CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Observations from January 25, 2005, entry into unventilated portions of the Enhanced Characterization of the Repository Block (ECRB) tunnel (20.06002.01.262)

DATE/PLACE: January 24–25, 2005; Yucca Mountain, Nevada

AUTHORS: J. Winterle

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AUTHORS: J. Winterle

Purpose of Trip: James Winterle of the Center for Nuclear Waste Regulatory Analyses (CNWRA) traveled to the Yucca Mountain site on behalf of the U.S. Nuclear Regulatory Commission (NRC) to observe and photograph underground moisture conditions during an entry into unventilated sections of the ECRB tunnel.

Background

Excavation of the ECRB tunnel was completed on October 13,1998. During and after construction, the tunnel was ventilated, resulting in significant dryout of wall rock. The ECRB Passive Test was initiated to allow the host rock surrounding the tunnel to return to an ambient state representative of long-term moisture conditions in sealed tunnels at Yucca Mountain and to observe and characterize any occurrences of seepage or dripping into the open drift cavity.

The ECRB Passive Test was begun in June, 1999, when bulkheads were installed at ECRB Stations 17+63 and 25+03. A third bulkhead door was installed at Station 25+99 in July, 2000; a fourth bulkhead was installed at Station 22+01 in November, 2001. [Note: the "Stations" refer to distance along the ECRB tunnel (i.e., Station 22+01 is located 2,201 m from the beginning of the ECRB cutoff in the Exploratory Studies Facility tunnel.]

Bechtel SAIC Company, LLC (2003, Section 6.2.10), provides a summary of the ECRB Passive Test activities and observations through early 2001. This documentation includes a summary of water potential, relative humidity, temperature, and barometric pressure data collected inside and outside of the sealed portions of the ECRB tunnel through approximately May 2001. The following items of interest are evident in the data presented.

- Barometric pressure fluctuations are transmitted through all four of the ECRB bulkheads, indicating some degree of natural ventilation by barometric pumping. This barometric pumping may be occurring through either fracture networks in the host rock, leaks in the bulkheads, or both.
- Relative humidity behind the bulkheads rose to approximately 95 percent within few days after bulkheads were closed. This can be compared to relative humidity that typically varied between 10 to 40 percent in the ventilated portion of the tunnel.

- Heat sources from the tunnel boring machine, electrical transformers, and lighting result in dryout near the heat sources, and are possibly a driving factor in the observation of significant amounts of condensate on ventilation ducts, conveyor belts, utility pipes, insulated electrical wires, rock bolts and painted surfaces in zones between and away from the heat sources. In several locations, small puddles were observed that were likely the result of dripping condensate.

- No seeping fractures were observed within the entire sealed off portion of the tunnel.

- Water-potential measurements in horizontal boreholes in the sealed portion of the tunnel indicate that the rock within 1 m from the drift wall remained slightly drier than the host rock deeper in these boreholes.

- Bulkheads were opened and ventilated on several occasions, resulting in rapid drops in relative humidity within the previously sealed portions of the tunnel. These brief periods of ventilation may partially explain why rock within 1 m of the drift wall remained drier (more negative water potential) than the deeper host rock as of May, 2001.

Data continues to be collected from within the sealed portions of the ECRB. Since mid-2001, a significant change to the Passive Test is that heat sources within the sealed tunnels have been eliminated. Power to the tunnel boring machine, electrical transformers, and tunnel lighting systems has been removed. Additionally, longer periods of unventilated conditions have been allowed to occur without opening bulkheads. None of the data collected since mid-2001, however, have been reported. It is, thus, not clear whether the elimination of heat sources or longer periods without ventilation have resulted in rock moisture conditions that might be deemed representative of long-term conditions without forced ventilation.

There have been several unventilated entries behind the ECRB bulkheads since mid-2001 and NRC representatives have visually observed several of these entries. Following is a brief summary of the history of ECRB bulkhead openings, periods of ventilation, and visual observations of moisture conditions during ECRB entries.

- June 1999. Bulkheads were installed at ECRB Stations 17+63 and 25+03 and ventilation ceased beyond 17+63. The initial plan was to open and ventilate the isolated sections of tunnel approximately every two months to perform maintenance on the tunnel boring machine and to collect data from neutron moisture monitoring boreholes.

- August 31, 1999. Bulkheads were opened for several days and no evidence of moisture was observed.

- January 13, 2000. Bulkheads opened to collect data and perform visual observations of potential rewetting on rock surfaces. No free water or dripping from rock surfaces was observed. However, DOE scientists did observe condensation on both the ventilation ducts and conveyor belt near the bulkhead at 25+03. This water was sampled for chemical and isotopic analyses. The presence of mold was also observed at a couple of locations. On February 14, 2000, DOE scientists reentered bulkheads to collect mold samples.

- June–August 2000. Bulkheads were opened and ventilated for several weeks to install cloths treated with pH indicator (to detect drips) and other install and maintain other monitoring equipment . A third bulkhead was installed at Station 25+99. All three bulkheads were resealed on August 2, 2000.

- September–December 2000. Problems with loss of power to instrumentation were noted on several occasions. It was suspected that high humidity caused tripping of circuit breakers. An estimated 75 percent of data collection capabilities were lost.

- January 2001. All three bulkheads were opened on January 22 and ventilated to permit servicing of test equipment. Bulkheads 25+03 and 25+09 were resealed on January 25. The bulkhead at 17+63 was resealed on February 1.

- April–May 2001. Power to tunnel boring machine and data loggers was lost between Stations 25+03 and 25+99. All three bulkheads were briefly opened on May 22 to restore electrical power; however, ventilation was not used for this entry. Power was restored to data loggers, but not to tunnel boring machine, and the bulkheads were resealed. [Note: the interpretation of data collected up to this point in time are summarized in Bechtel SAIC Company, LLC (2003). Interpretations of data collected later than this period of time are not yet published].

- October 1–2, 2001. All three bulkheads were opened and observations by an NRC onsite representative were made prior to ventilation. Moisture accumulation was identified in various locations from Stations 17+63 to 25+99. In particular, water droplets were noted on the ventilation ducts, insulated cables, rock bolts, wire mesh and on the conveyer belt.

- October–December 2001. Ventilation was introduced for several weeks to accommodate rock sampling, geologic mapping, data collection, and installation of video cameras, plastic sheets, drip collection equipment, and gas sampling devices. A fourth bulkhead was installed at Station 22+01; this and the two bulkheads beyond it were sealed on November 14. The first bulkhead at 17+63 was resealed on December 20.

- June 2002. Bulkhead at 17+63 was reopened on June 24 to initiate geotechnical investigations. NRC onsite representatives entered this section of the tunnel on June 25 to observe moisture conditions prior to ventilating. NRC representatives observed drier conditions than had been seen during the October 2001 entry. However, small amounts of liquid water were seen on the plastic sheets in two areas. No water droplets or pools were seen on the conveyor belts and no moisture had collected on signs or cables. The drip cloths appeared damp and were almost uniformly covered by mold, which caused them to badly deteriorate. One drip cloth, located near a transformer at Station 21+00, contained almost no mold and retained its original orange color near the transformer; a few meters away, however, the cloth had turned bluish-green in the presence of moisture. Bulkheads at and beyond 22+01 remained sealed and moisture conditions behind them were not observed.

- January 2003. The bulkhead at 17+63 remains open since June 24, 2002. Smoke was detected behind the bulkhead at 22+01 on January 13. All bulkheads were opened by mine rescue personnel to sample air and to isolate electrical power. U.S. Department of Energy (DOE) and Yucca Mountain site representatives entered and photographed unventilated moisture conditions on January 15. Photographs show some occurrences of condensation on ventilation ducts, and insulated cables, beyond 22+50. This condensation was not continuous, however, and appeared limited to a relatively few zones. Most drip cloths are badly deteriorated by mold and some have fallen.

- February 2003. DOE and Yucca Mountain site personnel entered and photographed unventilated moisture conditions on February 3. Conditions similar to the January 15 entry are evident in the photographs. Some plate-sized puddles on conveyor belts are also noted on this entry. Power to the electrical transformer beyond Bulkhead 22+01 was turned off on February 13 to eliminate the effect of any heat source behind the bulkhead.

- July 2003. An NRC onsite representative entered the bulkhead beyond 22+01 on July 8. The general observations made by the NRC observer are summarized in a July 14, 2003 Email from Jack Parrot, NRC on-site representative: "...the ECRB was basically dry from 22+01 to 22+50, a little wet from 22+50 to 23+00, very wet from 23+00 to 24+80, wet from 24+80 to 25+00, very wet from 25+00 to 25+60, and a little wet from 25+60 to 26+70. Although there were no heat sources behind these bulkheads, there was still a zonal distribution of moisture behind the bulk heads. Most of the moisture observed appeared to be condensation on the vent line, steel sets, rock bolts, wiring, and piping in the tunnel....If there was [natural] seepage, it would have been difficult to tell with all of the condensation....It should be noted that the wettest part of the ECRB did not coincide with the [Solitario Canyon] fault zone....There were places where the rock appeared wet but the best way to tell is to take 'before and after' pictures of the same rock upon initial entry and after it has been allowed to dry out. Since I made only a one time entry, I could not do this." Photographs taken by the NRC observer are available.

- September–November 2003. A ventilated entry beyond Bulkhead 22+01 began on September 8 to maintain and update equipment, and to remove drip cloths and video cameras. This activity concluded in November 2003 and all four bulkheads, including the one at 17+63, were sealed.

- January 24–25, 2005. All four bulkheads were opened for observation of moisture conditions, data collection, and maintenance of instruments. This entry is the subject of this trip report and is summarized in detail in the following section.

Observations from January 24–25, 2005, Unventilated ECRB Tunnel Entries

ECRB tunnel entry was scheduled for January 24, 2005. All bulkheads had been closed since November 2003. During this time, no external power or ventilation was present beyond the bulkhead at ECRB Station 17+63. J. Winterle of CNWRA was present to observe moisture conditions on behalf of NRC.

The bulkhead at 17+63 was opened on the morning of January 24. No ventilation was applied during this entry. Mine safety personnel entered the unventilated tunnel section first to establish whether conditions were safe. Safety personnel had just reached the second bulkhead when electrical power was lost and everyone was required to immediately evacuate. Bulkhead doors were closed by safety personnel prior to evacuation. The power loss originated from a transformer substation elsewhere on the Nevada Test Site. By the time power was restored later that morning, it was too late to accomplish an unventilated tunnel entry that day.

On the morning of January 25, all four bulkhead doors were reopened and cleared by mine safety personnel for entry by technical staff and observers. The following general observations were made by J. Winterle.

- The first section of tunnel between bulkheads at 17+63 and 22+01, although humid and musty, had no visible signs of liquid water or condensation anywhere. The dust on the tunnel floor was dry enough that stamping of feet would raise dust into the air. Water spots on cables and utility pipes indicated that this section of tunnel was wet at one time (see Figure 2).

- Several meters past the second bulkhead, at approximately 22+12, a small spot of rust with some residual water was seen on the plastic sheeting that covered the floor beneath the inactive ventilation duct; however, no condensation or droplets could be seen on the overlying duct.

- At approximately 22+20, the first signs of condensation were noted on some of the black insulated electrical cables, but not elsewhere.

- At 22+81, a small rusty puddle approximately 10 cm in diameter was noted on the plastic sheet on the floor under the ventilation duct; again, however, there was no condensation or dripping present on the duct at that time. Condensation droplets were noted on the underside of the conveyor belt at this location. Also noted, was a small amount of condensation on the underside of the plastic sheet, between the sheet and a wooden rail tie (see Figure 3).

- Beginning at approximately 23+00 and beyond, condensation was present on the metal ventilation ducts, in addition to the condensation previously noted on the insulated electrical cables.

- At approximately 23+50 and beyond, the presence of moisture droplets on several rock bolts was noted. On the conveyor belt beneath some of these rock bolts, occasional locations could be seen where relatively large puddles had been present but were now either dry or reduced to small moist spots (see Figures 4 and 5). Also noted beyond this point, were evenly spaced puddles on the plastic floor sheet that were beneath every single location where sections of the metal ventilation duct were joined by rubber unions. These rubber unions also appear significantly wetter than the metal ducts they join (see Figure 6) and were obviously the source of the puddles found wherever plastic sheeting was placed beneath them.

- At approximately 24+45 and beyond, occasional puddles could be found on the lower conveyor belt (see Figure 7). These puddles appeared to be formed by dripping of condensation from the underside of the upper conveyor belt. An interesting observation was that condensation droplets on the conveyor belts were present only on the underside; the only moisture noted on the tops of conveyor belts appeared to be associated with dripping from above. Looking around, it also seemed evident that condensation was occurring preferentially on the underside of the insulated cables, utility lines, and ventilation ducts.

- Just beyond the third bulkhead at 25+03, the bulkhead itself had condensation and moisture conditions were similar to those just summarized for location 24+45 and beyond. At approximately 25+40 and beyond, however, the amount of condensation noted on ventilation ducts seemed less, with a few relatively dry sections, though condensation was still present on insulated utility cables and rubber duct unions. Stainless steel drip collection trays appeared dry and coated with dust.

- In the area of the Solitario Canyon Fault zone, the tunnel wall rock and floor were dry to the touch—just as they appeared everywhere else in the tunnel (see Figure 8). The fault core itself, however, was noticeably damp and had a texture similar to stiff modeling clay. The fault core is a band that is approximately 30 cm wide and the rock on either side of it is intensely fractured.

- Beyond the fourth bulkhead at 25+99, the tunnel boring machine is parked. Condensation was noted on the painted surfaces and insulated electrical cables on the tunnel boring machine (see Figure 9).

In summary, the entire 438-m section between the first and second bulkheads had no visible signs of water; however, ubiquitous water spots indicated that liquid water had been present in the past. Condensation was first noted a short distance beyond the second bulkhead and the amount of condensation gradually increased between approximately 23+00 and 24+45. From 24+45 to approximately 25+40 moisture conditions were fairly uniform with moderate amounts of condensation on utility pipes, insulated cables, ventilation ducts, rock bolts, and conveyor belts; small puddles were present beneath nearly all rubber duct unions that had plastic floor sheeting beneath them. Beyond 25+40, some dry sections of ventilation ducts were noted, but condensation generally was still present on the rubber duct unions, insulated cables, and conveyor belts. Throughout the entire unventilated section, from 17+63 to the tunnel boring machine at 26+70, the tunnel wall rock, ceilings and floors appeared dry and dust could be easily stirred up, despite the humid conditions and presence of liquid water on other types of surfaces.

Discussion

During the January 25, 2005, entry into the unventilated portion of the ECRB tunnel, moisture conditions appeared somewhat drier than those noted and photographed by the NRC onsite representative during the July 8, 2003, entry. This observation is interesting because, prior to the July 8, 2003, entry, the section between the first and second bulkheads had remained opened and ventilated since June 2002. The expectation had been that sealing the bulkhead at 17+63 would create an additional buffer zone to remove the effects of ventilation from behind the other three bulkheads, and that this might result in wetter conditions beyond the bulkhead at 22+01 than had been observed in the July 8, 2003, entry. The reason the moisture conditions were instead drier during the January 25 entry cannot be discerned without additional data related to temperature gradients, barometric pumping, and relative humidity. Such data have been collected by DOE and U.S. Geological Survey staff, but interpretations of these data are not yet available for review.

Another interesting observation from the January 25, 2005, tunnel entry is that different types of surfaces appear to have different affinities for forming condensation. The most common occurrence and greatest amount of condensation was noted was on the rubber unions between sections of ventilation ducts. Of the common materials found in the tunnel, the general hierarchy of surfaces that form condensation (from greater to lesser affinity) seemed to be, rubber duct unions, insulated electrical cables, glossy painted surfaces, bottom sides of conveyor belts, metal ventilation ducts, rock bolts, and metal utility pipes. Condensation did not appear evident on rock surfaces, plastic sheeting, or dust covered surfaces such as tunnel floors and the topside of conveyor belts.

Observations of moisture conditions between the third and fourth bulkheads are particularly of interest because the Paintbrush nonwelded tuff layer is not present in the overlying stratigraphic sequence (see Figure 1). The Paintbrush nonwelded tuff has a permeable matrix that is generally thought to prevent episodic fast flow and result in relatively steady and uniform flow in the layers beneath it. In addition to the lack of overlying Paintbrush tuff in this area, the highly fractured rock adjacent to the Solitario Canyon Fault provides a potential highly permeable pathway from the land surface. It also had been a relatively wet Winter at the Yucca Mountain site and the month of January saw several heavy rainfalls that were sufficient to generate runoff to washes and substantial streamflow in Fortymile Wash. In fact, it had rained at the project site in the early morning hours of January 24 and 25, just prior to the tunnel entries. Despite the relatively wet rainy season and the potential fast-flow path from the surface, the tunnel section between the third and fourth bulkheads appeared somewhat drier than other sections of the tunnel. The observed moisture conditions suggests that the wet surface conditions had not yet propagated to the depth of the ECRB tunnel.

Recommendations

Observations of moisture conditions in the unventilated portions of the ECRB tunnel are valuable as a potential source of verification for the DOE seepage models used in performance assessments of the potential Yucca Mountain repository. NRC representatives should continue the program of observing moisture conditions in unventilated tunnels.

Moisture, temperature, and relative humidity data collected from the ECRB tunnel after mid-2001 have yet not yet been made available for review. Therefore, it cannot be established whether the unventilated tunnel sections have rewetted to a point that may reflect the range of long-term dynamic responses of the wall rock to ambient moisture inputs. The data collected prior to mid-2001 suggests that such a state had not yet been reached. NRC may wish to encourage DOE staff and contractors to complete and publish interpretations of more recent data. This data should be reviewed before making any determinations as to the meaning of moisture conditions observed during the tunnel entries.

Reference

Bechtel SAIC Company, LLC. "*In-Situ* Field Testing of Processes." ANL–NBS–HS–000005. Rev. 02. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003.

Figures

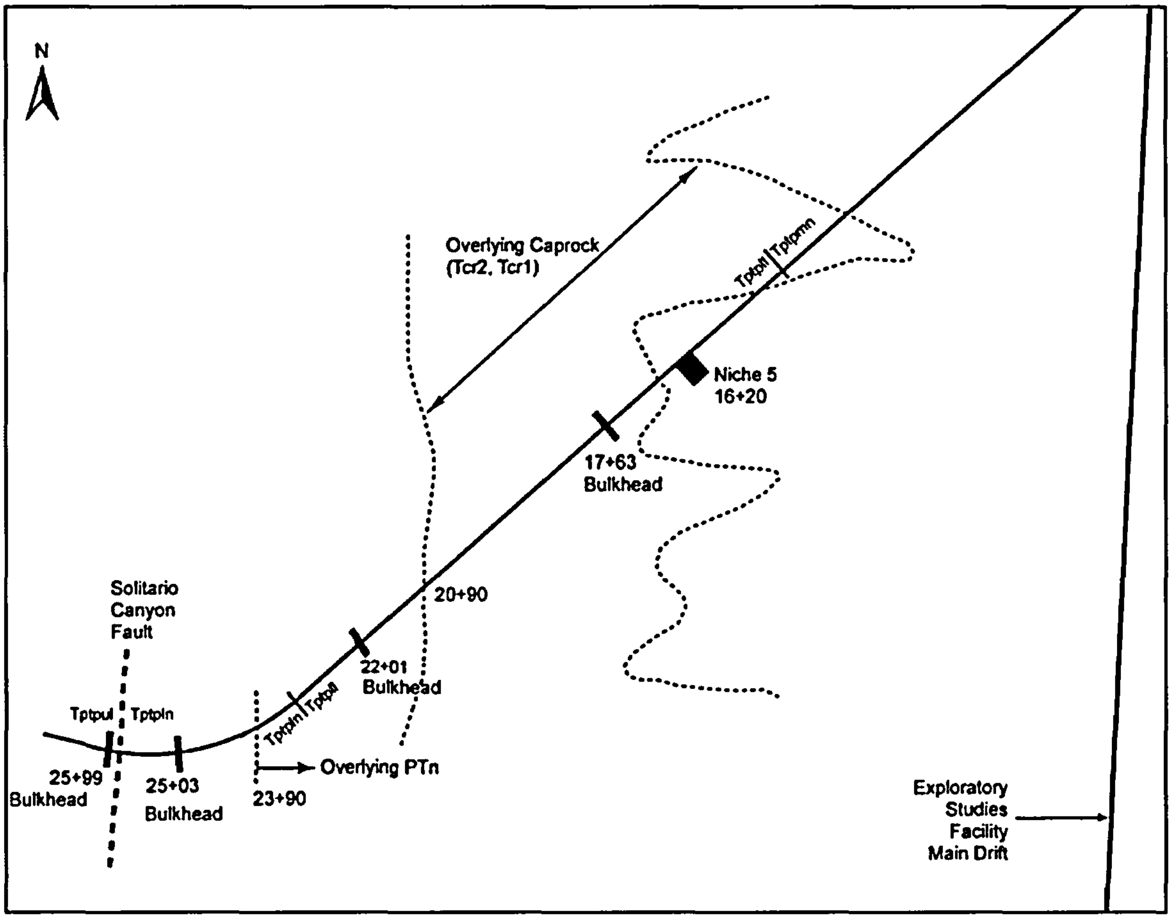

Figure 1. Schematic illustration showing location of ECRB tunnel with respect to Exploratory Studies Facility main drift, and locations of bulkheads, Solitario Canyon Fault Zone (heavy dashed line), transition zone between lithophysal (Tptpll) and nonlithophysal (Tptpln) rock types. The horizontal extent of overlying caprock and Paintbrush nonwelded tuff (PTn) are also superimposed (thin dashed lines).

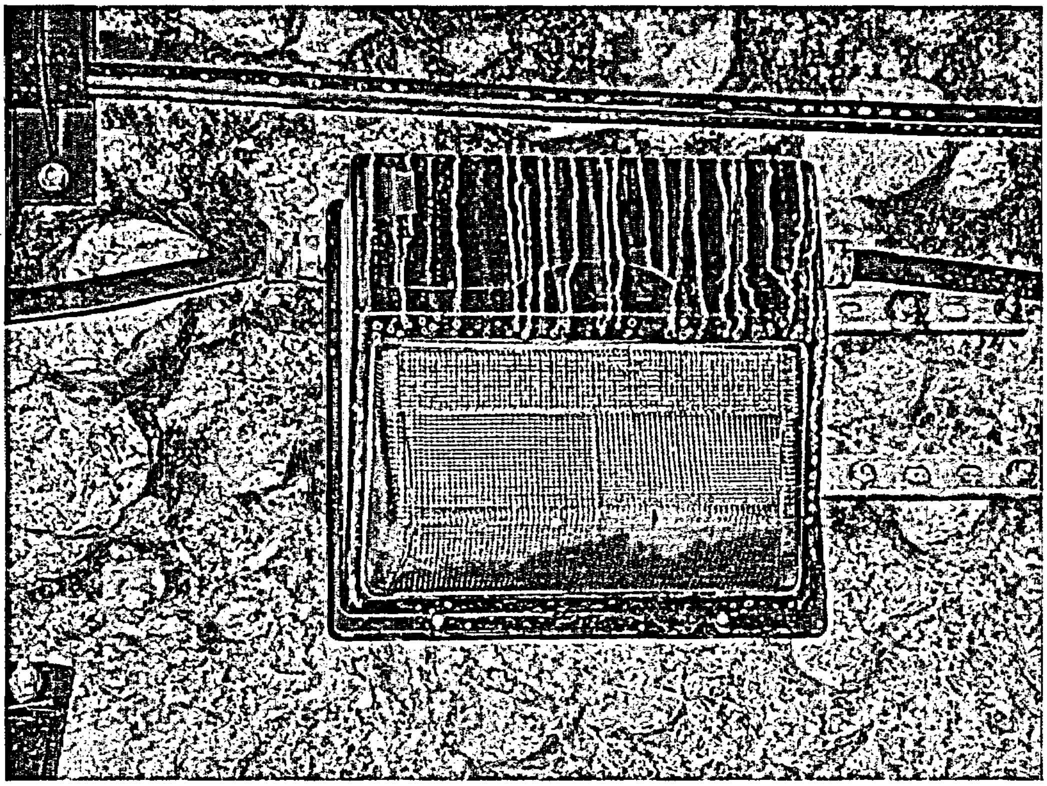

Figure 2. Photograph showing marks where water had been present at one time on utility cables and light fixtures in the tunnel section between Bulkheads at 17+63 and 22+01.

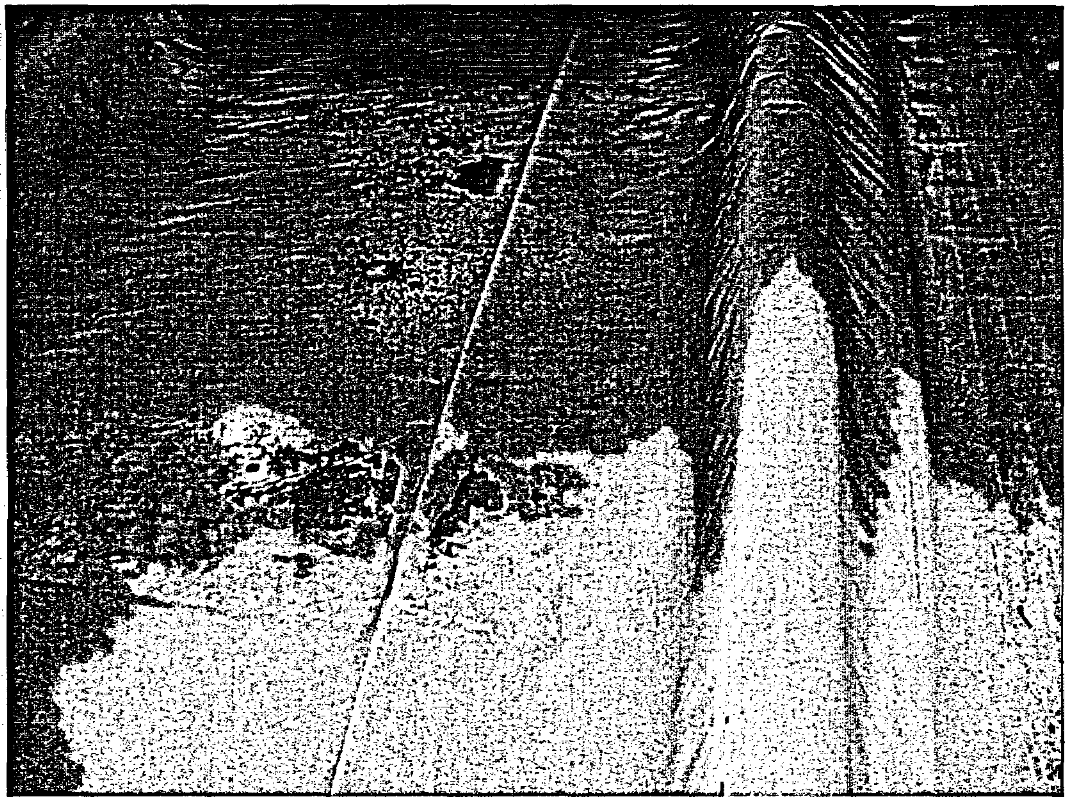

Figure 3. Signs of dripping on plastic sheet beneath ventilation duct at Station 22+81. Note also condensation on underside of plastic on top of rail tie.

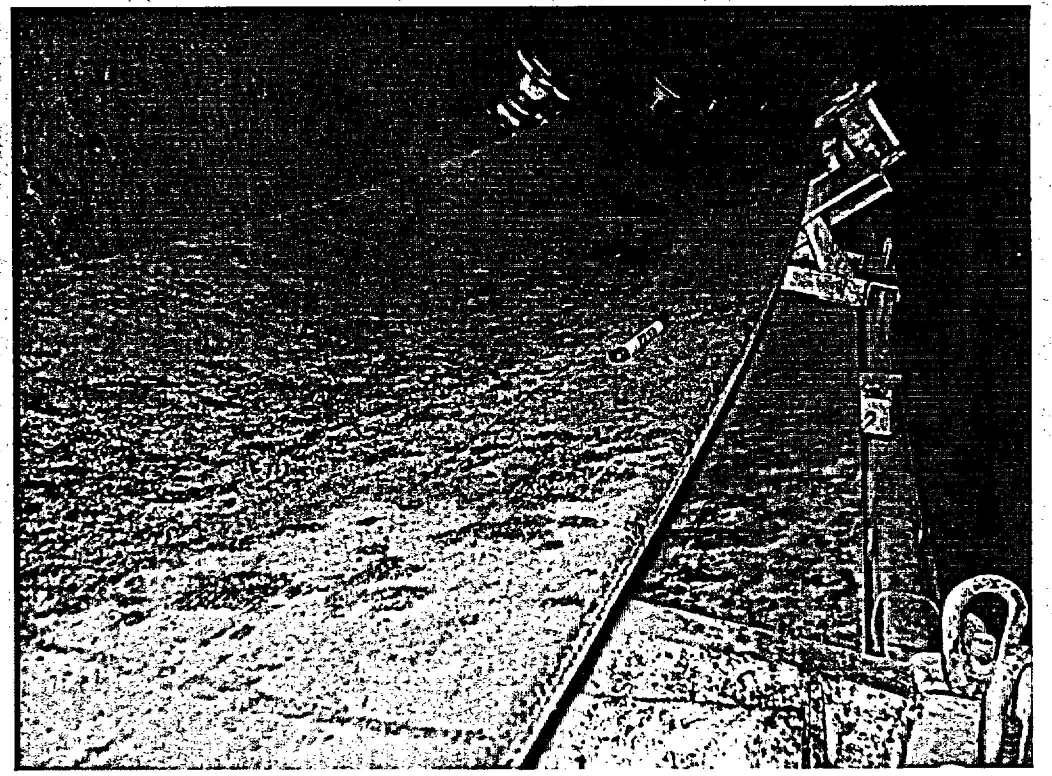

Figure 4. Dark area on conveyor belt shows where a puddle was once present but is now reduced to a small damp spot in the center. Dripping from an overhead rock bolt was likely the source of water (see Figure 5).

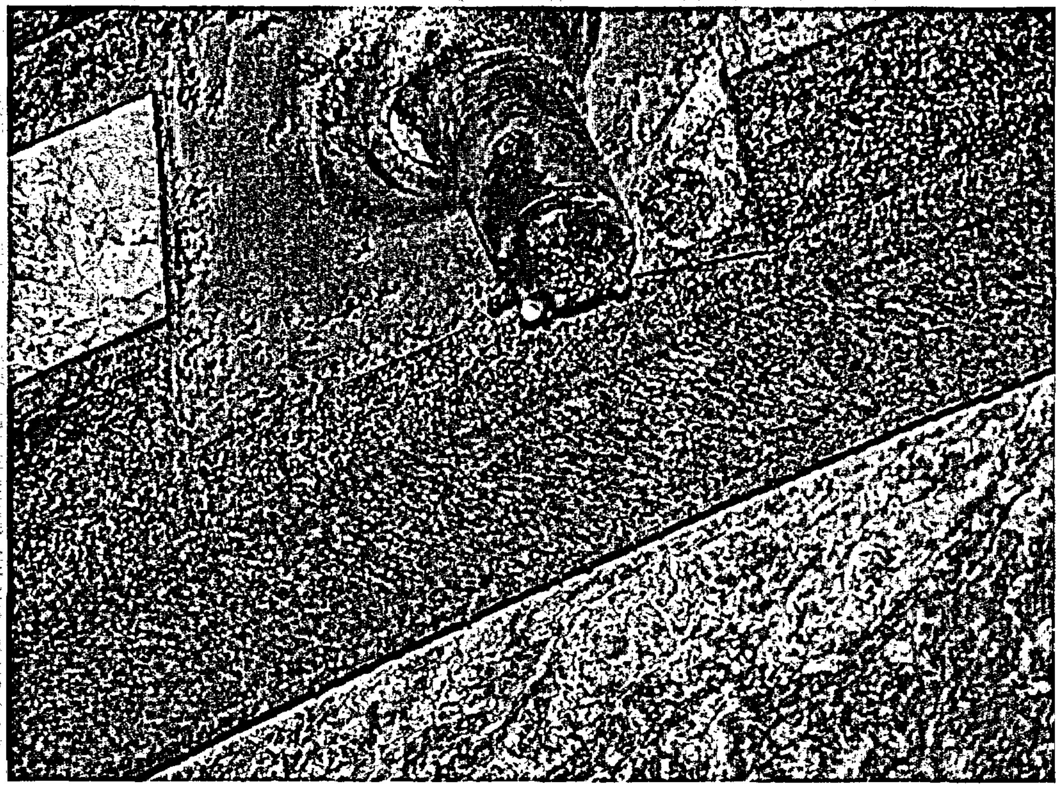
Figure 5. Small droplet dangling from a rock bolt in the ceiling above a damp spot on the conveyor belt (see Figure 4).

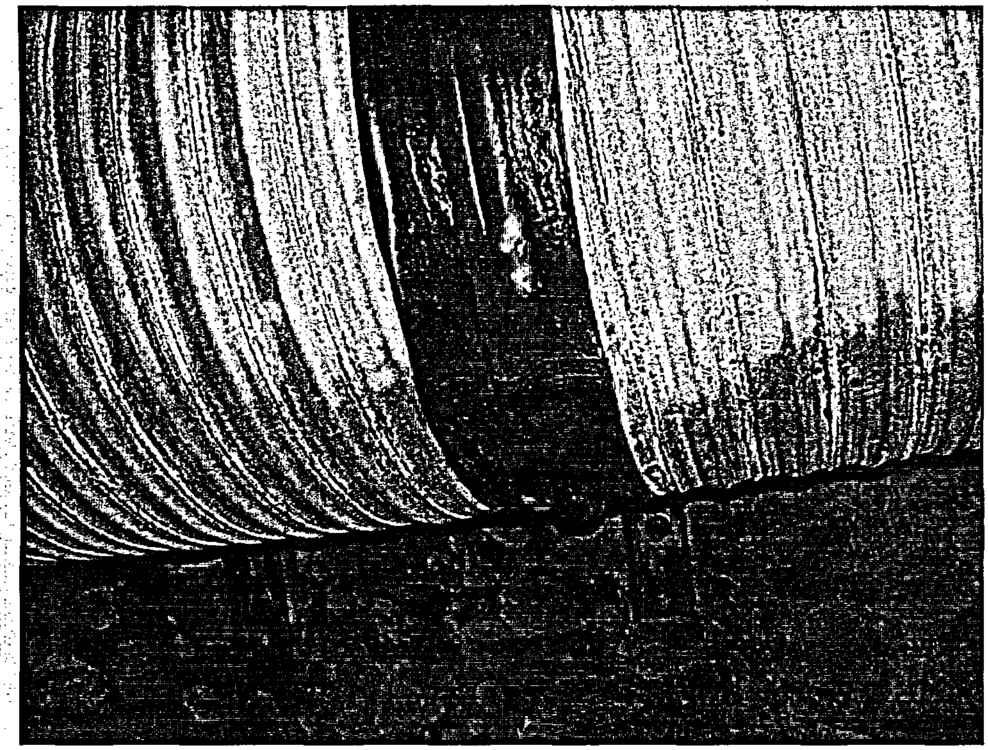

Figure 6. Streaks of water running down rubber union on ventilation duct where adjacent metal duct is relatively dry. Small puddles were observed beneath most of these rubber unions beyond ECRB Station 23+50.

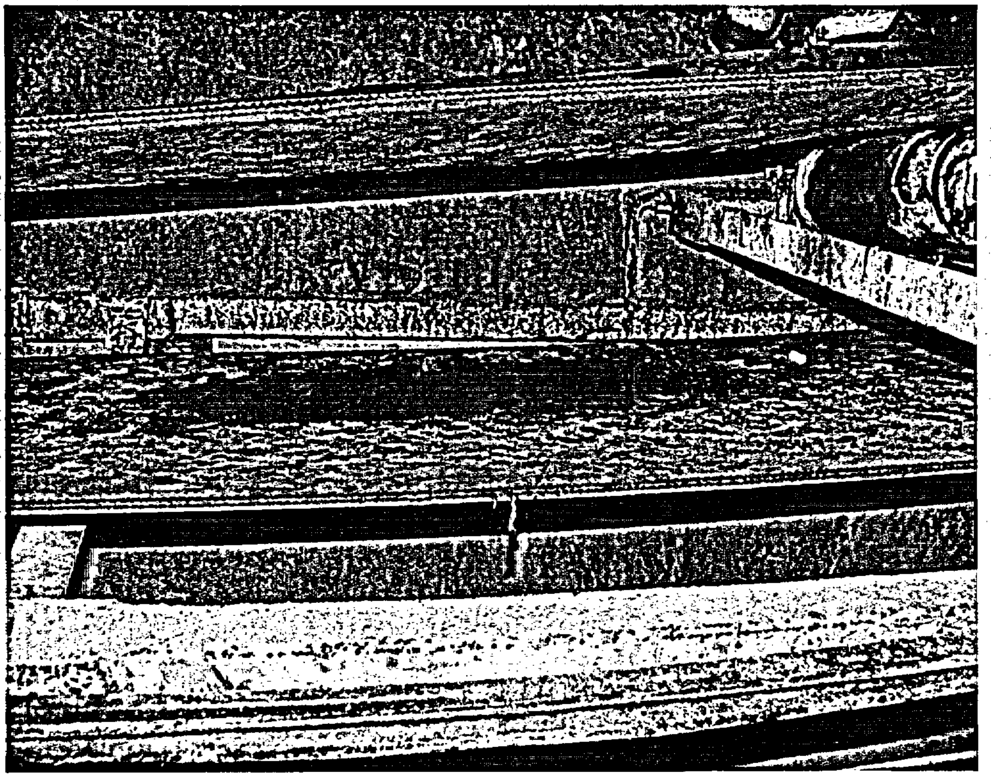

Figure 7. Puddle of water on lower conveyor belt appears to be the result of dripping condensation from bottom side of upper belt. The condensation drops on the bottom of the upper belt do not show up well in this photograph, but were quite ubiquitous.

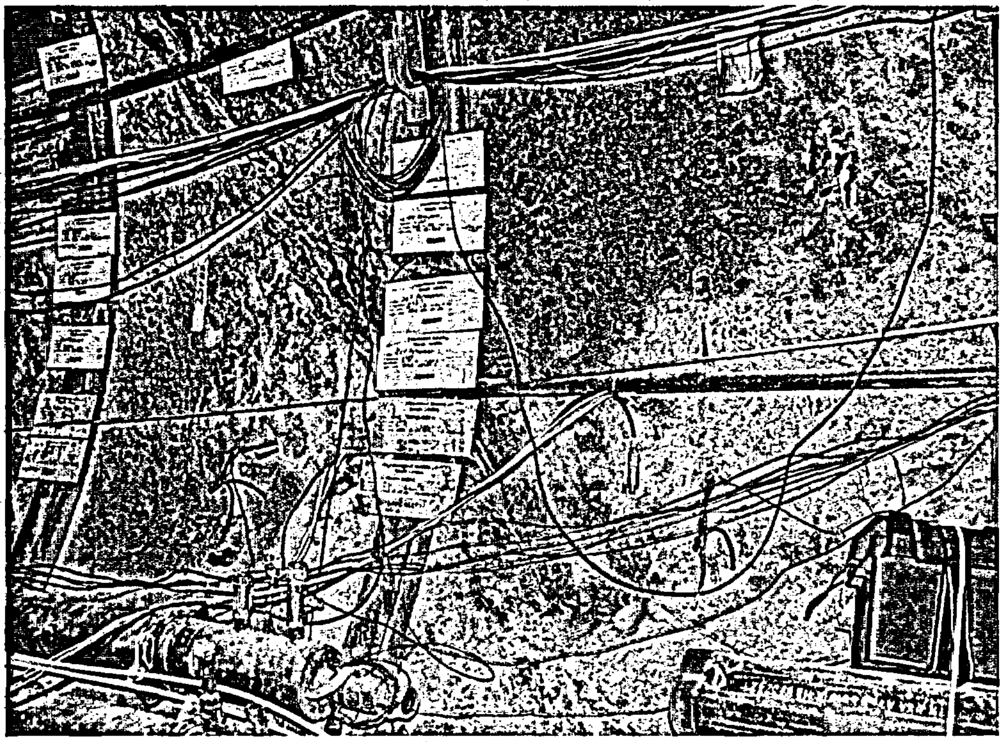
Figure 8. Solitario Canyon Fault zone. Dark diagonal band is a damp claylike fault core. Intensely fracture rock on either side of fault core appeared dry. No condensation was noted in the immediate vicinity.

Figure 9. Condensation and mold forming on insulated electrical cables on the tunnel boring machine at the end of the ECRB tunnel.

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