



# Hydraulic conductivity determination by Lugeon test – testing in practice

Workshop – Drainage of large rockslides  
Oslo 30 – 31<sup>st</sup> January 2017

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# History

Originally suggested as a test for assessing need for foundation grouting at dam sites.

- Lugeon, M. 1933. *Barrages et Geologie*. Dunod, Paris.
- Lancaster-Jones, P. F. F. 1975. *The interpretation of the Lugeon water-test*. *Q. Jl Engng Geol.* Vol 8 pp. 151-154.
- Houlsby, A. C. 1976. *Routine interpretation of the Lugeon water-test*. *Q. Jl Engng Geol.* Vol 9 1 pp. 303-313.

# History

ASTM D4630 - 96(2008)

Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

# Set up

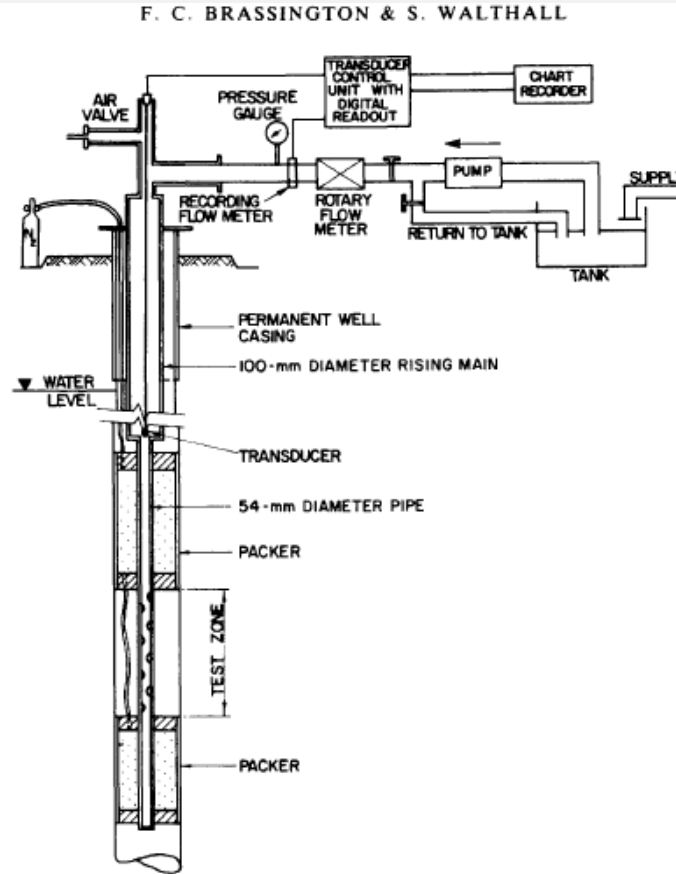
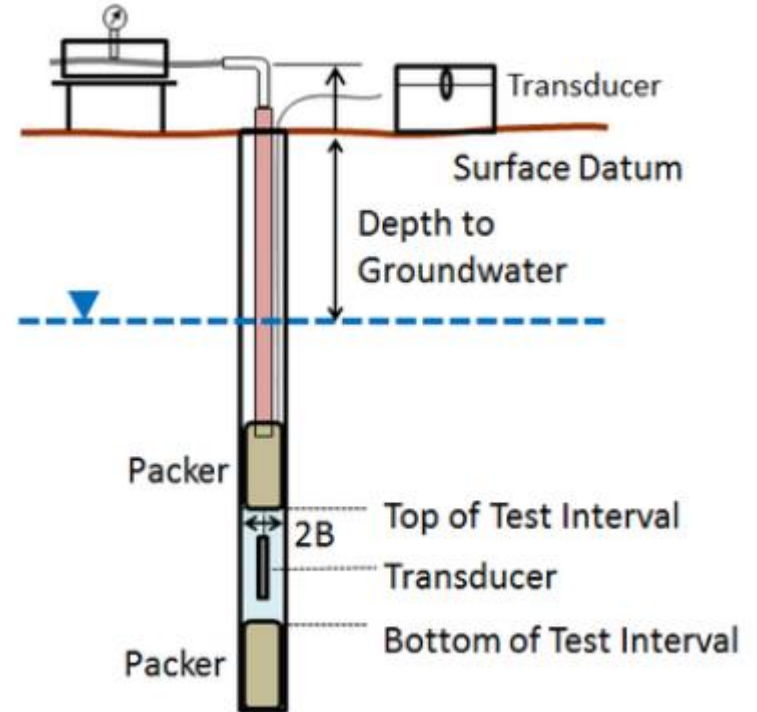
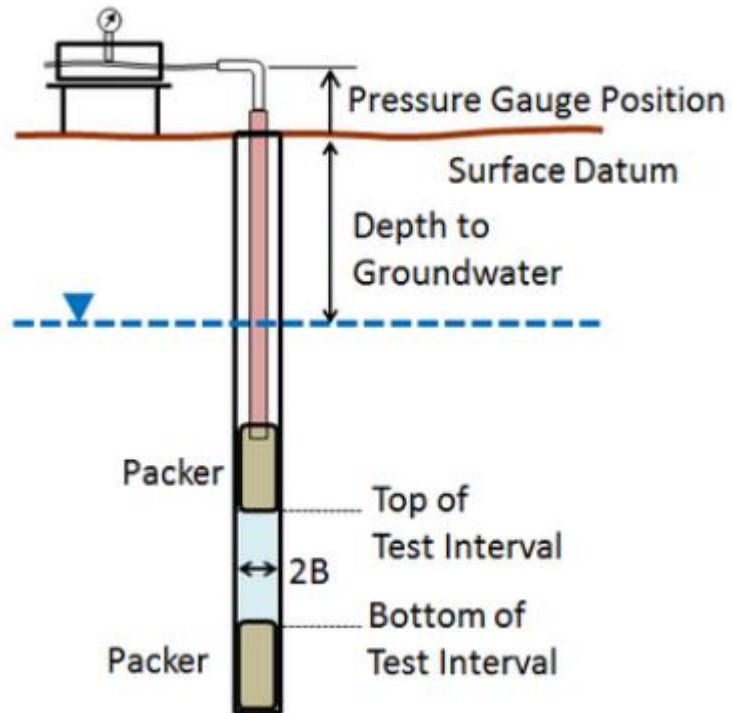


FIG. 2. General arrangement for inflow packer testing.

# Set up



# Set up



# Set up



# Test procedure

Five consecutive water (pump-in) tests are done, each of ten minutes duration; the

- 1st 10 minutes is at a low pressure--(pressure "a")
- 2nd 10 minutes run is at a medium pressure--(pressure "b")
- 3rd 10 minutes run is at a peak pressure--(pressure "c")
- 4th 10 minutes run is at a medium pressure--(pressure "b" again)
- 5th 10 minutes run is at a low pressure--(pressure "a" again)

# Test procedure - simplified

Three consecutive water (pump-in) tests are done, each of five minutes duration at the same pressure – if flow rates are not consistent then continue with more five minute tests.

# Interpretation

A single Lugeon value is then calculated for each one of these five tests, using the formula:

$$L = \frac{10 \times Q}{P}$$

L = Lugeon value

Q = water taken in test (litres/metre/min)

P = test pressure (bars)

10 as correction for standard test pressure of 10 bar.

# Interpretation

TABLE 1: *Lugeon patterns for various occurrences during testing:  
Their interpretation and percentage occurrences*

ation

| TEST PRESSURES<br>(SHOWN IN APPROX.<br>RELATIVE MAGNITUDE) | LUGEON PATTERN<br>LUGEONS CALCULATED<br>FOR EACH 10 MINUTE RUN<br>(RELATIVE MAGNITUDES SHOWN<br>IN GENERALISED PATTERNS.<br>ACTUAL MAGNITUDES CAN VARY<br>WIDELY) | CHARACTERISTICS OF<br>THE PATTERN, &<br>INTERPRETATION<br>OF IT | WHICH OF THE LUGEON<br>VALUES IN THE PATTERN<br>SHOULD BE USED AS<br>THE REPORTED<br>PERMEABILITY? | PERCENTAGE OF<br>ACTUAL CASES<br>IN EACH GROUP<br><br>(SUMMARISED FROM TABLE VI)<br>WHEN THE REPORTED PERMEABILITY IS |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
|                                                            |                                                                                                                                                                   |                                                                 |                                                                                                    | 1, 2, OR 3 LUGEONS   4 OR MORE LUGEONS                                                                                |

### GROUP A -LAMINAR FLOW

|                    |       |  |                                                        |                                                                                |     |    |
|--------------------|-------|--|--------------------------------------------------------|--------------------------------------------------------------------------------|-----|----|
| 1ST TEN MINUTE RUN | a     |  | ALL 5 LUGEONS ARE<br>ABOUT EQUAL<br>HENCE LAMINAR FLOW | USE THE AVERAGE OF<br>THE FIVE LUGEONS<br><br>(TO THE NEAREST<br>WHOLE NUMBER) | 78% | 5% |
| 2ND                | b     |  |                                                        |                                                                                |     |    |
| 3RD                | c     |  |                                                        |                                                                                |     |    |
| 4TH                | d = b |  |                                                        |                                                                                |     |    |
| 5TH                | e = a |  |                                                        |                                                                                |     |    |

### GROUP B -TURBULENT FLOW

|                    |       |  |                                                                                 |                                                     |     |     |
|--------------------|-------|--|---------------------------------------------------------------------------------|-----------------------------------------------------|-----|-----|
| 1ST TEN MINUTE RUN | a     |  | LOWEST LUGEON VALUE<br>OCCURRING AT HIGHEST<br>PRESSURE HENCE<br>TURBULENT FLOW | USE THE LUGEON<br>VALUE FOR THE<br>HIGHEST PRESSURE | 13% | 53% |
| 2ND                | b     |  |                                                                                 |                                                     |     |     |
| 3RD                | c     |  |                                                                                 |                                                     |     |     |
| 4TH                | d = b |  |                                                                                 |                                                     |     |     |
| 5TH                | e = a |  |                                                                                 |                                                     |     |     |

### GROUP C -DILATION

|                    |       |  |                                                                      |                                                                    |    |    |
|--------------------|-------|--|----------------------------------------------------------------------|--------------------------------------------------------------------|----|----|
| 1ST TEN MINUTE RUN | a     |  | HIGHEST LUGEON<br>OCCURRING AT HIGHEST<br>PRESSURE<br>HENCE DILATION | USE THE LUGEON<br>VALUE FOR THE<br>LOWEST (OR MEDIUM)<br>PRESSURES | 1% | 9% |
| 2ND                | b     |  |                                                                      |                                                                    |    |    |
| 3RD                | c     |  |                                                                      |                                                                    |    |    |
| 4TH                | d = b |  |                                                                      |                                                                    |    |    |
| 5TH                | e = a |  |                                                                      |                                                                    |    |    |

### GROUP D -WASH-OUT, ETC

|                    |       |  |                                                                                                     |                                                                                    |    |     |
|--------------------|-------|--|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----|-----|
| 1ST TEN MINUTE RUN | a     |  | LUGEONS INCREASING<br>AS TEST PROCEEDS<br>HENCE THE TEST IS<br>CAUSING CHANGES TO<br>THE FOUNDATION | USE THE HIGHEST<br>LUGEON VALUE<br><br>UNLESS SPECIAL REASONS<br>REQUIRE OTHERWISE | 2% | 21% |
| 2ND                | b     |  |                                                                                                     |                                                                                    |    |     |
| 3RD                | c     |  |                                                                                                     |                                                                                    |    |     |
| 4TH                | d = b |  |                                                                                                     |                                                                                    |    |     |
| 5TH                | e = a |  |                                                                                                     |                                                                                    |    |     |

### GROUP E -VOID FILLING

|                    |       |  |                                                                                                     |                                          |    |     |
|--------------------|-------|--|-----------------------------------------------------------------------------------------------------|------------------------------------------|----|-----|
| 1ST TEN MINUTE RUN | a     |  | LUGEONS DECREASING<br>AS TEST PROCEEDS<br>HENCE THE TEST IS<br>GRADUALLY FILLING<br>EXTENSIVE VOIDS | USUALLY USE THE<br>FINAL LUGEON<br>VALUE | 6% | 12% |
| 2ND                | b     |  |                                                                                                     |                                          |    |     |
| 3RD                | c     |  |                                                                                                     |                                          |    |     |
| 4TH                | d = b |  |                                                                                                     |                                          |    |     |
| 5TH                | e = a |  |                                                                                                     |                                          |    |     |

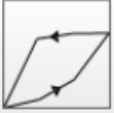
\*CALCULATED USING DIRECT PROPORTION TO RELATE TO  
LUGEON'S "DEFINITION" PRESSURE OF 10 BARS (150 P.S.I.)

THIS TABLE GIVES GENERAL PATTERNS ONLY.  
DISCRETION IS NECESSARY IN ADAPTING THESE TO THE  
INEVITABLE VARIATIONS MET IN PRACTICE

\*CALCULATED USING DIRECT PROPORTION TO RELATE TO  
LUGEONS 'DEFINITION' PRESSURE OF 10 BARS (150 P.S.I.)

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DISCRETION IS NECESSARY IN ADAPTING THESE TO THE  
INEVITABLE VARIATIONS MET IN PRACTICE

# Interpretation

| Behaviour      | Lugeon Pattern                                                                    | Flow vs. Pressure Pattern                                                           | Representative Lugeon Value                                                                                   |
|----------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Laminar Flow   |  |  | Average of Lugeon values for all steps                                                                        |
| Turbulent Flow |  |  | Lugeon value corresponding to the highest water pressure (3rd step)                                           |
| Dilation       |  |  | Lowest Lugeon value recorded, corresponding either to low or medium water pressures (1st, 2nd, 4th, 5th step) |
| Wash-out       |  |  | Highest Lugeon value recorded (5th step)                                                                      |
| Void Filling   |  |  | Final Lugeon value (5th step)                                                                                 |

Based on Houlsby (1976)

# Interpretation

- The following table describes the conditions typically associated with different Lugeon Values, as well as the typical precision for reporting these values (Quiñones-Rozo, 2010).



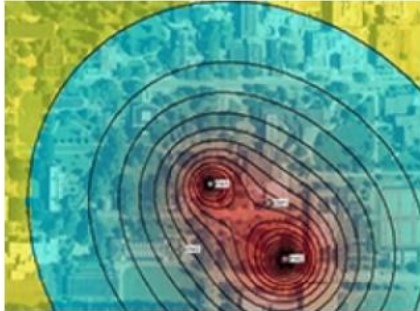
| Lugeon Range | Classification | Hydraulic Conductivity Range (cm/sec) | Condition of Rock Mass Discontinuities | Reporting Precision (Lugeons) |
|--------------|----------------|---------------------------------------|----------------------------------------|-------------------------------|
| <1           | Very Low       | $< 1 \times 10^{-5}$                  | Very tight                             | <1                            |
| 1-5          | Low            | $1 \times 10^{-5} - 6 \times 10^{-5}$ | Tight                                  | $\pm 0$                       |
| 5-15         | Moderate       | $6 \times 10^{-5} - 2 \times 10^{-4}$ | Few partly open                        | $\pm 1$                       |
| 15-50        | Medium         | $2 \times 10^{-4} - 6 \times 10^{-4}$ | Some open                              | $\pm 5$                       |
| 50-100       | High           | $6 \times 10^{-4} - 1 \times 10^{-3}$ | Many open                              | $\pm 10$                      |
| >100         | Very High      | $> 1 \times 10^{-3}$                  | Open closely spaced or voids           | >100                          |

# Interpretation - software

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