Dust exposure in TBM and Drill & Blast tunnel excavation

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TBM Applications III

The Norwegian Tunnelling Society and Tekna

Trondheim, November 5th, 2019

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Exposure to dust and other occupational factors in tunnel boring, including crystalline silica

Increased risk of chronic obstructive pulmonary disease (COPD), silicosis, and of cardiovascular effects

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Why is more knowledge needed in this field?

- TBM is a new technology (in Norway) and therefore knowledge of health and safety is needed
- Important to know for future planning of tunnel operations, since TBM is ”here to stay”
- Engineering-based actions have for long been applied in drill-and-blast tunneling, and there is a need for further preventive measures also regarding TBM operations
- Comparing today’s exposure levels between the two technologies thus is meaningful, although TBM must be considered still to have a large potential for improvements through engineering measures

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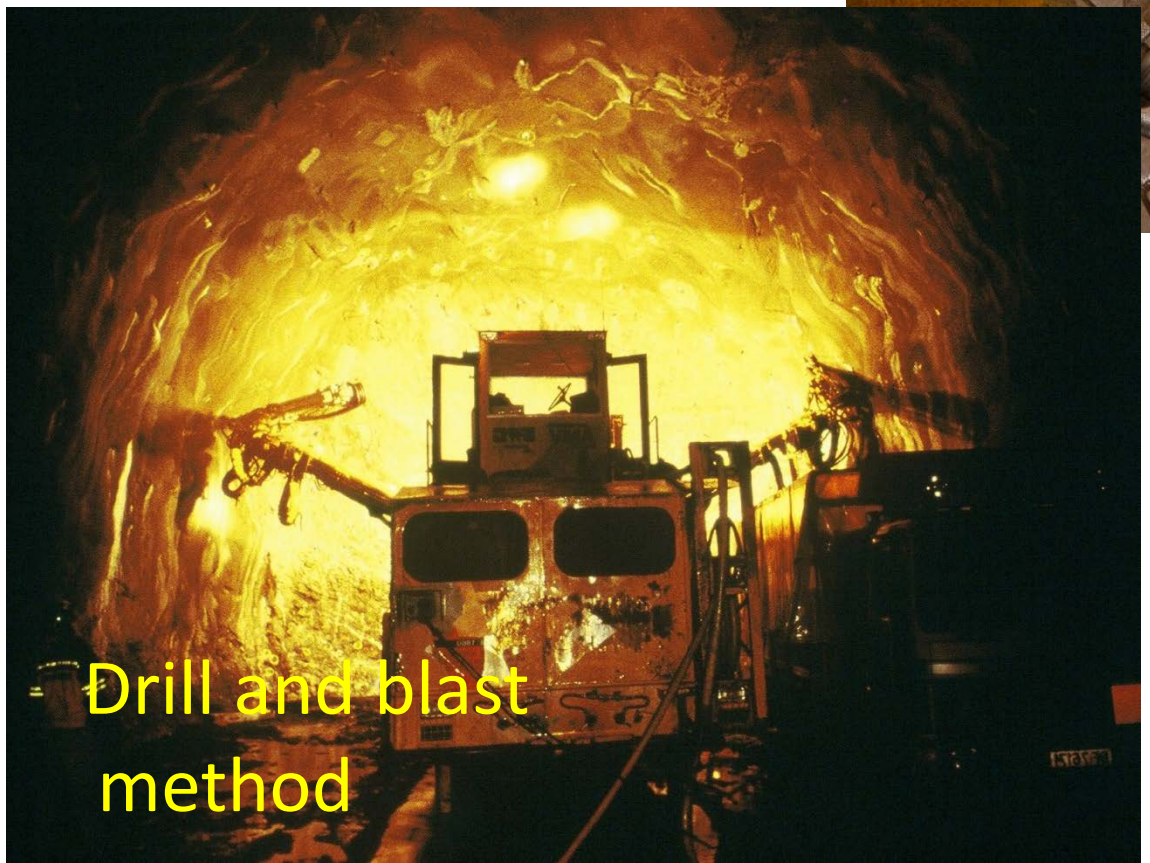
Traditional method. Well-known exposure levels and health effects
Some well-developed exposure-limiting methods are available



New method (to Norway). Less is known about exposure levels and thus about potential health effects.
Development of exposure-reducing actions are quite immature yet

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Tunnelling and dust exposure

Boring

Shaft drilling

Shotcreting

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Comparison of exposure sources

- Drill & Blast
  - Dust including RCS
  - Diesel exhaust
  - Oil mist
  - Nitrogen oxides
  - Combustion products from the explosives
- TBM
  - Dust including RCS
  - Less diesel
  - Less oil mist
  - Less nitrogen oxides
  - No combustion products (except shaft excavations)

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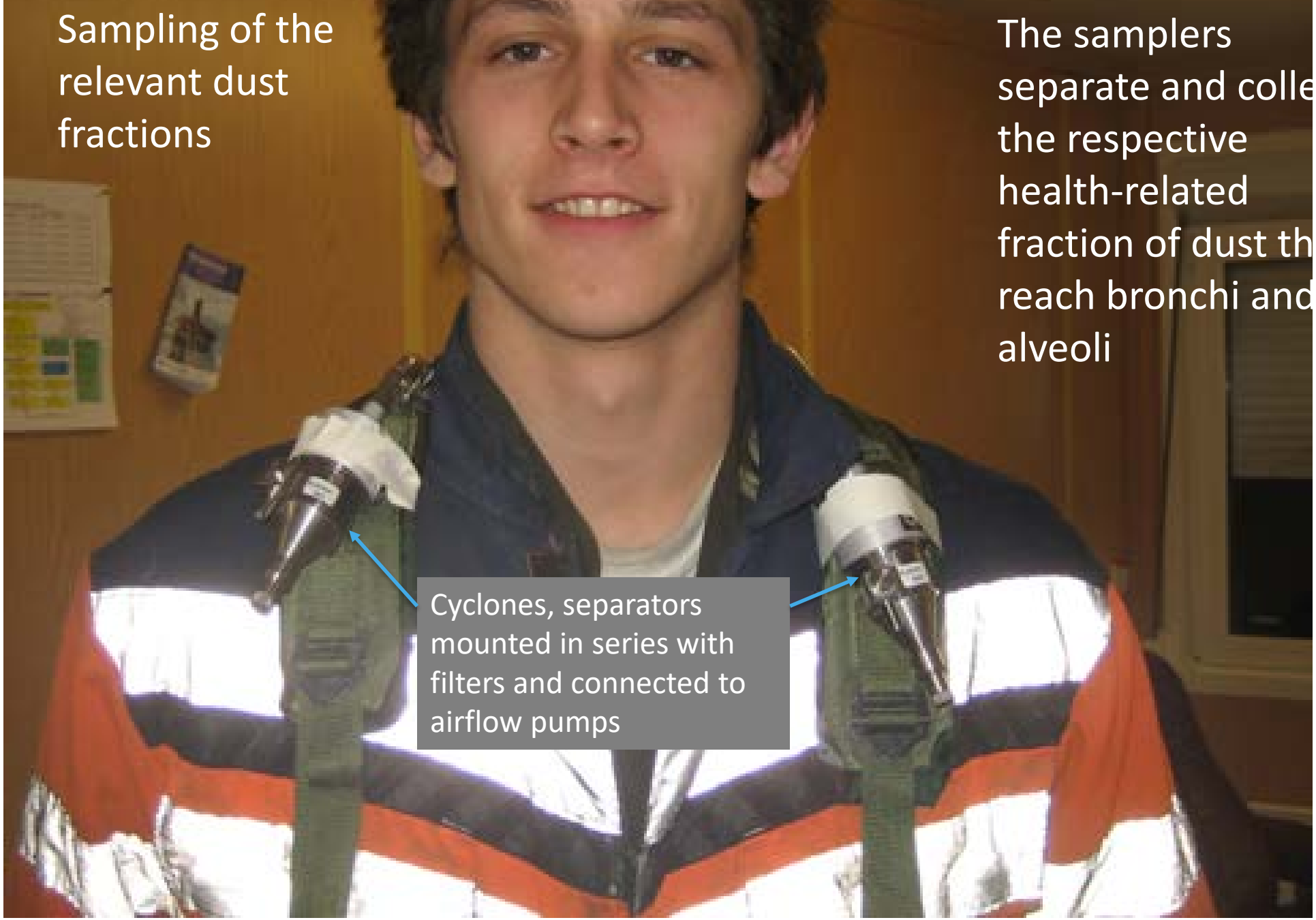

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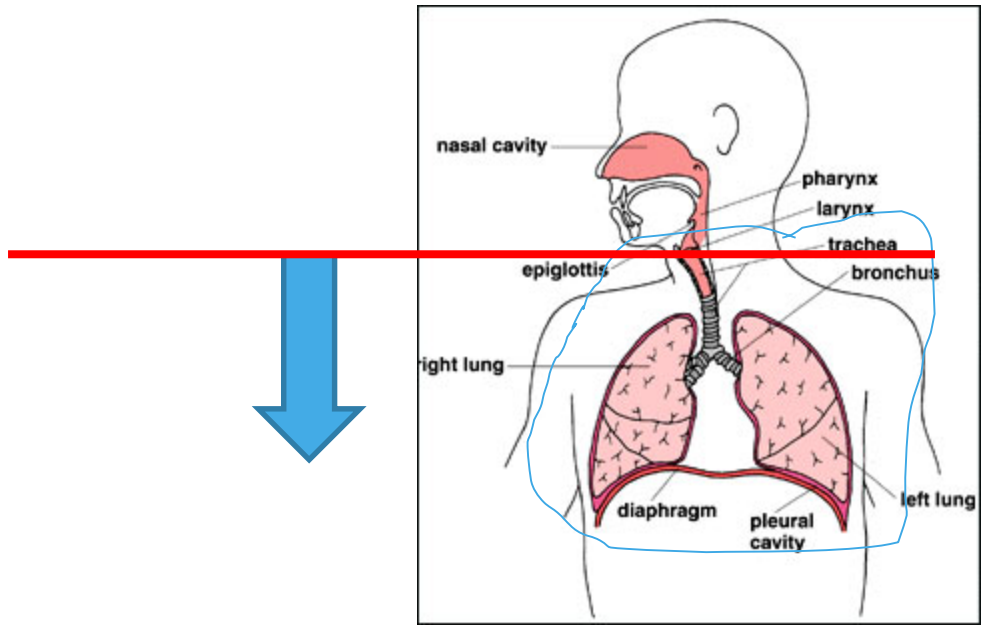
Definitions, aerosols

- Thoracic aerosol (below red line)
  - The aerosol fraction that enters beyond the larynx on inhalation (trachea, bronchi, alveoli)



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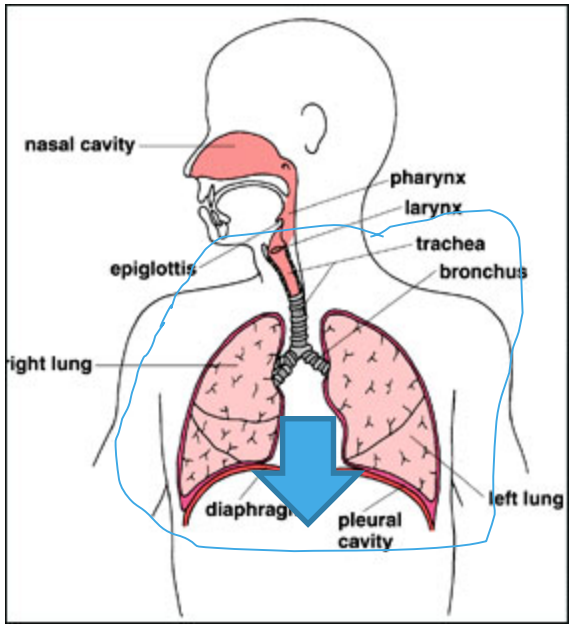
Definitions, aerosols

- Thoracic aerosol
  - The aerosol fraction that enters beyond the larynx on inhalation (trachea, bronchi, alveoli)
- Respirable aerosol
  - The aerosol fraction that enters the smallest airways (alveoli)



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Measurements on D&B operations

- Varying exposure situations including respirable crystalline silica / α-quartz, the level of respirable dust times the content of silica in the rock determines the content of RCS
- In Norway a mean RCS of 0.019 to 0.044 was found, depending on task performed (Ulvestad et al., 2001)

- Norwegian OEL is 0.10 mgm^{-3}
- NIOSH (USA) recommended exposure limit is 0.05 mgm^{-3}
- EU/ECHA is presently preparing documents for new exposure limits in EU (lowering from 0.10)

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Measurements on TBM operations

- Varying exposure situations including respirable crystalline silica / α-quartz as in D & B operations
- The exposure levels of α-quartz could reach levels amounting to 2.1 mgm^{-3} - appox. 20 times the present occupational exposure limit (OEL)

  (Bakke et al., 2001a – in a Norwegian study from Italy)
- A Canadian database including US data from 2013 indicates that some groups of workers in the existing TBM operations at the time were exposed at a mean of 0.4 mgm^{-3} 4 times the OEL for RCS (Beaudry et al., 2013)
- Measurements in more recent tunnelling operations with TBM show a median exposure level of approx 0.04-0.06 mgm^{-3}, with variations indicating need for exposure reduction among higher-exposed groups

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London Crossrail excavation, Galea et al., 2016

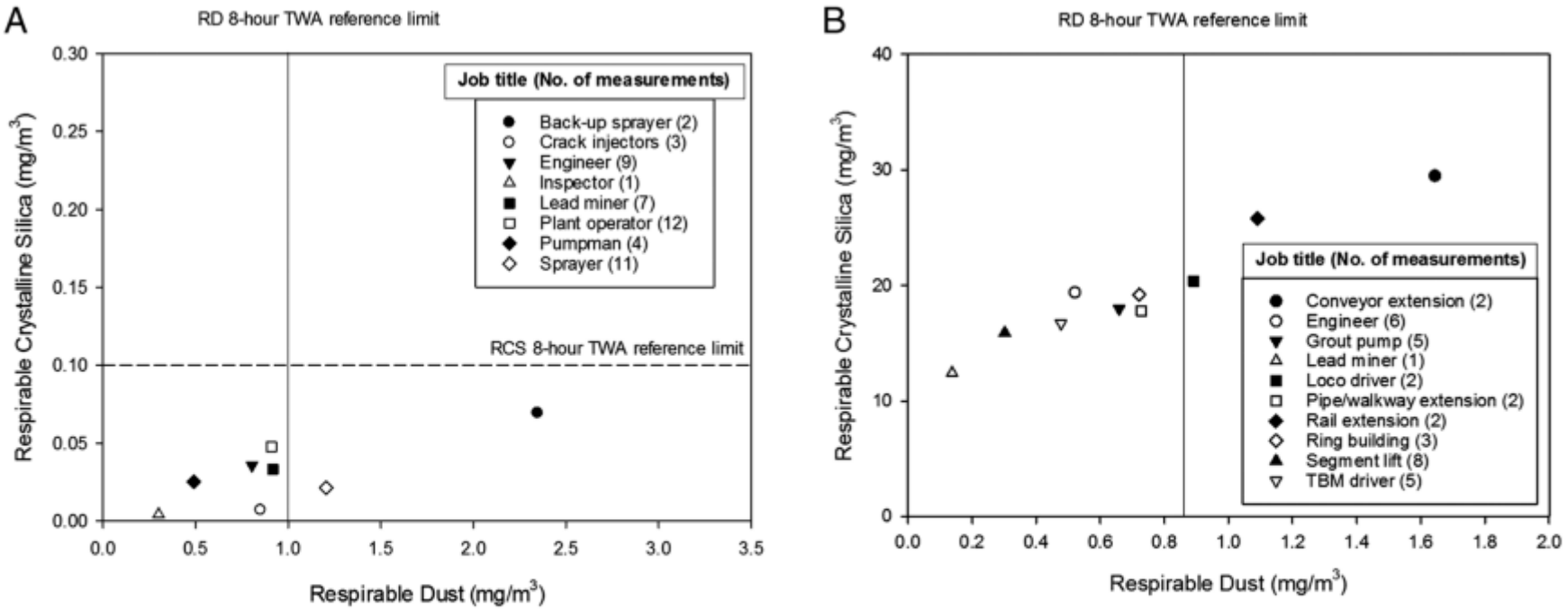

Figure 3 GM personal respirable dust versus respirable crystalline silica results collected in the SCL environment (a) and GM personal respirable dust versus respirable elemental carbon results collected in the TBM environment (b). Solid vertical line shows recommended BOHS and IOM RD limit of 1 mg m^{-3} and hashed horizontal line shows RCS 8-h TWA WEL of 0.1 mg m^{-3}.

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What is the potential for exposure reduction?

- Exposure assessment during tunnel boring machine (TBM) operations has been performed to a limited degree, thus exposure reduction by engineering is supposed to have a potential for improvement
- Today's TBM - equipment is more sophisticated than older equipment
- Further development of the equipment from the producers as well as during operations is expected
- Development of cleaning operations related to maintenance and production has still a potential for improvement in both methods

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Exposure reduction – cross talk between exposure measurements and preventive measures

- Efforts to reduce exposure includes cleaning surfaces before maintenance and during operations
- Avoid cleaning with pressurised air as far as possible
- Variation in work techniques affect personal exposure
- Cleanliness (dust removal) prevents re-suspension of settled dust
- The use of PPE – feasible in some situations – seldom feasible for full-shift use

Exposure reduction activities, some possibilities

- Drill & Blast
  - Ventilation/remove aerosol
  - Water irrigation after blasting to prevent resuspension of dust from the resulting rock material
  - Waiting time to enter tunnel after blasting
  - Closed-cabin machinery
  - Exhaust ventilation during drilling using pressurised air
  - Water-driven drills (when drilling with upwards inclination)?
  - EU-6 diesel engines in the machinery powered by diesel
- TBM
  - Water irrigation in the drilling zone
  - Ventilation/remove aerosol
  - Remove settled dust from machinery and parts, especially before dismounting and remounting procedures
  - Dust control/reduce levels from conveyor belts (reduce falling height of materials, isolate using sealing, exhaust ventilation at points of dust generation

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Different grouping categories that have been considered in the Follo Line Project (measurements are being processed in order to study changes in lung function from start to end of drilling

PRODUCTION CREW		MAINTENANCE CREW	
TBM operator		Cutter Head Mechanic:	
Shift boss		Cutter Head Welder	
Erector operator/ Segment installer:		Electrician	
Grout pump operator/ Grouter		Mechanics	
Segment crane operator		Helpers	
Pipe crane operator/pipe erector			
Conveyor belt erector			
Electrician			
Mechanics			
Helper			

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