Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 78 (1998)

Artikel: Laser scanning for tunnel state assessment
Autor: Röshoff, Kennet / Meixner, Jörg / Wiesler, Andreas
DOI: https://doi.org/10.5169/seals-59071

Laser Scanning for Tunnel State Assessment

Dr. Kennet Röshoff, Berg Bygg Konsult AB
S-16523 Hässelby, Box 3439
Jörg Meixner, Dr. Andreas Wiesler
Spacetec Datengewinnung GmbH
D-79098 Freiburg, Salzstr.47

Summary

In this paper a technology to obtain a maintenance and safty inspections in tunnls is presented. The measurements are carried out with a laser scanner. This measurement method is fast and relieable and does not obstruct the normal traffic or work in the tunnel.

In addition to the surface covering visual and thremal image, distance measurements can be obtained. All the data is stored on a normal PC. That means the tunnel is always ready for inspection in the office.

1 The Technology

1.1 The Scanner

The time available to carry out survey work on track and tunnel systems is strictly limited. In addition, the project requirements are getting more demanding. The TS 360 scanners was developed as a tool for maintenance and engineering professionals in order to carry out fast, accurate and reliable inspections of the total track and tunnel surface.

Figure 1 shows the measuring principle. A rotating scan mirror directs the laser beam outward. The reflected beam energy is collected by the same scan mirror and led though the optical system to the register electronics. The optical signals are digitized and stored. The scan mirror rotates 200 times per second and with each rotation 2.500 individual measurements are taken. Each measurement comprises of different informations.

While the scan mirror rotates 360° the measuring vehicle moves ahead a distance which corresponds to the width of the laser beam. Thus, a surface-covering recording is obtained.

Typically, to record 1 km with this multi spectral data collection system will take approximately 10 minutes.

2 Maintenance and Quality Conrol

2.1 The image and thermal scanner

The image and thermal scanner allows to chart structural damages even when the damaged sections are not visible on the surface. This type of measurement is primarily used for periodical structural surveillance, but also for approval acceptance of new constructions.

Figure 2 shows the approval acceptance for a new tunnel in Stuttgart. It was a two-channel measurement with a thermography image and a visual image. Both show the same section of the tunnel. The thermography image shows a striking anomaly on the wall at the left-hand side, which indicates that water has intruded into the concrete of the lining. After drilling a boarhole at the indicated place at a depth of 70 cm a strong jet of water poured out of the hole. By pressing in 300 litre of material the problem could be solved before the tunnel got under traffic.

It is notable that the visual image shows no trace of water on the lining. Hence, this anomaly could only be detected using the thermography laser scanner.

Figure 3 shows another example for the quality control in a new concret tunnel. The lower section shows a very homogenose heat distribution which means that there are no major demages in the lining. The upper image shows a very inhomogenos heat distribution. That is an example for what we call in Germany a Monday concrete. The thermal image is always good for getting an overview of what is going on in a tunnel. Based on that knowlege refurbishment work or additional local measurements can be planed much more costeffective.

2.2 High resolution image scanner

The high-resolution scanner is used for charting small surface structures. Cracks in the walls larger than 0,3 mm can be charted with close surface coverage (Figure 4). If these surveys are repeated at regular intervals, objective results on cracks and crack development can be obtained and repair works can be planed and calculated.

3 Clearance Control

Besides other features, it is the surface covering measuring techniques, which allows new solution to known problems. One of these "classical" problems is concerned with "measuring the clearance" or determining the place of the narrowest points if an excess load has to be transported.

3.1 Clearance Control for Tunnels and open tracks

To determine if an excess load can be transported over a certain railroad track, it is important to know the distances to all intruding objects on the track and to know the profile of the tunnels in relation to the rails. To enable a quick decision if the excess load is transportable by train, the required data of the distances were measured with the laser scanner and stored in a database. Figure 5 shows the clearence map of a tunnel in Scotland. The profile of the excess load is indicated on the bottom left.

3.2 Clearance Control during Tunnel Construction

A very similar problem is the outbreak control during tunnel construction. In this case one has to determine whether a concrete tube with a given cross section and given position will fit into the outbreak after the blasting.

Common to all these problems is that they call for measuring the distance between a given theoretical profile and the actual tunnel surface. This distance is termed "Clearance". The theoretical profile may be a vehicle shape or cinematic envelope shown in the cross section perpendicular to the track axis. For the case of outbreak control it is the cross section of the concrete tube to be placed in proper position.

Due to the fact that the measured distances are available for every point on the registered surface, the result may be represented as an issue oriented map. With the measured clearance distances displayed by colors on a map showing the vault surface, a Clearance Map is obtained. For the Clearance Map presented here, only certain critical values of the clearance are displayed. The remaining portion of the surface shows the visual image as a kind of "background layer".

The profile plot in Figure 6 shows the measured profile together with the theoretical profile at a specific place in the tunnel. This theoretical profile has been used to generate the Clearance Map. The origin of the coordinate system is in the virtual track center.

A portion of the Clearance Map at the entrance of the eastern tube of the Hallandsås Tunnel in Sweden is shown in Figure 7. The background layer displays a black and white image of the developed tunnel surface. The bare rock covered with shotcrete is well recognizable. The tunnel crown with a ventilation tube can be seen in the center of the figure.

There are two classes shown: "Close Clearance" means that the surface approaches the theoretical profile between 20 to 0 cm, "Obstruction" means that the surface intrudes the given theoretical profile.

Using colors in the Clearance Map several classes with "Close Clearance" or "Obstruction" can be highlighted. This feature enables the quick and convenient discovery of critical zones in the tunnel or open track under inspection.

The advantages of using a scanner-based method for outbreak control are evident:

- The Clearance Map immediately displays the places where problems may arise, either with the help of drawings or as colored map.
- Due to the availability of the visual image the places where problems may arise can easily be recovered in the object itself, eventually intruding objects can be identified.
- The additional volume that has to be broken out can be calculated from the digital data.

4 Conclusions

The laser scanning technique enables a surface covering measurement of a tunnel or open railway track. Clearance maps, crack charts and tunnel state surveys are systematically and reproducibly obtained. The measurements are carried without disturbing the normal traffic.

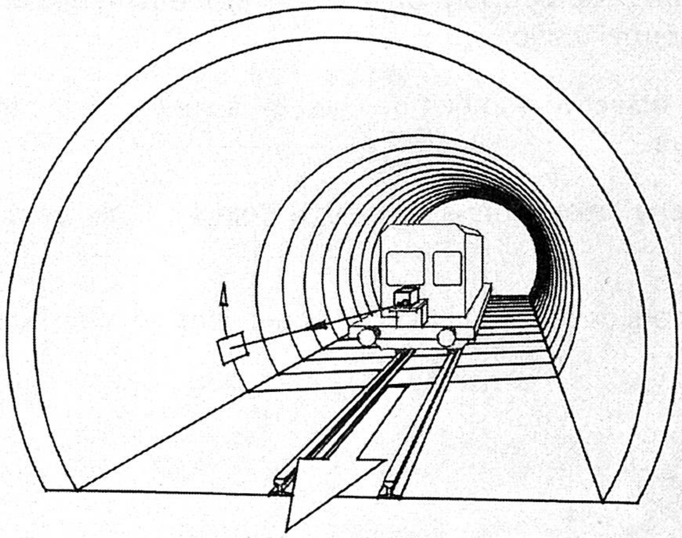
The results are objective and can be used for a surveying the trend of the state of a tunnel over years.

The thermography laser scanner is able to detect anomalies that are not visible by human eyes.

The laser scanners described in this paper are used all over the world for projects.

Tunnel Scanner TS 360

TS 360 scanner



- **TS 360 B**
  high resolution visual image scanner
  2500/5000 pixel/scan line
  measurement of the reflectivity of the surface

- **TS 360 BT**
  2 channel scanner, VIS/IR image
  2500 pixel/scan line
  measurement of the surface temperature; intensity of the emitted radiation

- **TS 360 BP**
  2 channel scanner, VIS image/profile
  2500 pixel/scan line
  measurement of the distance using the traveltime of light

Amberg Measuring Technique

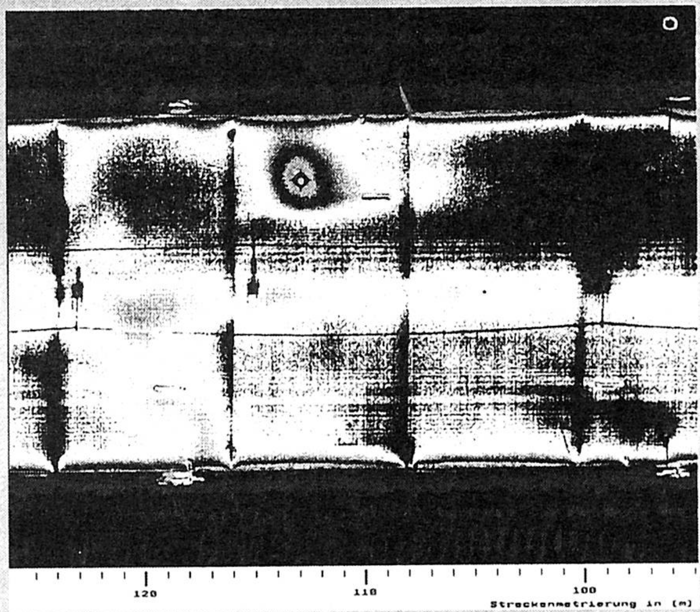
1

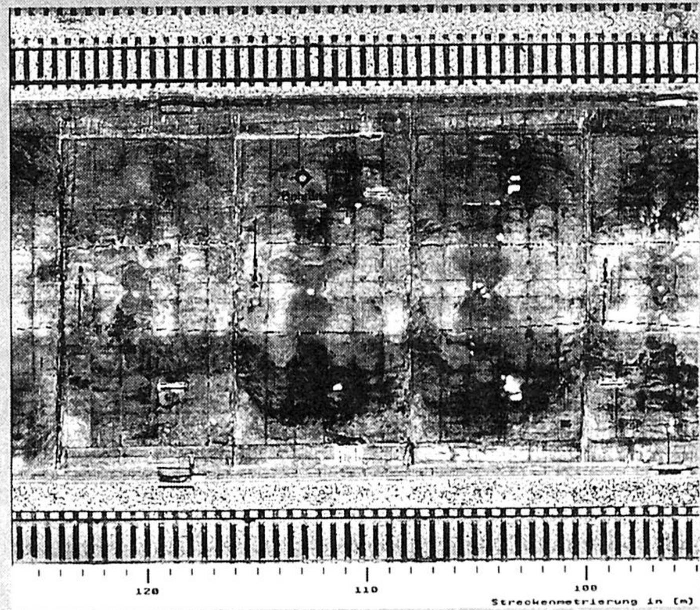
Figure 1: Measuring Principle

Tunnel Scanner TS 360

Stadtbahn Stuttgart

❒ **Thermography / endoscopic investigation**





Thermography shows a striking thermal anomaly on the left side wall. Water has intruded into the concrete of the lining.

The visual image shows no traces of water on the lining surface.

Drilling: **at the depth of 70 cm a strong jet of water exits from the drillhole.**

Amberg Measuring Technique

13

Figure 2: Acceptance approval

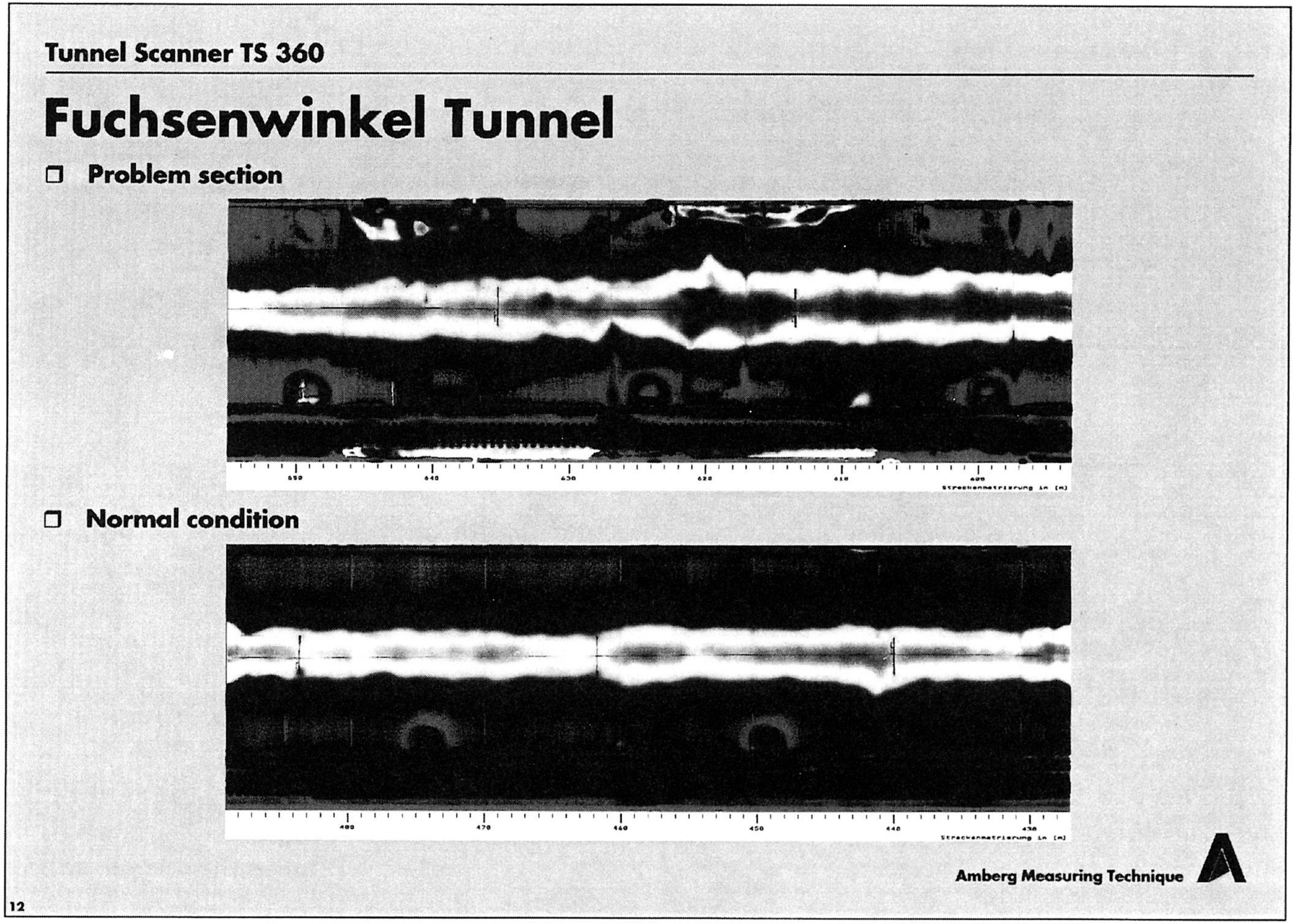


Figure 3: Quality control

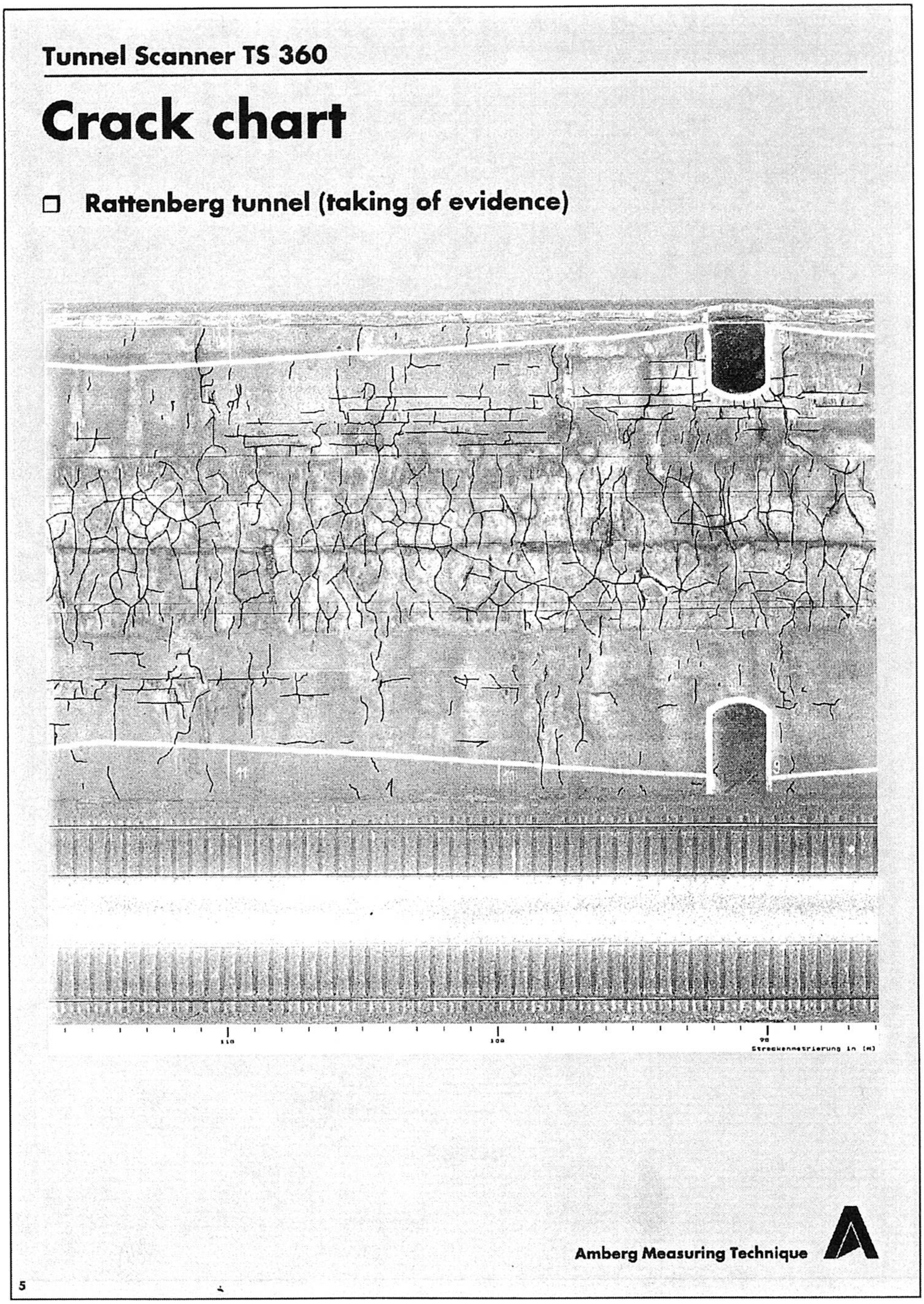


Figure 4: Crack chart

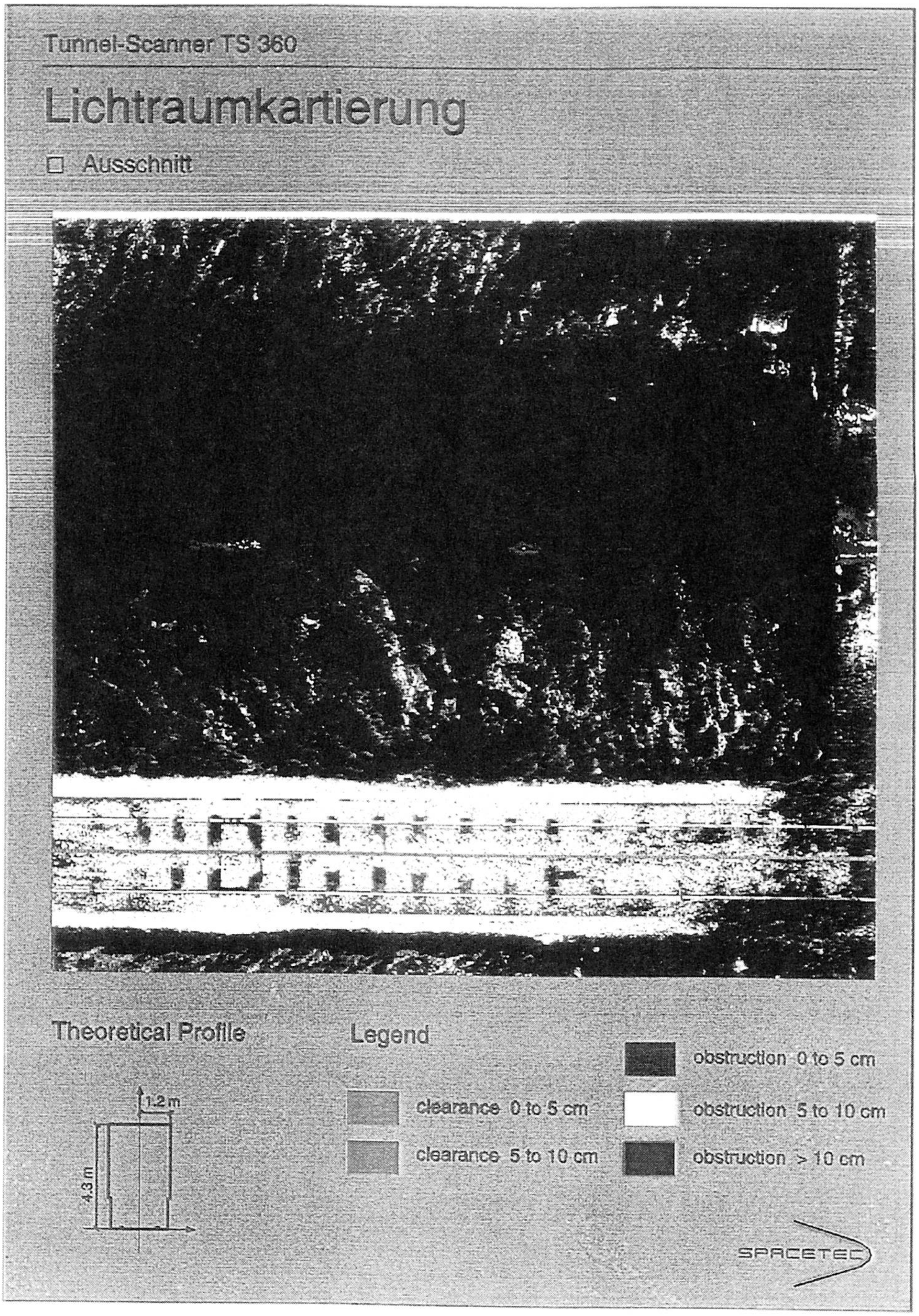


Figure 5: Clearence Map

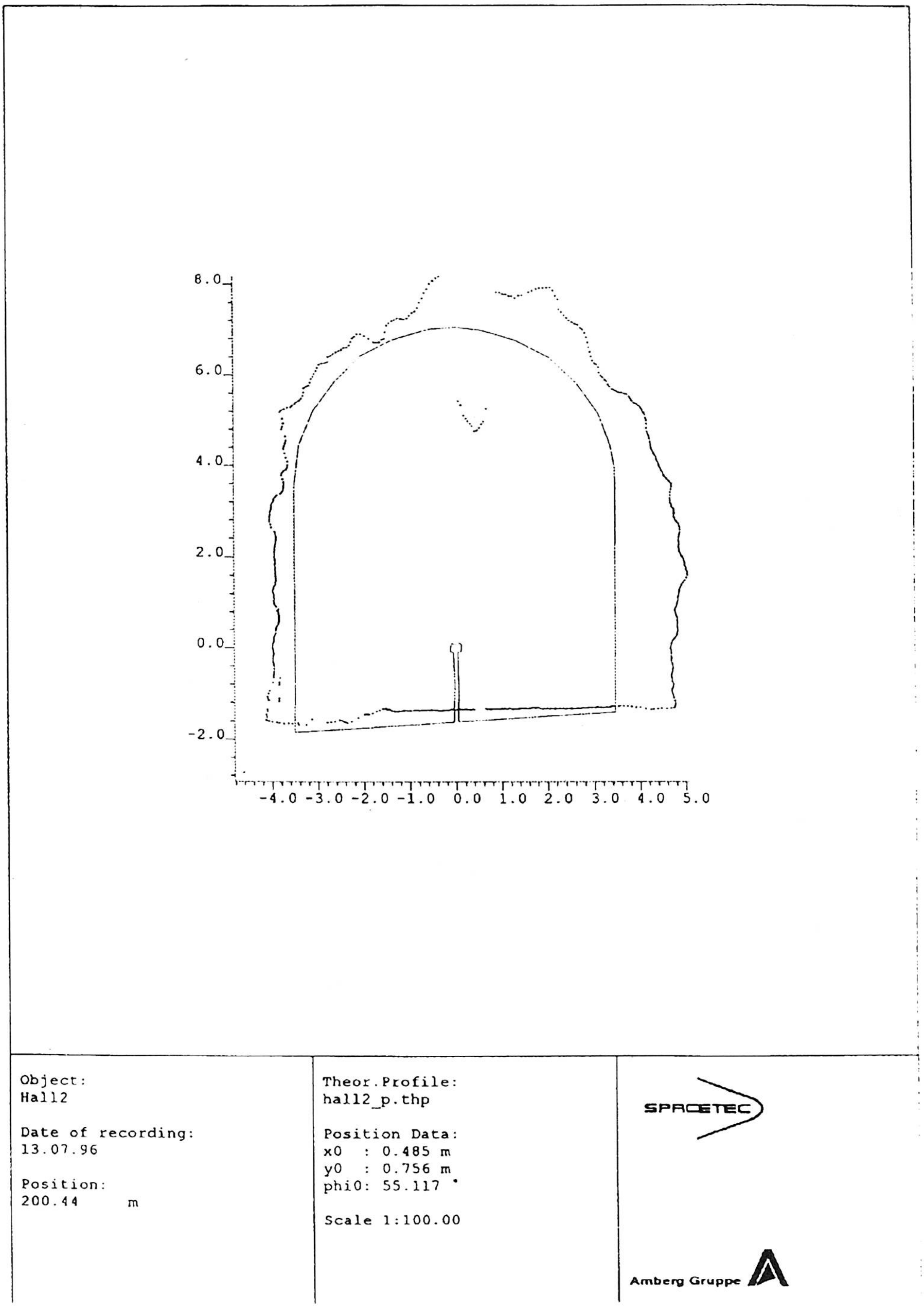


Figure 6: Cross section

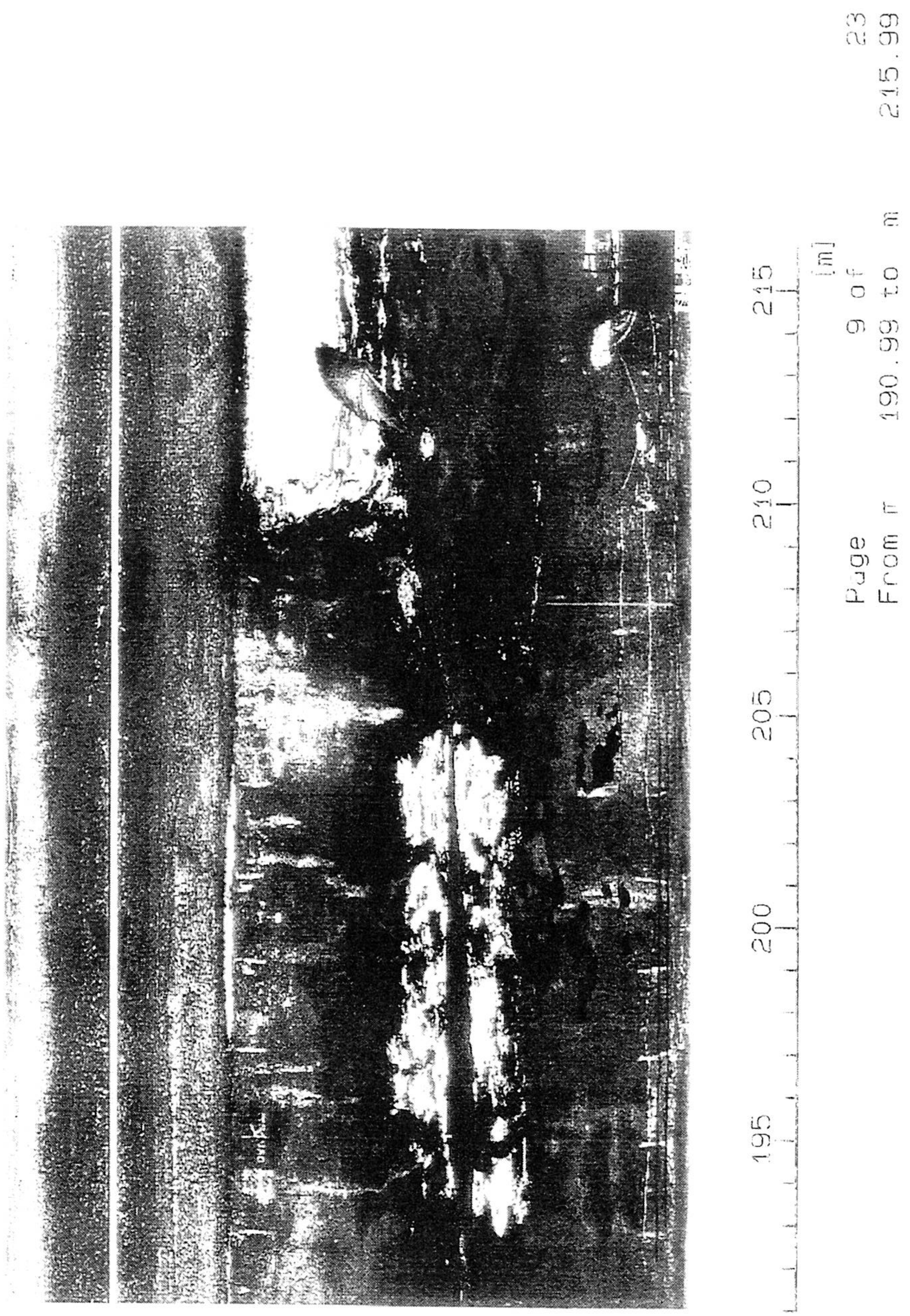


Figure 7: Clearence Map