Certificate in Rock Mechanics Paper 3.4: Open Pit

Examination Question Paper

May 2017

Examiner: Des Mossop

Moderator: Peter Terbrugge

Duration: 3 hrs

Special Requirements:

1. Answer **all five** questions;
2. References other than those provided are not permitted;
3. Hand-held scientific calculators may be used, but programmable electronic calculators are not permitted;
4. Put your examination number on the outside cover of each book used and on any graph paper, sketch or other loose sheets handed in;
   NB: Your name must not appear on any answer book or loose sheets;
5. **Write in ink on the right hand side of the paper only (only the right hand pages will be marked). Request as many answer books as needed;**
6. **Include the stereonet with your answer book, the stereonet should be drawn on the transparency sheet provided;**
7. Show all calculations on which your answers are based;
8. Illustrate your answers by sketches and/or diagrams wherever possible;
9. In answering these questions, full advantage should be taken wherever possible of your practical experience as well as of the given data; and
10. Answers must be given to an accuracy that is typical of practical conditions.

Question 1

A 12m high rock slope has been excavated at an angle of 60°. There is persistent foliation dipping at 35° into the excavation. A 4.35m deep tension crack has developed 4m behind the crest, and is filled with water to a height of 3m above the sliding surface (Figure 1). The strength parameters of the sliding surface have been determined as:

Cohesion (c) = 25 kPa
Friction (ϕ) = 37°

The unit weight of the rock is 26 kN/m^3, and the unit weight of water is 9.81 kN/m^3.

The formula for FoS for a planar failure is given as:

$$FS = \frac{cA + (W \cos \psi_p - U - V \sin \psi_p) \tan \phi}{W \sin \psi_p + V \cos \psi_p}$$

$$A = (H + b \tan \psi_s - z) \operatorname{cosec} \psi_p$$

$$U = \tfrac{1}{2} \gamma_w z_w (H + b \tan \psi_s - z) \operatorname{cosec} \psi_p$$

$$V = \tfrac{1}{2} \gamma_w z_w^2$$

$$W = \gamma_r \Big[(1 - \cot \psi_f \tan \psi_p) \left(bH + \tfrac{1}{2} H^2 \cot \psi_f \right) + \tfrac{1}{2} b^2 (\tan \psi_s - \tan \psi_p) \Big]$$

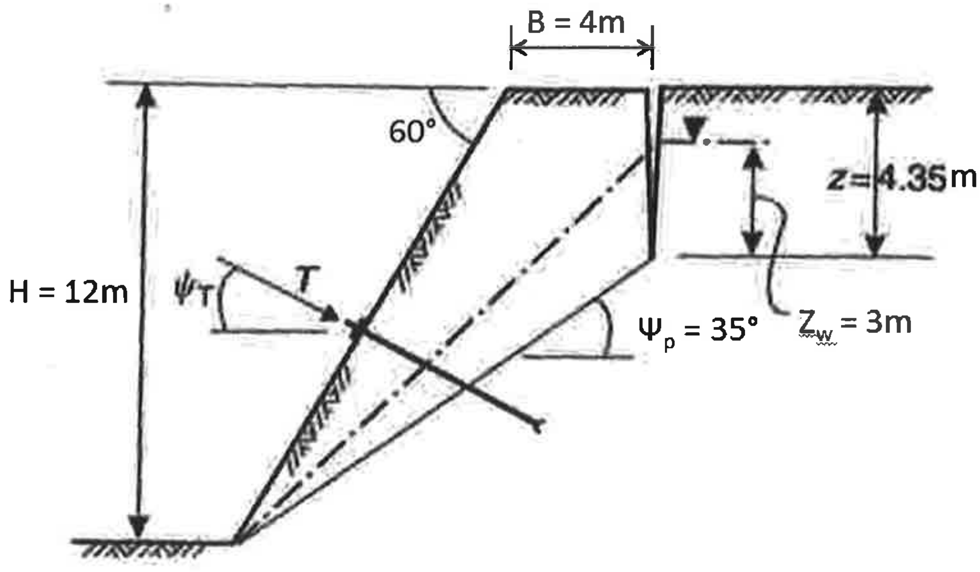

Figure 1: Plane failure geometry

Assuming that a planar failure is the most likely mechanism, and that the sliding block has a weight W of 1241 kN/m and the area A of the sliding plane is 13.34m^2/m, using the formulae provided, analyse the following stability condition:

a.) Calculate and comment on the factor of safety (FoS) for the condition given in Figure 1.

[4]

b.) Determine and comment on the FoS for the tension crack being completely water filled.

[4]

c.) Determine and comment on the FoS for the slope being completely drained.

[4]

d.) Determine and comment on the FoS for cohesion reduced to zero due to nearby blasting activities, assuming that the slope is still completely drained.

[4]

e.) Assuming the total load per linear metre of the slope is 400 kN, calculate the number of rock bolts required per vertical row to achieve a FoS of 1.3 for bolts with a load capacity of 250kN each. Assume that the bolts can be installed perpendicularly to the sliding plane, i.e. Ψ_T = 55°. The formula for FoS of a reinforced slope is given below:

$$FoS = \frac{cA + (W\cos\Psi_p - U - V\sin\Psi_p + T\sin(\Psi_T + \Psi_p))\tan\phi}{W\sin\Psi_p + V\cos\Psi_p - T\cos(\Psi_T + \Psi_p)}$$

Where:

T = anchor tension at an angle Ψ_T below the horizontal.

[4]

(20 marks)

Question 2

An open pit rock slope at your mine dips in a direction of 155°. This slope is due to be excavated in a rock mass that is intersected by two fault planes and a major joint set. The dip and dip direction of these planes are given in the table below.

Plane	Dip	Dip direction	Friction angle
Fault 1	55°	115°	23°
Fault 2	72°	245°	20°
Joint Set 1	50°	270°	25°

Plot the great circles of the planes on the stereonet.

a.) What are the dips and dip directions of the lines of intersection of the planes (stereonets are to be handed in with your exam scripts)?

[4]

b.) What is the maximum dip of the slope face that could be excavated without being affected by the planes?

[4]

c.) If the slope was cut 30° steeper, what planes would define the potentially unstable wedge and what would the dip and dip direction of the failure be?

[6]

d.) Given friction angles of 23° for Fault 1, 20° for Fault 2 and 25° for Joint Set 1, determine the factor of safety (FoS) for the slope and briefly comment on the failure mechanism/s.

[6]

(20 marks)

Question 3

Discuss the effect of the individual components of the geotechnical model on a pit slope design, giving reasons for your assertions.

(20 marks)

Question 4

The slopes at your mine are excavated using Drill & Blast techniques. However, the blasting results in damage to the final walls due to excessive blast energy propagating back into the rockmass. The areas showing most damage have a structural set that dips obliquely towards the pit and strikes at 30° to the pit face in the direction of the blast.

Discuss how you would go about improving these results, with particular attention to:

a.) Explain the mechanisms by which blast damage is caused in the unexcavated rock mass.

[5]

b.) Explain the controlled blasting techniques that you would apply to limit the current damage, and how you would protect the resulting highwall from excessive damage.

[5]

c.) Describe how you would both qualitatively and quantitatively monitor the blast damage in your mine, and how this information can be used to continuously improve your limit blasting programme.

[5]

d.) Explain the effect of the prevailing structural set on the blast induced highwall damage and how you would adjust the blast design to compensate for this.

[5]

(20 marks)

Question 5

a.) Discuss the difference between deterministic and probabilistic design, giving advantages and disadvantages of both methodologies, and the suitability of each to anisotropic design analysis.

[15]

b.) Discuss the application of Hoek-Brown vs. Mohr-Coulomb failure criteria.

[5]

(20 marks)

(Total 100 marks)

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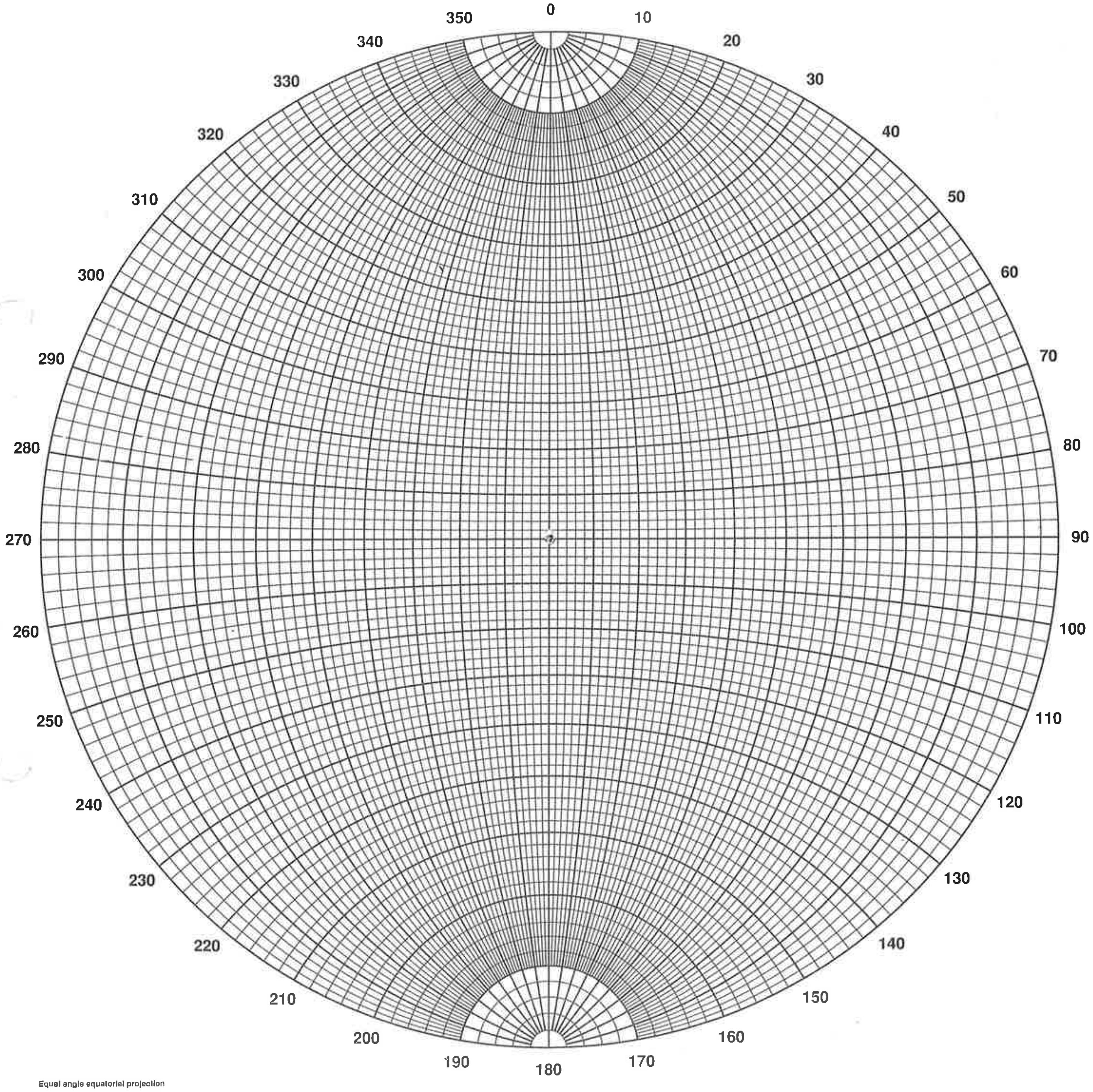
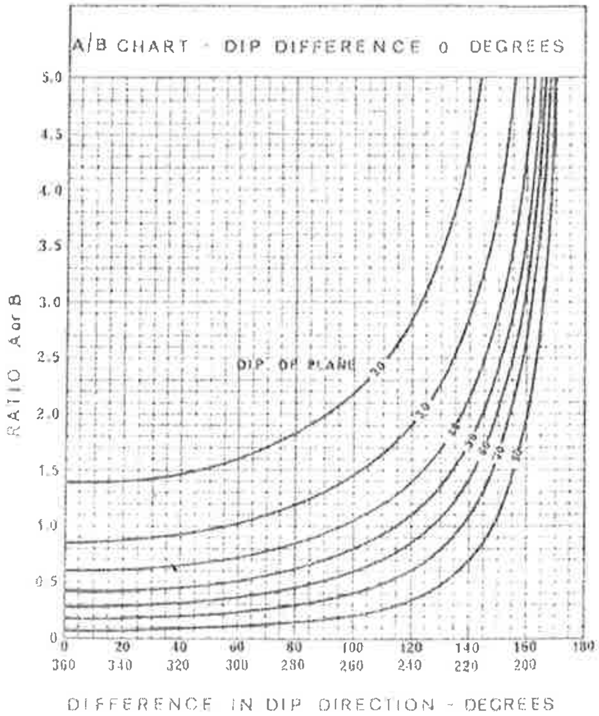
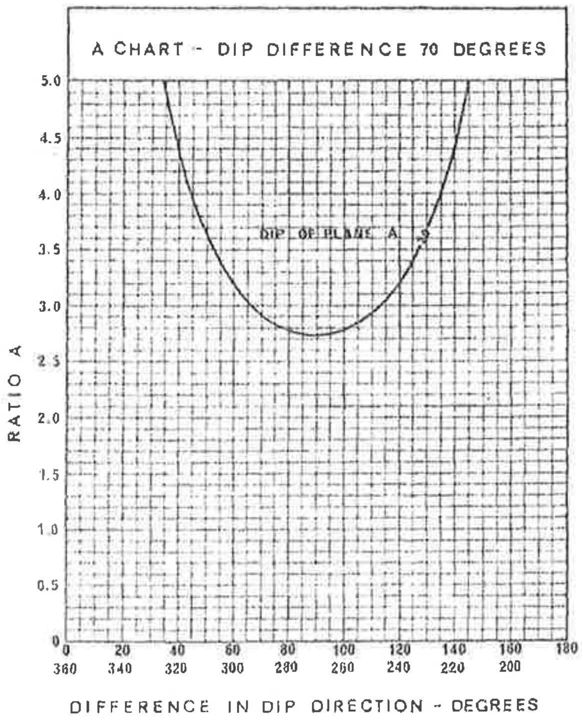
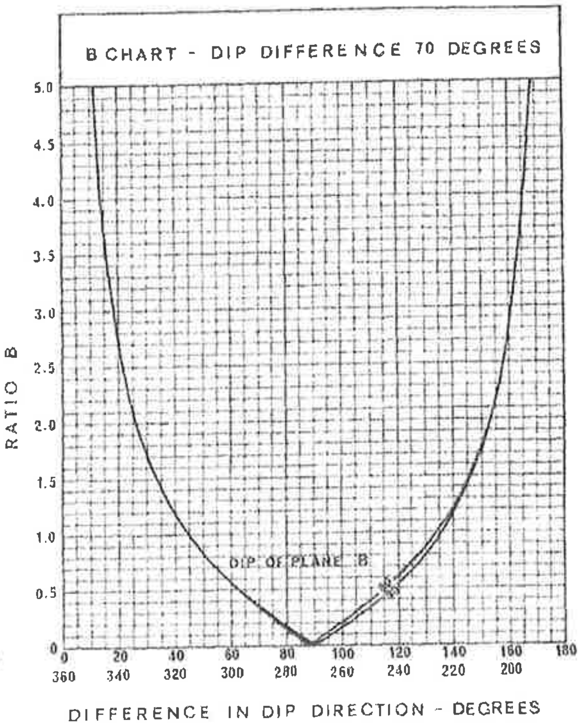


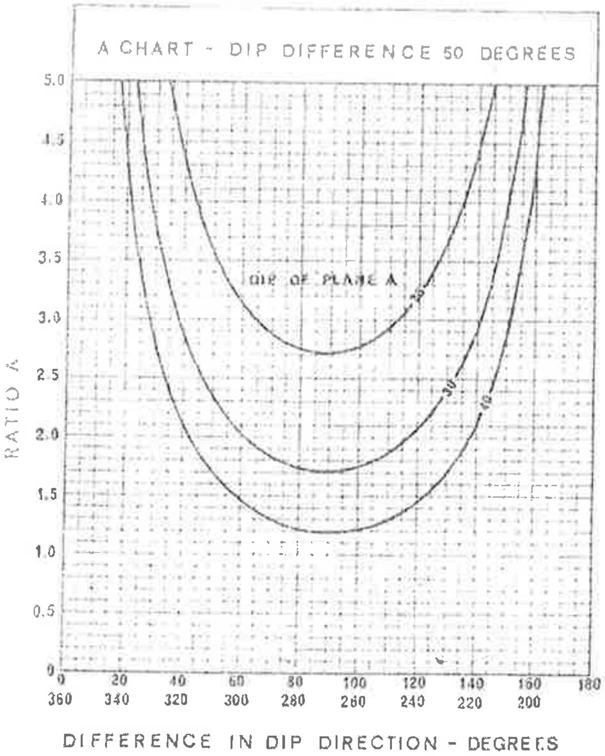
Equal angle equatorial projection
Produced using a PostScript program
developed by Dr J.P. Harrison, Imperial College

WEDGE STABILITY CHARTS





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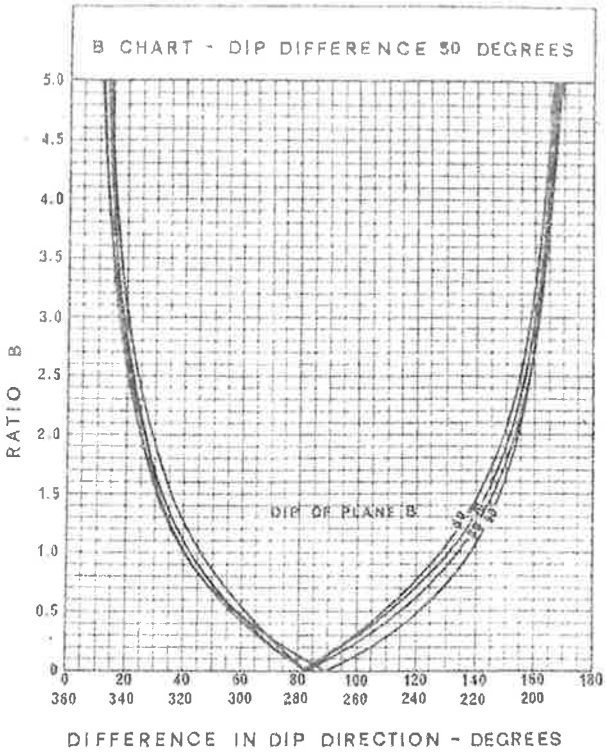
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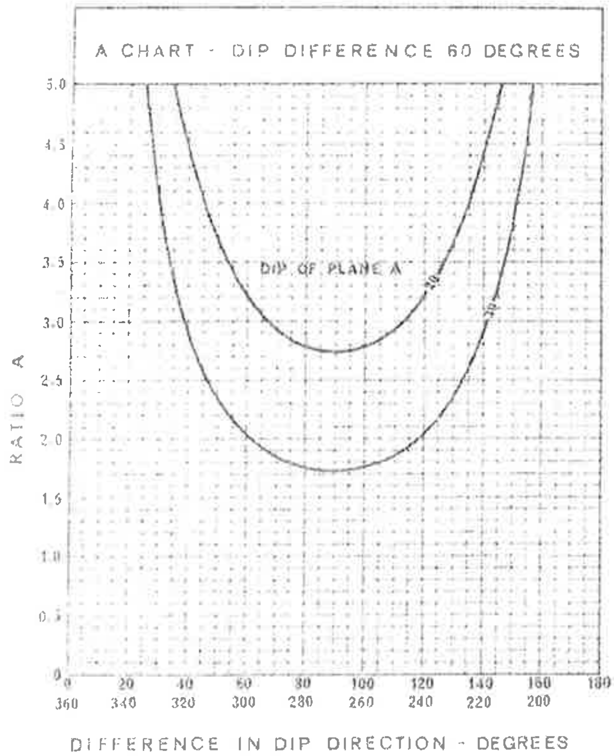
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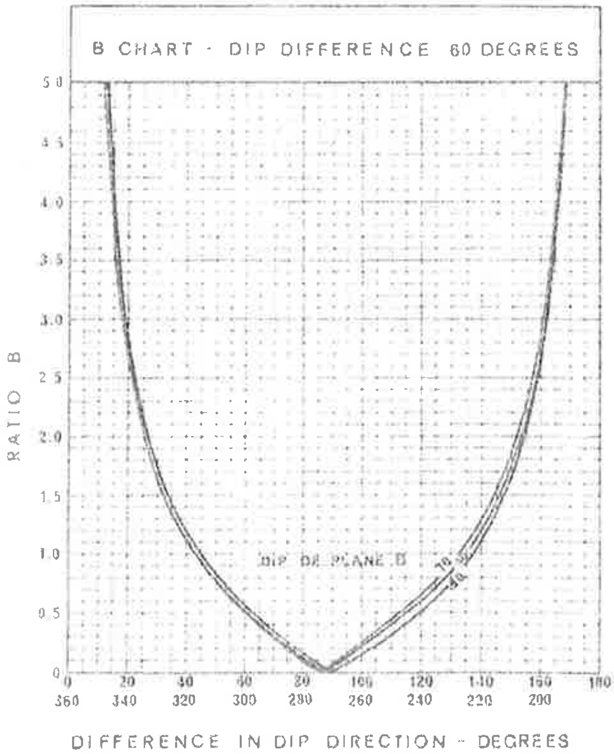
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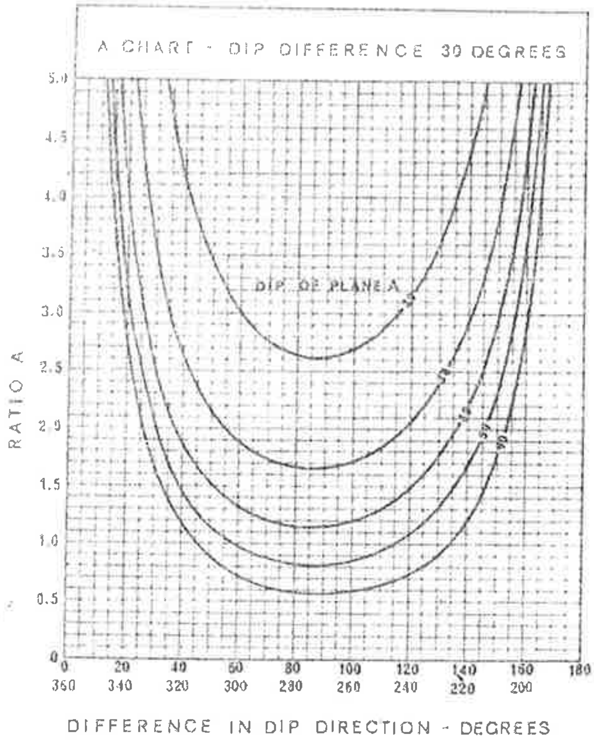
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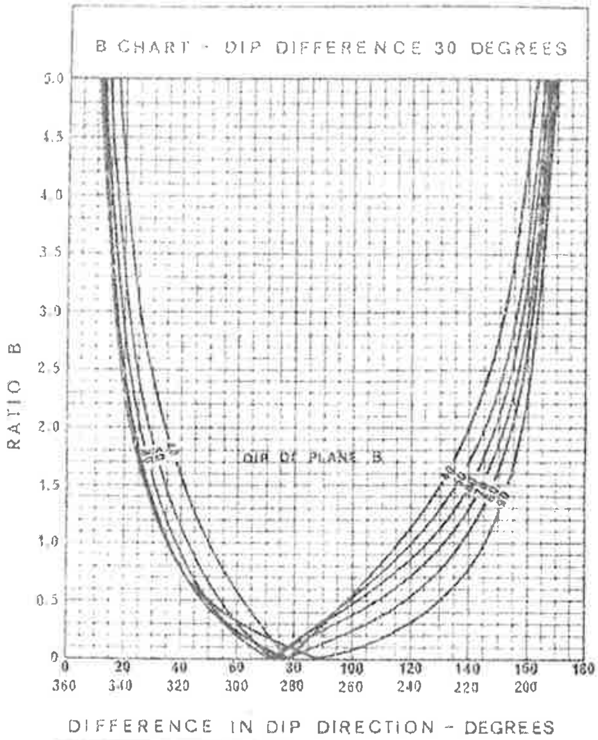
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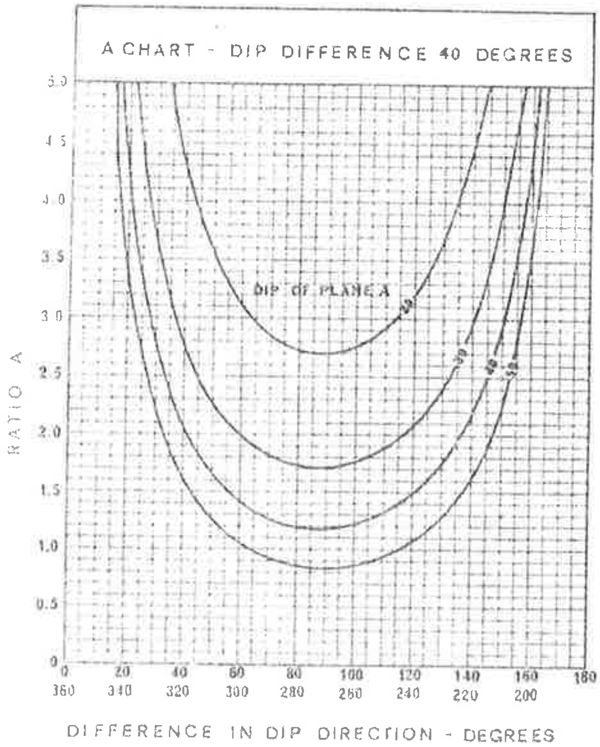
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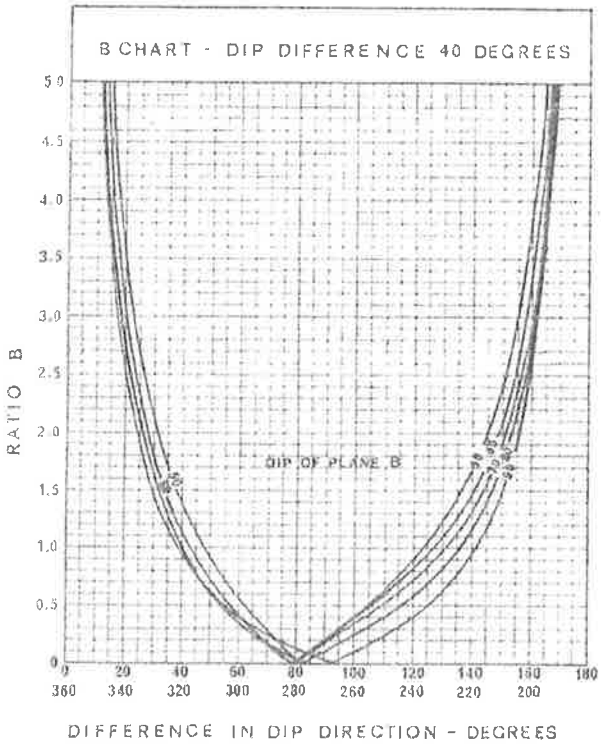
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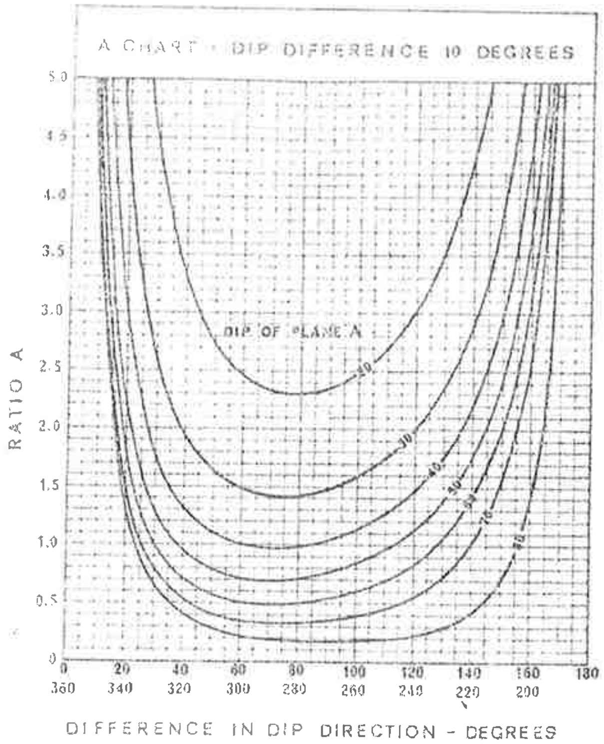
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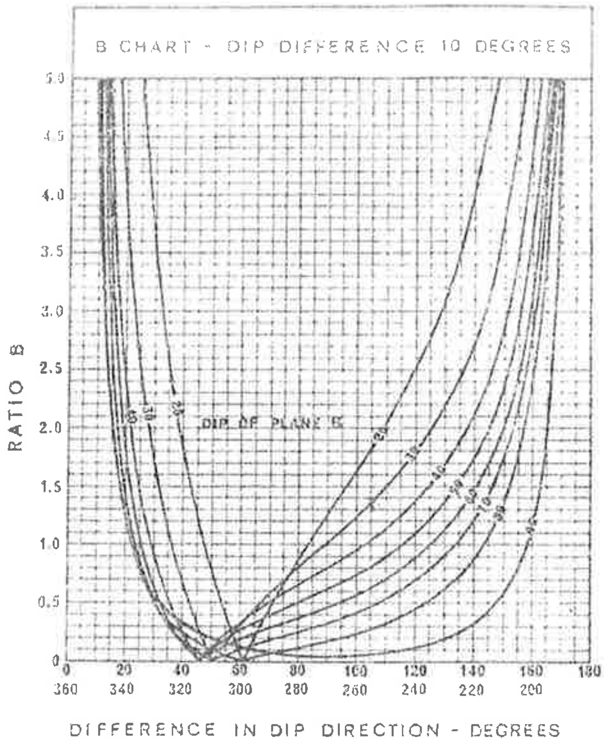
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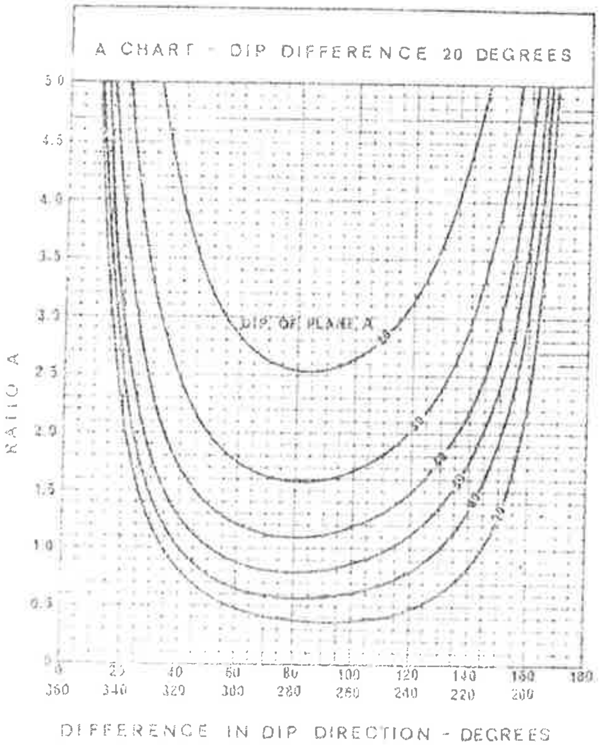
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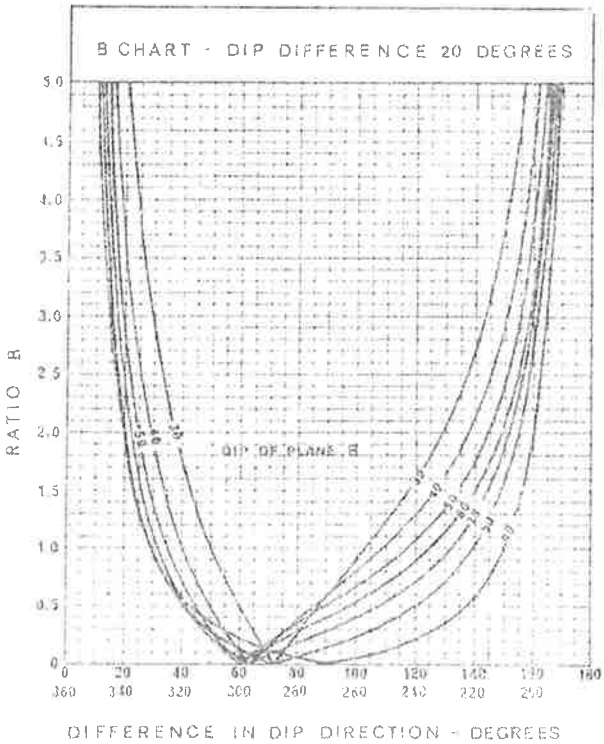
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