QUARRY FACE & BOREHOLE SURVEYING

An Integrated Solution

WORLD LEADERS IN LASER MEASUREMENT TECHNOLOGY

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October 1990
(Edited in July 1992 & March 1998)

FOREWORD

Accurate information about the blast geometry of a quarry rock face will profoundly effect the success of blasting operations. Traditional working practices and techniques are unable to provide accurate information. As a result it is the single largest reason for poor blasting efficiency and dangerous fly rock incidents.

Measurement Devices Ltd. have in the last ten years developed equipment and operating techniques using the very latest laser, electronic and computer techniques to provide an integrated survey system which enables blasting engineers to:-

1. Visualise the rock face on computer
2. Accurately determine face profiles
3. Plan blast hole patterns with optimum burden
4. To survey the actual boreholes throughout their length
5. Calculate the effect of borehole deviation on the planned explosive charge

Armed with this information, blasting engineers can, for the first time, precisely match burden with explosive charge, optimising blast ratios, not only for each hole but along the entire length of each hole. This results in significant reduction in drilling and blasting costs through increased efficiency. The integrated system that gives these results is known as the Quarry Face Master. The systems successful track record means it is now in operation within hundreds of quarries and mines world-wide.

INTRODUCTION

In general quarry owners, managers and blasting contractors do not fully consider the use of surveying techniques as an aid to **increasing production** and **reducing hazards**.

Burden is the single largest variable affecting blasting results, but it is rarely ever measured.

- Inadequate burden results in fly rock, air blast, high explosives and drilling costs, and poor crusher utilisation.

- Excessive burden results in high vibration, poor fragmentation, high crusher costs and often high drilling and explosives costs in multi-row shots.

- Incorrect face height determination results in excessive toe or high vibration and high drilling and blasting costs.

- Incorrect borehole angle setting or undetected borehole wander can create significant variations in blasting results.

It is surprising therefore, to find it is still common practice to rely solely on experienced visual assessment of the face only before drilling, priming and blasting. Little, or no consideration is given to checking the accuracy of drill holes.

Traditional manual and/ or visual face profiling survey methods are **crude**, **inaccurate** and **dangerous.** Accurate face and borehole surveys, until now, have been **slow**, **expensive** and **often required specialist outside skills**.

For blasting operations effective face and borehole surveys must be

FAST, ACCURATE and COST EFFECTIVE

and results must be

IMMEDIATELY AVAILABLE

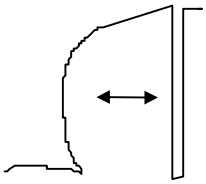
This paper reviews some common techniques presently in use and describes the integrate survey system technology developed by Measurement Devices Ltd. to achieve these objectives. The system is known as the Quarry Face Master.

TRADITIONAL REASONS FOR GEOMETRY ERRORS IN BLAST DESIGN

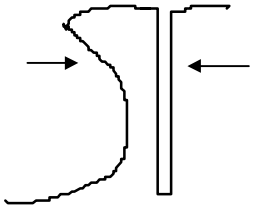
Face Assessment

Poor face assessment will, at the very least, lead to **poor yield**, **wasted explosive and drilling time**. At worst it will result in a major accident. In practice the half way position is more often the case and results in expensive

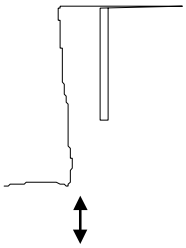
clearing up operations, excessive damage, wear and tear to plant and equipment. Common errors in face assessment are best illustrated as follows:-
Examples of common face profile assessment errors are given:-



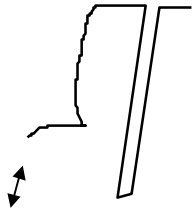
1. Under estimate of face burden



2. Over estimate of face burden



3. Under estimate of face height



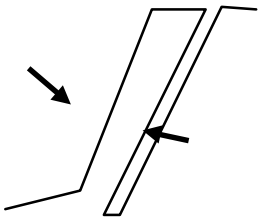
4. Over estimate of face height

DRILLING ERRORS

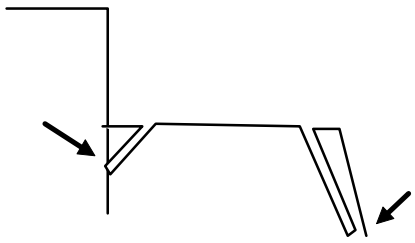
Failure to further consider and measure the effect of drilling errors can render good face assessment useless, as drilling errors have the same effect as poor burden estimation with the added danger of boreholes encroaching too close to neighbouring hole positions.

These errors are best illustrated:-

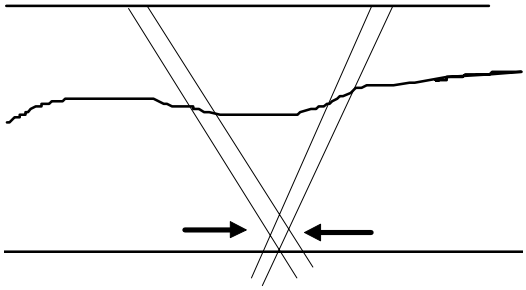
A) Errors due to poor Drill Angle Alignment.



1. Incompatible face/ drill

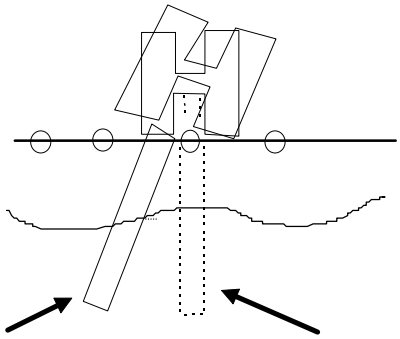


2. Side angle on corner shots



3. Crossed Holes

4. Drilling rig not at 90° to face line
Correct drilling direction = 90° to face line



Actual Hole Position **Intended Hole Position.**

The cause of the above are:-

1. Failure to measure actual face inclination
2. Incorrect setting of drilling angle
3. Measuring drill angle in one plant only
4. Measuring drill angles whilst the drill rig is not at right angles to the face
5. Hole deviation due to:
    - Geological problems
    - Drilling methods

Problems 1 - 4 can only be avoided by careful attention to drill rig alignment and investment in a good drill angle indicator is well worthwhile.

NOTE:-

The new UK Mines and Quarrying Regulations call for burdens to be within 10% of that specified for the blast design. In other words the drill rig must be set up to better than 1° and 0.5° for 15m and 30m faces respectively.

Drill rig set up and hole deviation errors can only be checked out using and affective borehole survey too!!

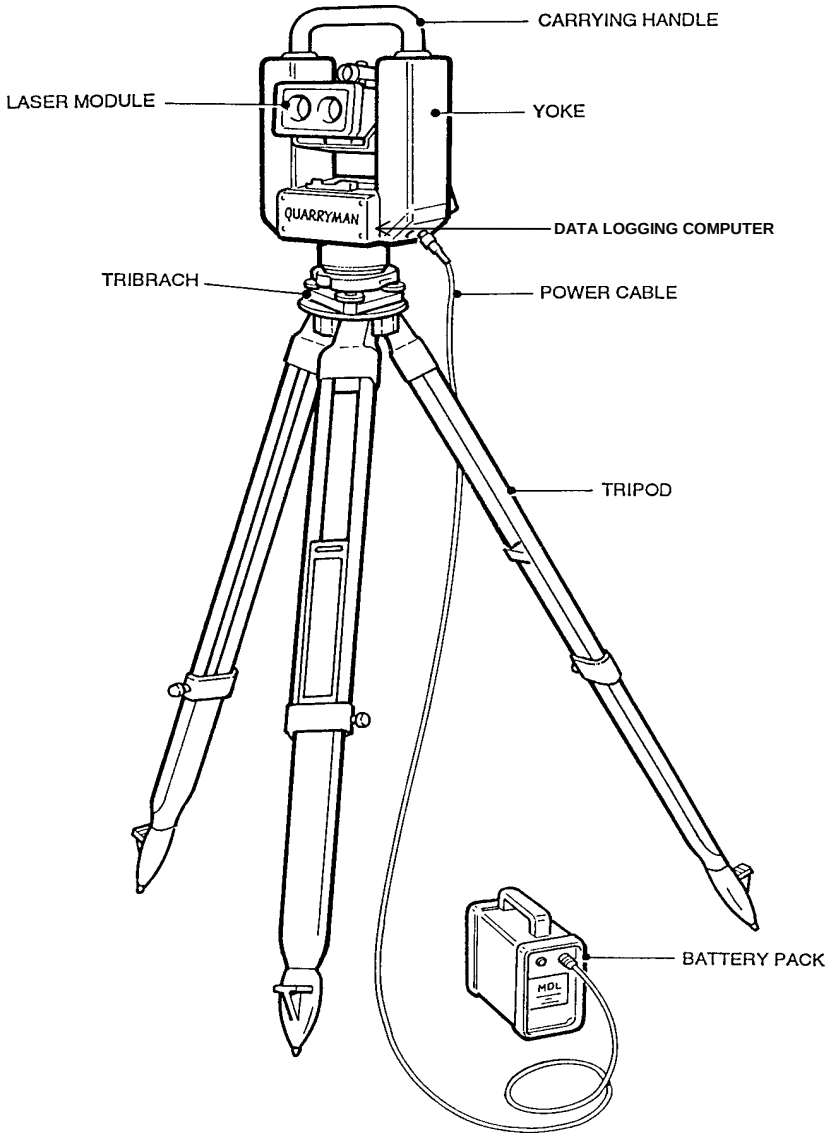
QUARRY FACE MASTER SYSTEM

With this system, quarry owners, managers and explosive engineers have the opportunity to accurately survey entire rock faces in minutes with complete safety, design borehole patterns for maximum yield and, finally, to rapidly cross-check drilling accuracy to minimise fly rock before blasting.

A Quarry Face Master comprises:

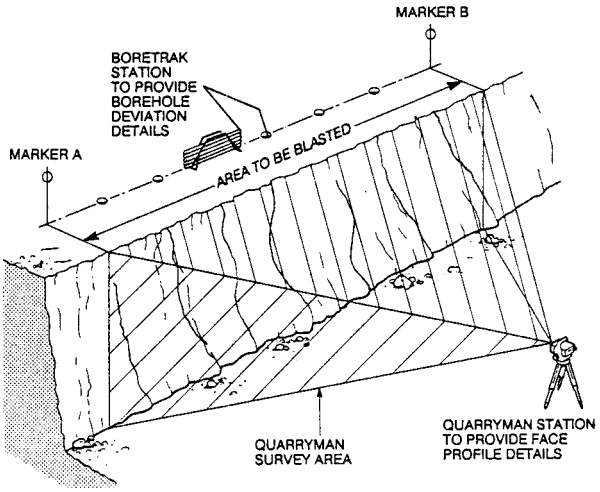
- A Quarryman® ALS - Autoscainning laser system for rock profiling
- An IBM PC compatible computer system
- A Quarryman Face 3D software package
- A Boretrak® - Borehole deviation system

1. The Quarryman® ALS

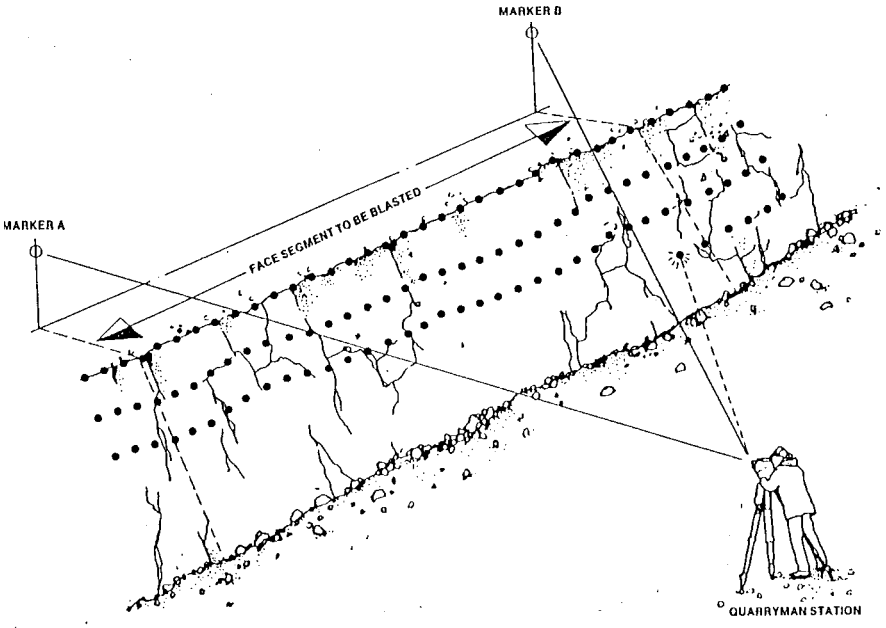


Basic Principles - Quarryman® ALS

- Operator points the laser at the face and measures:
  distance, horizontal and vertical angles
- Laser scans are made directly across the rock face
- An IBM compatible PC computer processes the data on-site. Interactive graphics and editing facilities allow optimisation of face design and drilling hole positions
- Print and plot results for records
- Survey as drilled holes with Boretrak®
- PC Computer corrects computations for borehole deviations



A Quarryman® ALS for rock profiling may be manually or automatically operated and is capable of measuring bearing, distance and vertical angle directly to a rock faces up to 500 m. No special skills are required to operate the equipment.



Scans are made across the rock face from a suitable vantage point until sufficient readings have been obtained to accurately define the face features, quarry floor and two face-line reference markers. Measurements are automatically recorded in the systems electronic notebook which prompts the operator at every stage, avoiding booking errors and speeding measurement. Once the observations are completed the survey data can be downloaded from the electronic notebook into the PC computer system, ready for processing.

2. The IBM PC Compatible Computer System

Any PC computer system may be utilised to process Quarryman® and Boretrak® results. There are two basic options to be considered:-

1. A Pentium desk top PC with high resolution colour graphics for making full use of the graphics visualisation of the rock face geometry.

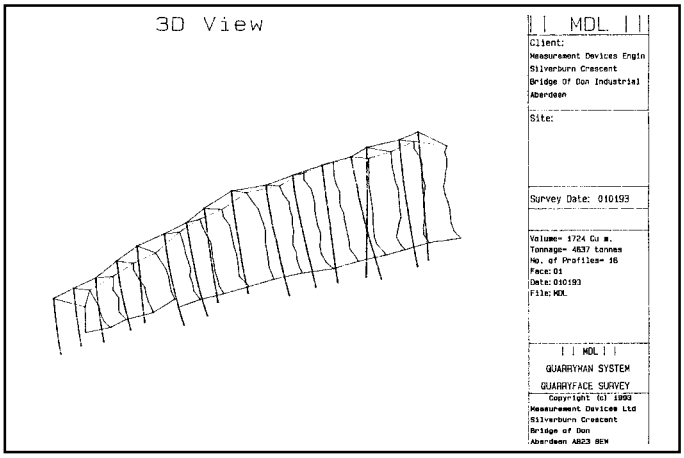
2. A high speed 486 Laptop PC for direct on-site processing to minimise operational delays.

The office based peripherals units - a graphics printer to provide hard copy data records.

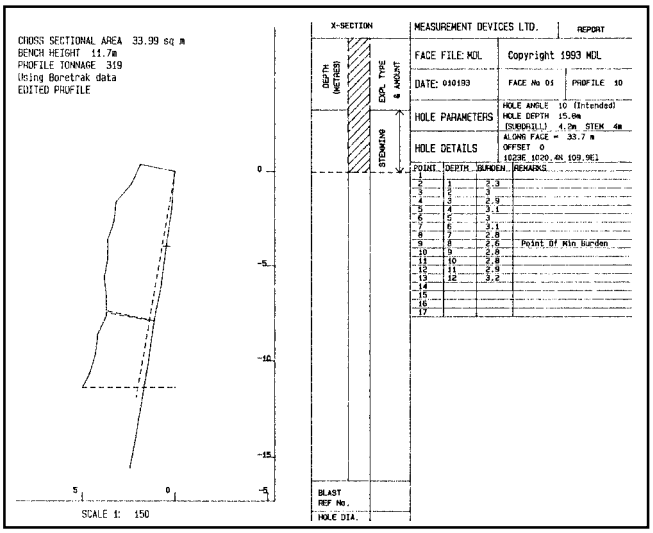
3. Quarryman Face 3D Software

The easy to use menu driven software achieves four purposes:-

- Processes and integrates the raw data from Quarryman® systems
- Allows manipulation of the data to optimise face design
- Produces graphic displays in 2D and 3D
- Provides concise survey documentation



The Face 3D software introduces interactive graphics and advanced mathematics to enable face data manipulation in 3 dimensions into a quarry face survey.



This gives the operator a real feel for the measured data which boosts confidence and simplifies the understanding of the complex borehole-face burden relationships.

PRINCIPLE OF SOFTWARE OPERATION

The rock face survey point data is down-loaded into the host PC computer. The points which can be observed in random order are then sorted into a logical array.

The user is prompted to enter the variables affecting face design. i.e.,

1) The start point for the boreholes - expressed as a distance from the left hand marker along a straight line towards the right hand face marker
2) Borehole spacing and drill angle
3) Rock density

Alternatively if the boreholes were already drilled prior to the face survey, the collar positions are surveyed at the time and step 1) is skipped.

The PC then automatically computes the projected borehole profile intersections at 90° to the face-line. It then calculates the projected face burden and plots the face profiles on the graphics screen in 3 dimensions and calculates the tonnage of rock that would be produced from the blast. An opportunity is then given to the blast designer to adjust the design to optimise the blast geometry and

- Vary the drill angle for individual profiles
- Vary the borehole spacing
- Adjust the face-line back, forward or skew
- Edit the profile data and remove screen toe debris
- Vary rock density

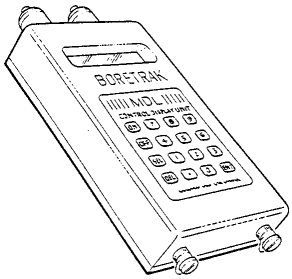
A reporting module gives individual profile and horizon plan plots for issue to the drillers.

Once drilled, Boretrak data may be downloaded into the face file and a re-run of the software re-computes and reports the face parameters of burden, borehole to borehole closing distances and tonnage based on the **actual** borehole positions.

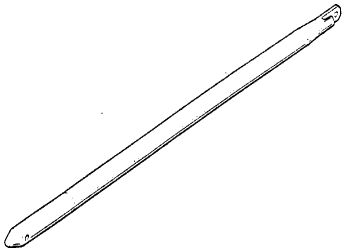
The important advantages of this measurement and processing technique are given as follows:-

- No need to measure specific profiles - obviating the need to consider face inclination and angle of observation - removing observations errors.
- Face profiles are interpreted from the data array. Should the borehole spacing be changed during design new profiles can be interpreted. This removes the need to re-survey the profiles.
- Inter-profile/ inter-borehole relationships are exactly known without the need for complicated tape and offset surveys.
- Actual volume/ tonnage calculations enable the designer to know exactly what yield the face will produce, and thus adjust the explosive loading accordingly, maximising the use of quarry resources.
- With the addition of MDL's Blastfile software suite the operator is given the ability to automatically compute blast ratios at intervals down each profile, given operator input of explosive density. The full hole loading can be planned and verified prior to blasting based on actual blast geometry.

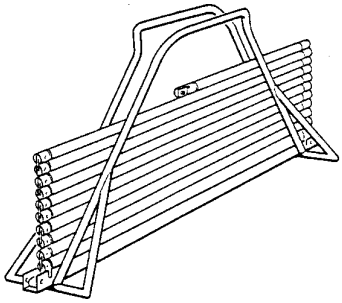
BORETRAK - MDL's BOREHOLE DEVIATION SURVEY SYSTEM
(Patent applied for)



Control Display Unit



Sensor Probe



Single (m) Rack

Boretrak II is the latest version of MDL's borehole deviation survey system. Boretrak is 38mm in diameter and is suitable for use in dry or flooded holes 45mm in diameter down to a maximum depth of 100m.

Boretrak consists of:-

a. A two axis *(pitch & roll)* measuring head 1 m
b. A set of lightweight alignment rods 2 m / 1 m
c. An electronic notebook and battery pack
d. PC compatible software

The measuring head is constructed from stainless steel and aluminium. The rods are made from fibre glass or carbon fibre. Total weight for a typical 30m system is 11.5 KGs.

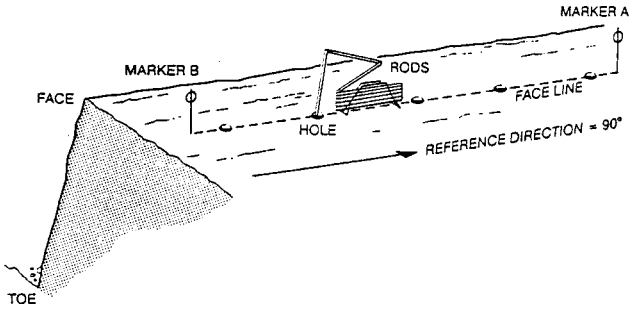
MEASURING PRINCIPLE

Boretrak based on MDL's Trim® technology has a integral single chip microcomputer which utilises electrolytic gravity sensors to determine inclination, compensate for temperature and voltage fluctuations, store calibration data, and format and control data output.

The rods which are used to lower the sensor head down a hole, flex, but do not twist enabling each reading to be related to the face orientation at the surface. Sensor depths are indicated by counting the number of rods in the hole.

MODE OF OPERATION

The measuring head is connected to the lightweight rods by means of a lynch pin. The lightweight rods which are continuously connected by a single axis hinge system and the measuring head are lowered down the borehole. Depth is logged at regular intervals by pressing the electronic notebook enter button until the bottom of the hole is reached.

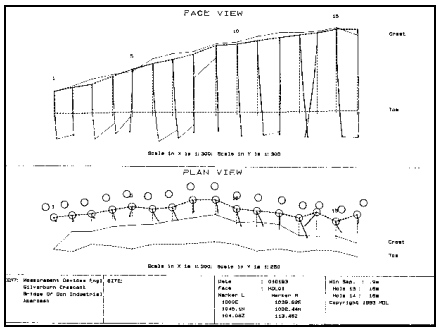


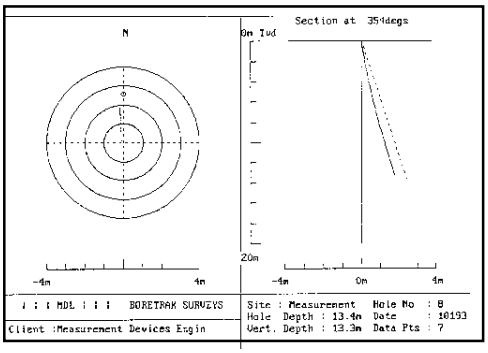
The notebook's electronic menu prompts the operator to enter the file reference data, such as date, hole number, rod interval and rod offset.

On completion of the survey, data from the measuring head and electronic notebook are downloaded to the PC when depth angle integration takes place.

SOFTWARE

The Boretrak data may be downloaded into the host PC. The data may be integrated into the Quarryman® Face 3D software to modify and re-compute face survey data from intended to actual hole positions. Alternatively, the standard stand-alone Boretrak PC software may be used.
Bullseye and section displays and plots are provided to give the operator visual as well and alpha numeric data about the hole position.





Hole pitch and roll angles are automatically recorded at three second intervals. Longer system record automatically at 10 second intervals.

Measuring head depths are logged at 1, 2 or 4 m intervals.

OPERATIONAL ADVANTAGES SUMMARY

1. Quarryman® ALS scanning entire rock faces in minutes in complete safety Typically 50 m x 15 m face takes 10 minutes.

2. Quarryman® Face 3D software provides fast, and accurate graphics. The software also provides alphanumeric results which aid the operator to design the optimum borehole arrangement for maximum face yield resulting in:-

    - Reducing Drilling Time
    - Saving Explosives
    - Minimising Plant Wear and Tear

3. Boretrak® results, when integrated with results from the Quarryman® ALS using Face 3D software enables:-

    - Final adjustment of charging parameters
    - Increased blast design confidence
    - Warning of hole collisions or deviations

    Typical hole survey time is 5 minutes

QUARRYMAN FACE MASTER SYSTEM OWNERSHIP BENEFITS SUMMARY

- Increases safety
- Reduces direct costs

SAFETY

- Quarryman® ALS accurately determines face burdens: It enables efficient priming, reducing **fly rock**, **air over pressure** and **noise**.
- No need to have personnel dangerously close to the rock face during survey operations.

REDUCES DIRECT COSTS

- Reduced explosive costs
- Better face yields
- Better fragmentation *i.e. no secondary breading/ blasting*
- Less wear and tear on plant
- Fly rock control *i.e.No expensive clearing up operations*
- No damage to plant
- Reduction in man hours to survey

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