Dust Control at Yucca Mountain Project

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ABSTRACT

This report describes actions taken to control silica dust at the Yucca Mountain Exploratory Studies Facility, a tunnel located in Southern Nevada that is part of a scientific program to determine site suitability for a potential nuclear waste repository. The rock is a volcanic tuff containing significant percentages of both quartz and cristobalite. Water use for dust control was limited because of scientific test requirements, and this limitation made dust control a difficult task. Results are reported for two drifts, called the Main Loop Drift and the Cross Drift.

In the Main Loop Drift, dust surveys and tracer gas tests indicated that air leakage from the TBM head, the primary ventilation duct, and movement of the conveyor belt were all significant sources of dust. Conventional dust control approaches yielded no significant reductions in dust levels. A novel alternative was to install an air cleaning station on a rear deck of the TBM trailing gear. It filtered dust from the contaminated intake air and discharged clean air towards the front of the TBM. The practical effect was to produce dust levels below the exposure limit for all TBM locations except close to the head.

In the Cross Drift, better ventilation and an extra set of dust seals on the TBM served to cut down the leakage of dust from the TBM cutter head. However, the conveyor belt was much dustier than the belt in the main loop drift. The problem originated with dirt on the bottom of the belt return side and muck spillage from the belt top side.

Achieving lower dust levels in hard rock tunneling operations will require new approaches as well as a more meticulous application of existing technology. Planning for dust control will require specific means to deal with dust that leaks from the TBM head, dust that originates with leaky ventilation systems, and dust that comes from conveyor belts. Also, the application of water could be more efficient if automatic controls were used to adjust the water flow rate to the mining rate.

KEYWORDS

Tunnels, Dust, Silica, Dust Control, Tunnel Construction, Respirable Dust, and Silica Dust.

BACKGROUND

This report details the actions taken to control respirable dust at the Yucca Mountain Exploratory Studies Facility (ESF), located in Southern Nevada. This experimental facility is a network of access tunnels for a DOE scientific test program to determine site suitability for a potential nuclear waste repository. The rock being excavated is a volcanic tuff containing about 5 pct quartz and 12 pct cristobalite, so dust control in the ESF is an important consideration. The general layout of the facility and the ventilation design have been reported elsewhere (Jurani, 1995). Water use for dust control was limited because of scientific test requirements, and this presented a major challenge to the design of an effective dust control system. Results are reported for two drifts, called the Main Loop Drift and the Cross Drift

MAIN LOOP DRIFT

The Main Loop Drift was 7.62 m (25 ft) in diameter, and when completed, 7860 m (25,800 ft) long. The primary ventilation duct extended from the rear of a tunnel boring machine (TBM) to the portal. It was configured to exhaust the air, and was provided with regularly spaced vaneaxial booster fans. The air quantity provided to the rear of the TBM by the primary duct varied from 37.8 m^3/s (80,000 cfm) at the start of the main loop drift to 26.0 m^3/s (55,000 cfm) at its completion 7860 meters away.

Dust Control

To control dust, a secondary ventilation system on the TBM extracted 6.3 m^3/s (13,000 cfm) of air from the enclosed cutter head and passed it through a dry dust collector (Figur , 1). Another 7.6 m^3/s (16,000 cfm) was extracted from the work face area. The combined flow was discharged into the primary ventilation duct. The cutter head of the TBM operated dry, but water was added to the belt at the transfer points. This system worked well for the first third of the main loop drift, but as the excavation entered a region of higher cristobalite levels, dust control requirements grew far more stringent. As a result, the ESF management established a respirator use program. It also began a concerted effort to develop the new engineering controls necessary to achieve dust levels below 0.35 mg/m^3. This is the total maximum respirable dust level generally allowed based on the composition of quartz and cristobalite minerals in the ESF.

Pinpointing Dust Sources

The first objective was to find where most of the dust was coming from. To pinpoint the dust sources, fixed location samples were taken along the length of the tunnel and at several spots within the TBM and its trailing gear. The results of this dust level survey, taken when the TBM was near the 5000 meter point, are shown in Figure 2. The general pattern of dust levels was zero at the portal, then gradually increasing as one proceeds from the portal to the rear of the TBM. At the rear of the TBM (50 meters behind), the dust level was 0.6 mg/m^3. Continuing forward through the trailing gear, the dust level rose an additional 0.2 mg near the front of the TBM where rock drillers installed roof support. This pattern indicated that both the intake and the TBM head were significant sources.

In the intake, the likely dust sources were either the conveyor belt or a leaking primary ventilation duct. A sulfur hexafluoride (SF_6) tracer gas test was conducted to see if the ventilation duct could be ruled out as a dust source. For this test, SF_6 was pulse- injected for a few minutes into the primary ventilation duct at the rear of the TBM trailing gear. Bottle samples of the ventilation air were then taken in the tunnel every few minutes for 2 hours at a rear deck (#14) of the trailing gear. The result of this test indicated that some of the air in the duct was leaking out and recirculating back to the TBM. We concluded that intake dust was originating at both the ventilation duct and the conveyor belt. This meant that the intake dust would continue to grow as the duct and belt got longer.

To assess which of the TBM sources was important, a RAM-1 instantaneous dust monitor was used to measure the dust level close to each suspected source. The only dust of any consequence was measured at the front of the TBM near the cutter head as the cutter head operated. The dust level would rise with no delay after the cutter head began to rotate and immediately drop when the cutter head stopped. These rising and falling dust levels were only measured close to the cutter head, indicating that the dust was leaking out somewhere close to the cutter head. This leakage from the head was not surprising, considering that only 6.1 m^3/s (13,000 cfm) of air was being extracted from the cutter head space. To induce an effective containment of dust, Myran (1985) had recommended an airflow of 9 - 12.3 m^3/s (19,000 - 26,000 cfm) be extracted from the cutter head space of similar-sized TBM's in Norway, where the silica standard was 0.2 mg/m^3, twice the 0.1 mg/m^3 standard in the United States.

Actions Taken to Reduce Dust

Even though employees in the tunnel were provided with respiratory protection, it was necessary to implement engineering control measures. Belt bottom sprays and scrapers were added to the belt, since their effectiveness has been documented (Ford, 1973). The obvious leaks in the primary ventilation duct were sealed. A clean-up program to remove settled dust was initiated. Water spray systems were upgraded. Unfortunately, these changes resulted in no significant reductions in dust levels, possibly because the conveyor and ventilation duct were growing longer as the tunnel advanced.

The next step was to install an air cleaning station on a rear deck of the TBM trailing gear. A ventilation schematic of the air cleaning station and the adjacent tunnel ventilation system is shown in Figure 3. The air cleaning station filtered dust from the contaminated intake air and discharged clean air towards the front of the TBM. Workers on the TBM would then be exposed only to dust generated at the TBM rather than both TBM dust and intake dust. The result would be to produce dust levels below the exposure limit for all TBM locations except those close to the cutter head. The air cleaning was achieved by a 17 m^3/s (36,000 cfm) vane-axial fan which forced air through 2 stages of filtration. The first filtration stage was 20 units of 24" x 24" M-80 Prefilter Pad from American Air Filter (AAF). The second filtration stage consisted of 20 units of 24" x 24" Varicell 90 pct filters from AAF. This second stage removed 90-95 pct of the 1-micron dust. The air cleaning station also had an air barrier curtain that served to separate dusty air on the portal side of the barrier from clean air on the TBM side. The air barrier was made by hanging a commercial grade clear vinyl strip curtain completely across the tunnel (Figure 3). The air cleaning station flow quantity of 17 m^3/s (36,000 cfm) was selected based on the requirement to clean all of the 13.7 m^3/s (29,000 cfm) of intake air at that location. The excess of 3.3 m^3/s (7000 cfm) provided a flow of air moving outby (reverse leakage) through the plastic strip curtain, and helped to ensure there was only clean air on the TBM side of the curtain.

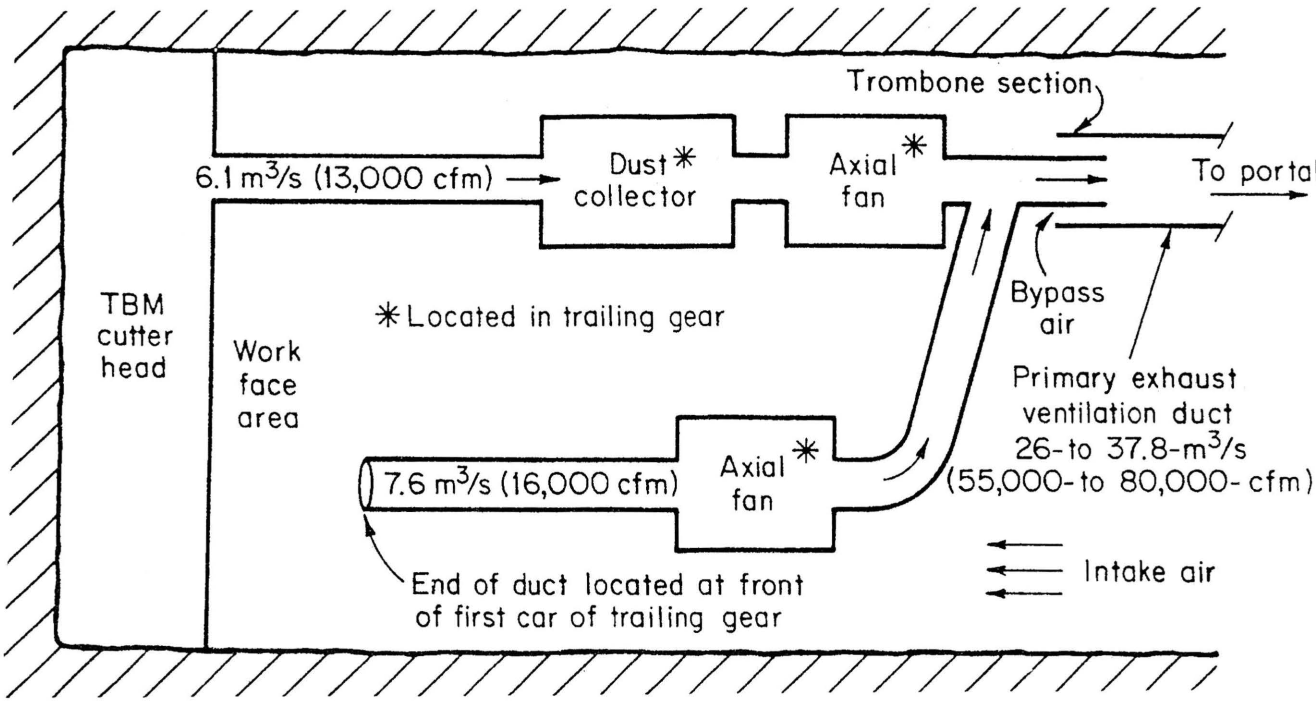

Figure 1. TBM and trailing gear ventilation in the Main Loop Drift (not to scale).

With the air cleaning station in operation the dust level in the intake air averaged 0.6 mg/m^3. The air from the filters averaged 0.04 mg/m^3.

Dust sources within the trailing gear and at the TBM head increased the dust level above this 0.04 figure. The dust level through most of the trailing gear ranged from 0.2 to 0.3 mg/m^3, except close to the TBM cutter head, where it was twice as high. The filters had to be changed every 3 to 4 weeks, but the air cleaning station removed the 0.6 mg/m^3 of intake contamination for the TBM workers.

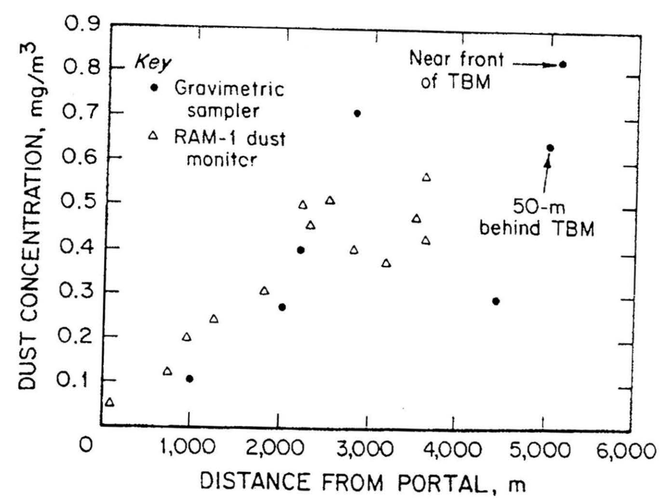

Figure 2. Fixed location dust level survey in the Main Loop Drift.

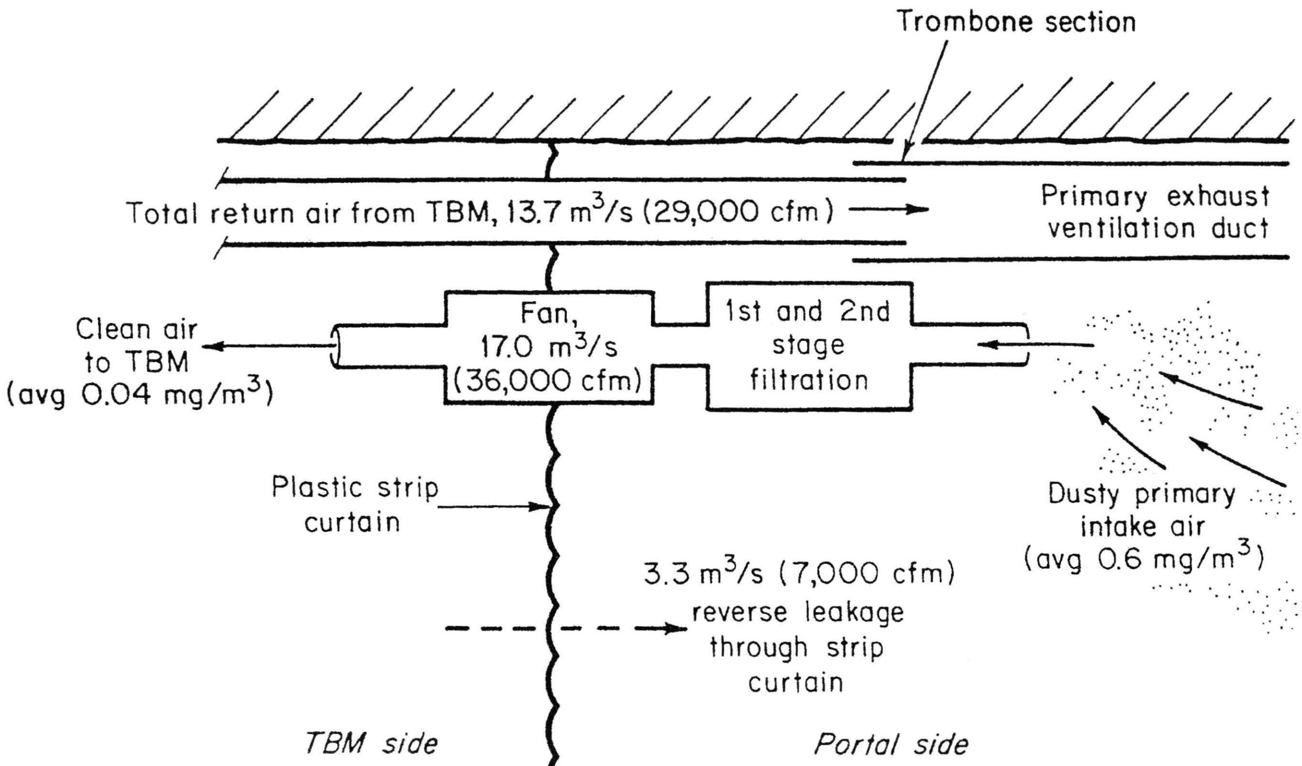

Figure 3. Air cleaning station in TBM trailing gear.

CROSS DRIFT

The cross drift was a secondary drift which intersected the main loop drift 2000 m (6560 ft) from the north portal. It was 5.0 m (16.4 ft) in diameter and 2681 m (8796 ft) long. The ventilation layout was similar to that used to excavate the main loop drift, with an exhausting secondary system on the TBM feeding into an exhausting primary duct. The only difference was that the air in both legs of the TBM secondary system passed through the dust collector. Airflow in the cross drift primary duct ranged from 27.4 to 30.7 m^3/s (58,000 to 65,000 cfm).

Dust Control

Based on a "lessons learned" exercise after excavation of the Main Loop Drift, the Cross Drift TBM was modified to reduce the leakage of dust from the cutter head. The machine was fitted with a secondary set of dust seals at the cutter head and plans were made to extract more air from the cutter head space. The TBM was a "main beam" type machine which facilitates extraction of air from the head by drawing it out of the main beam. The original objective was to draw 11.8 m^3/s (25,000 cfm) from the main beam, but after ventilation duct constrictions and leakage intruded, the actual amount achieved was 6.1 m^3/s (13,000 cfm). However, relative to the size of the TBM used for the main loop drift, it was still a considerable improvement. Another TBM modification was a set of water spray nozzles on the rotating cutter head. The sprays were used during the first part of the Cross Drift but were discontinued because the resulting mud plugged the cutters and muck buckets. Water was instead sprayed on the conveyor belt immediately behind the head to wet the muck.

The primary duct line was also improved. Fans were better located so as to maintain a negative pressure over the entire length of the duct and 0.3 m wide neoprene bands were installed to wrap around the duct joints. This eliminated recirculation of dust back into the intake.

An air cleaning station was also installed in the Cross Drift (Figure 4). It had 30 units of M-80 prefilter pads and 30 modules of Varicell 90% filters from AAF. It was provided with an axial fan at 28.3 m^3/s (60,000 cfm) capacity. Because of size restrictions, the air cleaning station could not be located in the trailing gear. So, it was placed in mined- out notch in the cross drift at a distance of 150 meters (490 ft) from the cross drift - main loop drift intersection. The disadvantage of placing the air cleaning station at a fixed location in the cross drift is that belt dust generated at locations inby the air cleaning station was not removed. However, the design did allow the intake to be located at a greater distance from the exhaust (15.2 m, 50 ft), a feature which permitted the elimination of the strip curtain.

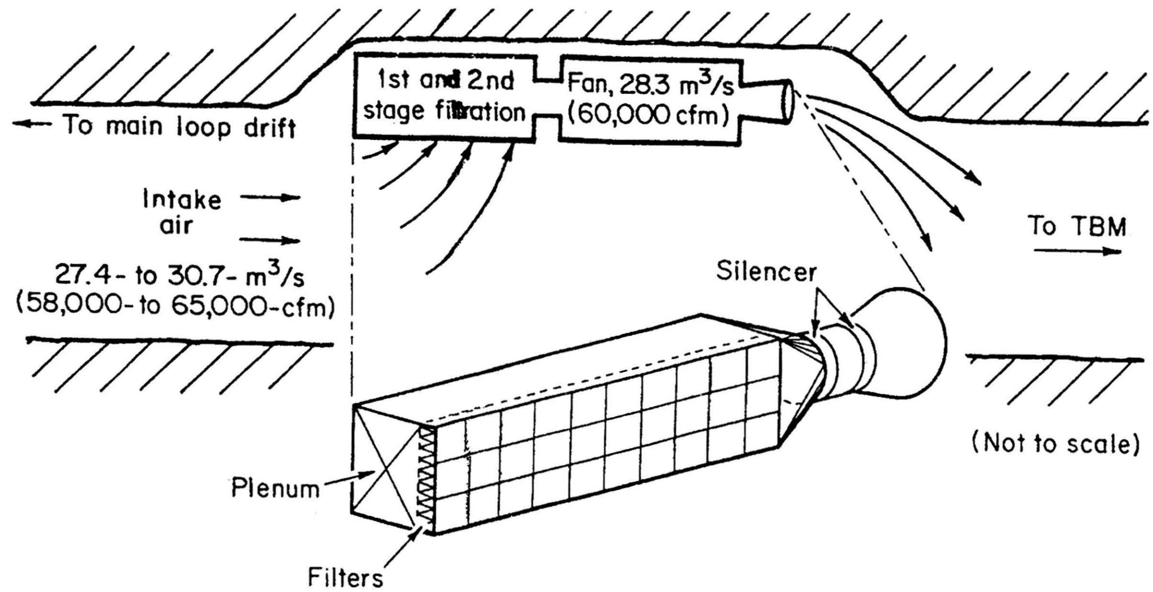

Figure 4. Air cleaning station in the Cross Drift.

Overall, it operated at 92 pct efficiency.

Pinpointing Dust Sources

Despite these improvements, sampling of worker dust levels continued to indicate that other dust sources remained. So, to pinpoint these dust source(s), fixed location samples were taken along the length of the cross drift in the same way that fixed location samples were taken in the main loop drift. The results of this dust level survey, taken when the cross drift TBM was near the 1200 meter point, are shown in Figure 5. In the first 100 meters (328 ft) of the cross drift, the dust level increased rapidly to 1.4 mg/m^3 The source here was the storage unit for the cross drift belt. Between the 100 and 200 meter points (328 and 656 ft), the dust level decreased to 0.2 mg/m^3 because of the air cleaning station. Beyond the 200 meter (656 ft) point, the dust level gradually increased until it reached a level of roughly 2 mg/m^3 at the TBM. This belt in the cross drift was considerably dustier than the one used during the excavation of the main loop drift.

The problem with the belt was two-fold. The return (bottom) belt emerged from the storage unit with muck on the underside. This muck on the underside was broken loose as the belt passed over the bottom rollers. Also, where the direction of the drift turned through a curve, the top belt shifted to one side when it loaded up. It then spilled dry muck to the bottom belt where it was shaken into the air.

Actions Taken to Reduce Dust

Since the cross drift was much shorter than the main loop drift, it was completed before a complete set of actions could be taken and the effect assessed. However, belt washers were installed and the belt was

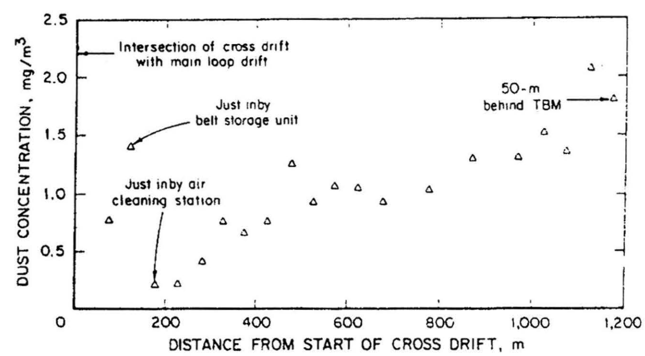

Figure 5. Fixed location dust level survey in the Cross Drift.

adjusted to prevent spillage. Had the drift been longer, the difficult redesign of the air cleaning station to make it fit on the rear of the TBM would have been undertaken. The higher belt dust levels in the cross drift made it clear that air cleaning must take place at the rear of the TBM.

RETROSPECTIVE

Achieving lower dust levels in hard rock tunneling operations will require new approaches as well as a more meticulous application of existing technology. Intermediate air cleaning is one new approach, since it is more practical to re-clean the air than it is to reduce every dust source to virtually zero.

Lowering dust levels at the head of the TBM is primarily a matter of providing multiple cutter head dust seals and adequate ventilation. The dust dilution air volume at the very front of the TBM work space is only determined by the quantity extracted from the cutter head space or directly adjacent to the cutter head space. For example, exhausting ventilation duct which stops at a point outby the rock drillers provides them little benefit.

Control of belt dust is a major concern. Where exhausting ventilation is used, workers on the TBM can be exposed to both TBM- and belt-generated dust. With blowing ventilation, the dust exposure of TBM workers may be reduced, but the exposure of those in the shaft or portal area increased unless dust scrubbing stations are installed along the drift.

Spray water management in tunnels is ripe for improvement. Particularly where water use is limited, the application of water could be much more efficient if automatic controls were used to adjust the water flow rate to the mining rate. Also, in those instances where it does not create operational difficulties, spray water added to the rotating cutter head can result in lower dust levels. Studies in coal mines (Organiscak, 1986) and silica sand plants (Volkwein, 1983) have shown that water added as early as possible in the process has the most benefit. In a tunneling context, it is better to have an additional 1.9 l/s (30 gpm) at the cutter head of the TBM than it is to have 0.63 l/s (10 gpm) at each of three conveyor transfer points downstream.

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