooden or metal louver-type baffles, the screen had a tendency to plug rapidly with solids. Cleaning these solids from the screen with a water spray was very difficult. Because louver-type baffles were found to be easy to clean and because certain types had been used with reported success in Great Britain, the decision was made to conduct a full-scale evaluation of the performance of this type of particulate-removal device.

Full-Scale Tests

The first trial set of louvers installed consisted of four different arrangements, each covering one-quarter of the cross

Table I – Screen Analysis of Coke Quench Tower Emission

Screen Mesh Size	Percent Above Size
6	0
16	1
30	10
50	45
100	84
200	97
−200	3

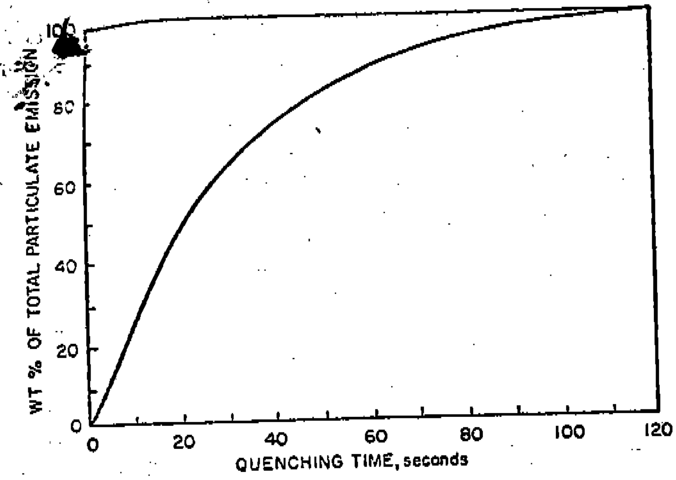

Fig. 4. Quench tower particulate emission variation with time.

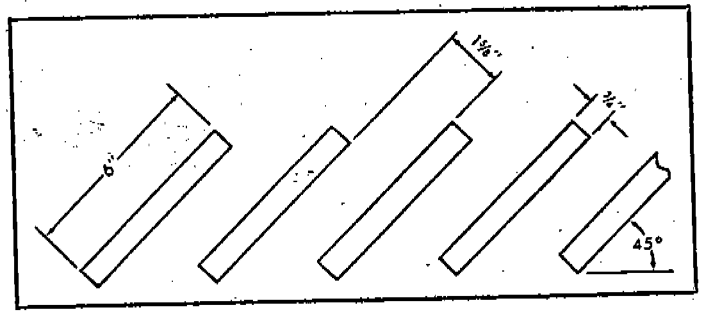

Fig. 5. Details of baffle design.

section of the quench tower, and included (1) a single bank of louvers inclined at 70 degrees from the horizontal, (2) a double bank of 70-deg louvers, (3) a single bank of 45-deg louvers, and (4) a double bank of 45-deg louvers. The construction was of a 1/2-in. thick by 3-in. wide redwood lumber. The double rows offered too much resistance to flow and also tended to accumulate deposits of solids, which could not be readily removed by flushing with water. Therefore, the second row of louvers had to be removed from each of the two double arrangements. Testing by the greased-plate technique indicated that the 70-deg louvers reduced solids emission to the atmosphere by about 60%, whereas the 45-deg louvers reduced emissions by about 85%.

Because of the higher efficiency achieved by the 45-deg louver arrangement in the preliminary trial, a new system was constructed having all 45-deg louvers. Heavier and wider lumber was used for increased strength to prevent warping, and also to provide a greater impingement area for particle removal. This second installation also included a water-spray system so that the louvers could be flushed periodically by an operator at ground level. The spray system consisted of a 4-in. stainless-steel pipe manifold with 16 full-cone stainless-steel nozzles located to provide coverage of the entire area.

Performance tests with the new louver system again showed a reduction in solids emission of about 85–90% as determined by the greased-plate sampling method. The emission of solids was reduced from about 6 to only about 0.75 lb/quench. This represents a reduction of over 1000 lb/day of solids to the atmosphere from one quench tower. The solids trapped by the louvers eventually are washed into the recycle sump, from where they are periodically reclaimed.

The louvers were satisfactorily kept clean by manually operating the water sprays for only 5 min during every 8 hr. This cleaning frequency was necessary to prevent solid deposits from building up. Since some of the spray nozzles tended to become plugged after several months of operation, it will be necessary to provide for access to the spray system on any permanent installation of this type.

In addition to the measured reduction of 85–90% of the solids emission, ground-level observations indicated that there was also significantly less fallout of liquid droplets around the quenching station containing the louver system than there was around the other quenching stations.

Final Design

Based on experience gained from this research program, the following design of an impingement baffle system to reduce solids emission from coke-quenching towers is recommended. As shown in Fig. 5, a single row of wooden louvers, set at an angle of 45 deg to the horizontal should be used. The louvers should be installed near the top of the tower. The lumber used should be 6 in. wide by 3/4-in. thick and spaced about 1 1/2–2 in. apart. Redwood should be used for durability. Stainless-steel nails should be used for fastening. The framework that holds the louver sections should be constructed either of redwood or of corrosion-resistant metal. Tests have shown that Type 316 or Carpenter 20 stainless steel or Inconel 600 are possible construction materials. However, even these steels became corroded in time, particularly in corners and other areas where buildups of solids accumulated. Smooth areas that did not accumulate solids did not corrode appreciably. This suggests the use of additional water sprays to keep the framework as well as the louvers clean.

The entire louver installation, including the water-spray system, should be so constructed that it can be lifted by a crane and hung in place over the quench-tower walls. Access should be provided to the top of the tower, by a stairway for example, to allow for maintenance of baffles and the water-spray system.

Quench-Tower Design Factors

The results of this investigation on the reduction of quench-tower emissions apply directly only to the square type (15 by 15 ft) wooden tower studied. There are, however, numerous other types of quench-tower designs. For example, the plant where this study was made also has several round brick-towers that are about 15 ft in diameter at the top. The applicability of the louver baffle system to these towers is not known at present. The higher velocity through the round towers with a smaller cross-sectional area is likely to have an effect on the efficiency of particle removal. Also, there would be design and construction problems involved in adapting the louver concept to a round cross section.

The louver system described is intended as an addition to existing towers. For future installations involving new or rebuilt quench towers, a tower design with the largest practical cross-sectional area should be considered, to minimize the steam velocity and thus, the entrainment of particles. A design feature involving a change in direction of the steam before it enters the stack section would also be effective.

Summary

In conclusion: A U. S. Steel research study has demonstrated that louver-type impingement baffles installed in a square coke quench-tower can reduce the emission of solids to the atmosphere by about 85–90%. These systems will be installed in other square quench towers in the plant as a step toward control of atmospheric emissions from coke-making operations.