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Aug 18/2004

Properties and initial conditions derived from reference material for Yucca Mountain differ from those used in Cases 7.1-7.4. To examine the implications of these differences, a new base case is developed using typical values on page 105. In this case, the joint inclination is set to 14° and initial stresses are set at $\sigma_v = 7$ MPa and $\sigma_H = 1.7$ MPa at the repository horizon, using a gradient of 0.022 MPa/m and a stress ratio of 0.266. For simplicity, an initial temperature of 25°C is assigned to the entire model. Dilation angle on joints is set to ~~zero~~ 15° (RR Aug 18/04) to account for the rough nature of joints; cases are also run with 0° dilation.

The history points in this case are modified from those in previous cases to provide coverage at critical zones identified in the earlier runs.

The input file for UDEC (R Aug 18/04) base case 7.5 is attached to pages 108 and 109. The original plan was to run this simulation to 100 years thermal time, but the low source term (58 W/m³) produced only slight temperature elevation that reached the model boundaries within about 30 years thermal time. Analysis beyond 30 years was therefore considered biased by the model boundaries, and was discontinued. A standard suite of plots was defined in the input file (INCLINED3.TXT). Select plots are contained in the WORD document Case 75 Plots.doc for ease of plotting. (Microsoft® Word 2002 (10.6612.6626) SP3)

Plots from previous cases are contained in Case 71 Plots.doc, Case 72 plots.doc, Case 73 plots.doc, Case 74 plots.doc and Case 74 extra plots.doc.

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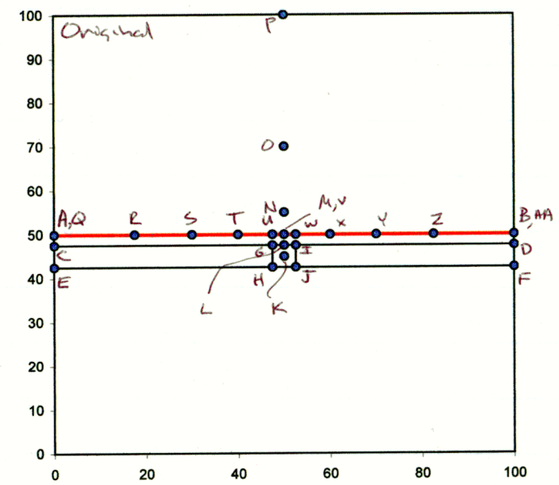
Rotation of Coordinate System

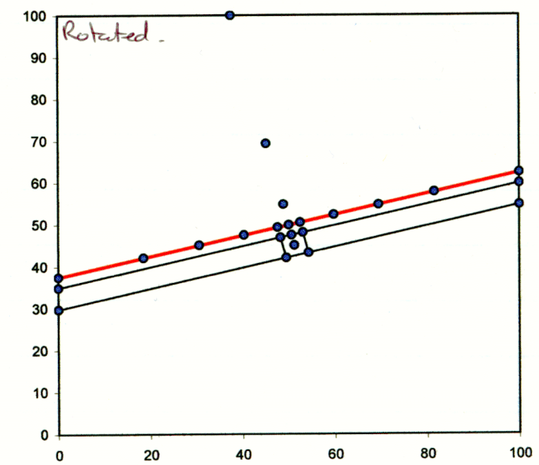
	Original			Rotated	
Point	x	y		x*	y*
A	0.000	50.000		0.000	37.534
B	100.000	50.000		100.000	62.466
C	0.000	47.500		0.000	34.957
D	100.000	47.500		100.000	59.890
E	0.000	42.500		0.000	29.804
F	100.000	42.500		100.000	54.737
G	47.500	47.500		48.179	46.969
H	47.500	42.500		49.389	42.118
I	52.500	47.500		53.031	48.179
J	52.500	42.500		54.240	43.328
K	50.000	45.000		51.210	45.149
L	50.000	47.500		50.605	47.574
M	50.000	50.000		50.000	50.000
N	50.000	55.000		48.790	54.851
O	50.000	70.000		45.162	69.406
P	50.000	100.000		37.534	100.000
Q	0.000	50.000		0.000	37.534
R	17.500	50.000		18.465	42.138
S	30.000	50.000		30.594	45.162
T	40.000	50.000		40.297	47.581
U	47.500	50.000		47.574	49.395
V	50.000	50.000		50.000	50.000
W	52.500	50.000		52.426	50.605
X	60.000	50.000		59.703	52.419
Y	70.000	50.000		69.406	54.838
Z	82.500	50.000		81.535	57.862
AA	100.000	50.000		100.000	62.466

Line	x	y		x*	y*
A-B	0.000	50.000		0.000	37.534
	100.000	50.000		100.000	62.466
C-D	0.000	47.500		0.000	34.957
	100.000	47.500		100.000	59.890
E-F	0.000	42.500		0.000	29.804
	100.000	42.500		100.000	54.737
G-H	47.500	47.500		48.179	46.969
	47.500	42.500		49.389	42.118
I-J	52.500	47.500		53.031	48.179
	52.500	42.500		54.240	43.328

Rotation angle (°) 14.0

RR Aug 18/04





Rotated coordinates calculated using the following formulae

$$\left.\begin{aligned} x^* &= x'\cos\theta - y'\sin\theta \\ y^* &= x'\sin\theta + y'\cos\theta \end{aligned}\right\} \text{ rotation centered on } x = 50,\ y = 50$$

using Microsoft EXCEL® 2002 (10.6501.6626) SP3 File: ROTATE.XLS

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```
; Case 7.5 Base case with inclined transgressing joint in a
heated
; infinite rock mass (no slip allowed on joint, typical Yucca
Mountain
; properties and conditions used).
;
config thermal
set mech on
;
; Key Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
; Geometry
;
rou 0.001
bl 0,0 0,100 100,100 100,0
crack 0.000 37.534 100.000 62.466 ; Main joint A-B
crack 0.000 34.957 100.000 59.890 ; Top C-D
crack 0.000 29.804 100.000 54.737 ; Bottom E-F
crack 48.179 46.969 49.389 42.118 ; Left side G-H
crack 53.031 48.179 54.240 43.328 ; Right side I-J
;
;
gen quad 2.0
;
; Material properties
;
prop m=1 de=2210.0 k=19.2e9 g=13.6e9
prop jm=1 jkn=5.0e11 jks=5.0e11
prop jm=1 jcoh=1.0e20 jfric=0.0 jten=1.0e20 jd=0
prop m=1 thexp=10.0e-6 cond=2.13 spec=990.0
prop jm=2 jkn=5.0e4 jks=5.0e4
prop jm=2 jcoh=100.0e3 jfric=41.0 jten=40.0e3 jd=15
;change jmat=2 range block 358 143
;change jmat=2 range block 143 358
;
; Initial conditions
;
initemp 25.0 0 100 0 100
ini syy -8.1e6 grad 0 0.022e6
ini sxx -2.1546e6 grad 0 0.005852e6
ini sxy 0.0
ini szz -2.1546e6 grad 0 0.005852e6
;
; Boundary conditions
;
bound yvel 0.0 range (0,100) (-0.1, 0.1)
bound yvel 0.0 range (0,100) (99.1, 100.1)
bound xvel 0.0 range (-0.1, 0.1) (0,100)
bound xvel 0.0 range (99.1, 100.1) (0,100)
;
; Apply heat source
;
thapp source 58 0 range 49.389 53.031 43.328 46.969
;
; Equilibrate model
;
step 4000
ini xd 0
ini yd 0
ini nd 0
ini sd 0
ini xv 0
ini yv 0
ini bxv 0
ini byv 0
ini brv 0
;
; Thermal histories
;
thist temp 51.210, 45.149  ; 1
thist temp 50.605, 47.574  ; 2
thist temp 50.000, 50.000  ; 3
thist temp 48.790, 54.851  ; 4
thist temp 45.162, 69.406  ; 5
thist temp 37.534, 100.000 ; 6
;
; Time and unbalanced force histories
;
hist thtime ; 1
hist unbal ; 2
;
; Histories of normal displacement along joint
;
hist ndis 0.000  37.534 ;3
hist ndis 18.465 42.138 ;4
hist ndis 30.594 45.162 ;5
hist ndis 40.297 47.581 ;6
hist ndis 47.574 49.395 ;7
hist ndis 50.000 50.000 ;8
hist ndis 52.426 50.605 ;9
hist ndis 59.703 52.419 ;10
hist ndis 69.406 54.838 ;11
hist ndis 81.535 57.862 ;12
hist ndis 100.000 62.466 ;13
;
; Histories of shear displacement along joint
;
hist sdis 0.000  37.534 ;14
hist sdis 18.465 42.138 ;15
hist sdis 30.594 45.162 ;16
hist sdis 40.297 47.581 ;17
hist sdis 47.574 49.395 ;18
hist sdis 50.000 50.000 ;19
hist sdis 52.426 50.605 ;20
hist sdis 59.703 52.419 ;21
hist sdis 69.406 54.838 ;22
hist sdis 81.535 57.862 ;23
hist sdis 100.000 62.466 ;24
;
; Histories of sratio along joint
;
hist srat 0.000  37.534 ;25
hist srat 18.465 42.138 ;26
hist srat 30.594 45.162 ;27
hist srat 40.297 47.581 ;28
hist srat 47.574 49.395 ;29
hist srat 50.000 50.000 ;30
hist srat 52.426 50.605 ;31
hist srat 59.703 52.419 ;32
hist srat 69.406 54.838 ;33
hist srat 81.535 57.862 ;34
hist srat 100.000 62.466 ;35
;
; Plot lines
;
set pline 0.000 37.534 100.000 62.466 100 ; 1
;
; Thermal mechanical analysis
;
damp auto
run age 50000
step 2000
set nther 2500
set nmech 2000
run age 315400000 temp 50 s 1000000
sav 7i5y10.sav
run age 630720000 temp 50 s 1000000
sav 7i5y20.sav
run age 946080000 temp 50 s 1000000
sav 7i5y30.sav
;run age 1261440000 temp 50 s 1000000
;sav 7i5y40.sav
;run age 1576899000 temp 50 s 1000000
;sav 7i5y50.sav
;run age 1892160000 temp 50 s 1000000
;sav 7i5y60.sav
;run age 2207520000 temp 50 s 1000000
;sav 7i5y70.sav
;run age 2522880000 temp 50 s 1000000
;sav 7i5y80.sav
;run age 2838240000 temp 50 s 1000000
;sav 7i5y90.sav
;run age 3153600000 temp 50 s 1000000
;sav 7i5y100.sav
step 2500
;
save 7i5final.sav
;
set plot emf color
title
Case 7.5  Thermally-Induced Joint Displacement (Inclined, No
Slip Allowed)
```

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File INCLINED3.TXT (UDEC Input, 1 of 2)

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```
;
; Geometry
;
set out 7i5grid.emf
set color iw
plo zone green blo iw
copy

; Joint condition plots
;
set out 7i5jndl.emf
set color iw
plot joint 0 25 100 75 ndisp 5
copy
;
set out 7i5jnsl.emf
set color iw
plot joint 0 25 100 75 nstr 5
copy
;
set out 7i5jsdl.emf
set color iw
plot joint 0 25 100 75 sdisp 5
copy
;
set out 7i5jssl.emf
set color iw
plot joint 0 25 100 75 sstr 5
copy
;
set out 7i5shear.emf
set color iw
plo blo iw shear red
copy
;
set out 7i5slip.emf
set color iw
plo blo iw slip red
copy
;
; Contour plots
;
set out 7i5tempc.emf
set color iw
plot temp fill int 50 temp int 50 iw blo iw
copy
;
set out 7i5dispc.emf
set color iw
plot disp green blo iw
copy
;
set out 7i5xdc.emf
set color iw
plot xd fill xd iw blo iw
copy
;
set out 7i5ydc.emf
set color iw
plot yd fill yd iw blo iw
copy
;
set out 7i5sig1c.emf
set color iw
plot sig1 int 1e7 fill sig1 int 1e7 iw blo iw
copy
;
set out 7i5sig2c.emf
set color iw
plot sig2 int 1e7 fill sig2 int 1e7 iw blo iw
copy
;
set out 7i5sdifc.emf
set color iw
plot sdiff int 1e7 fill sdiff int 1e7 iw blo iw
copy
;
set out 7i5sevol.emf
set color iw
plot evol fill evol iw blo iw
copy
;
; History plots
;
set out 7i5thisth.emf
set color iw
plo thist 1 2 3 4 5 6
copy
;
set out 7i5unbalh.emf
set color iw
plo hist 2
copy
;
set out 7i5jndhs.emf
set color iw
plo hist 3 4 5 6 7 8 9 10 11 12 13
copy
;
set out 7i5jndht.emf
set color iw
plo hist 3 4 5 6 7 8 9 10 11 12 13 vs 1
copy
;
set out 7i5jsdhs.emf
set color iw
plo hist 14 15 16 17 18 19 20 21 22 23 24
copy
;
set out 7i5jsdht.emf
set color iw
plo hist 14 15 16 17 18 19 20 21 22 23 24 vs 1
copy
;
set out 7i5jsrhs.emf
set color iw
plo hist 25 26 27 28 29 30 31 32 33 34 35
copy
;
set out 7i5jsrht.emf
set color iw
plo hist 25 26 27 28 29 30 31 32 33 34 35 vs 1
copy
;
; Plot lines
;
set out 7i5pl1ss.emf
set color iw
plo pline 1 ss
copy
;
set out 7i5pl1ns.emf
set color iw
plo pline 1 nstr
copy
;
set out 7i5pl1d.emf
set color iw
plo pline 1 disp
copy
;
ret
```

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File INCLINED3.TXT (UDEC Input, 2 of 2).

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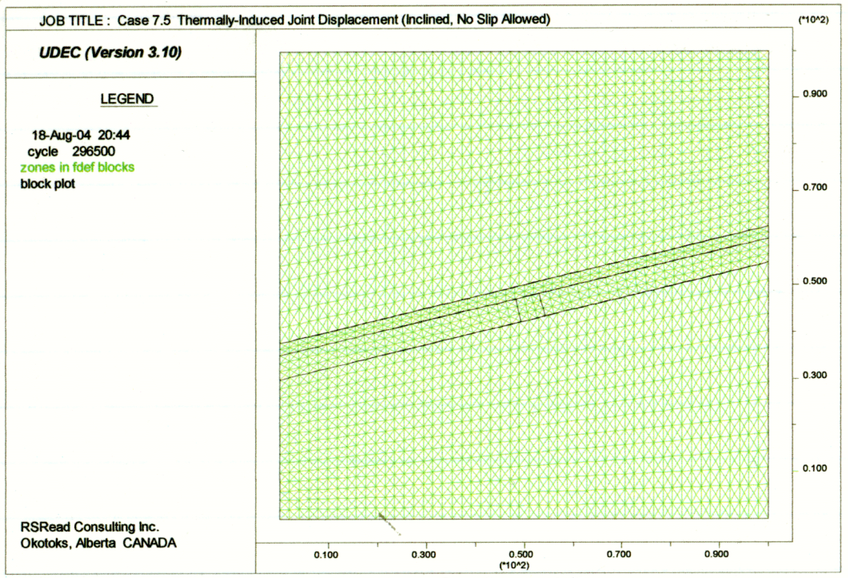

File 7.5grid.emf Grid for Case 7.5

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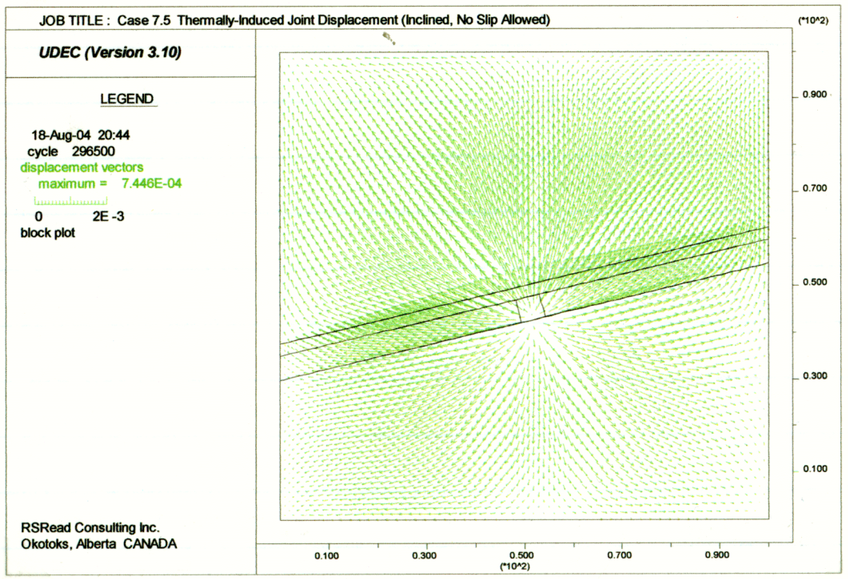

File 7.5dispc.emf Displacement vectors Case 7.5

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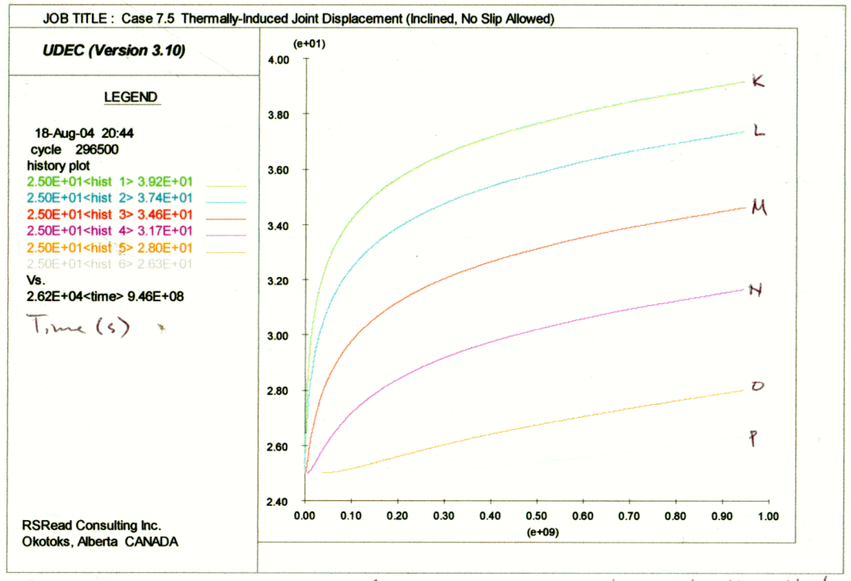

File 7.5thisth.emf Thermal histories at points K, L, M, N, O, P

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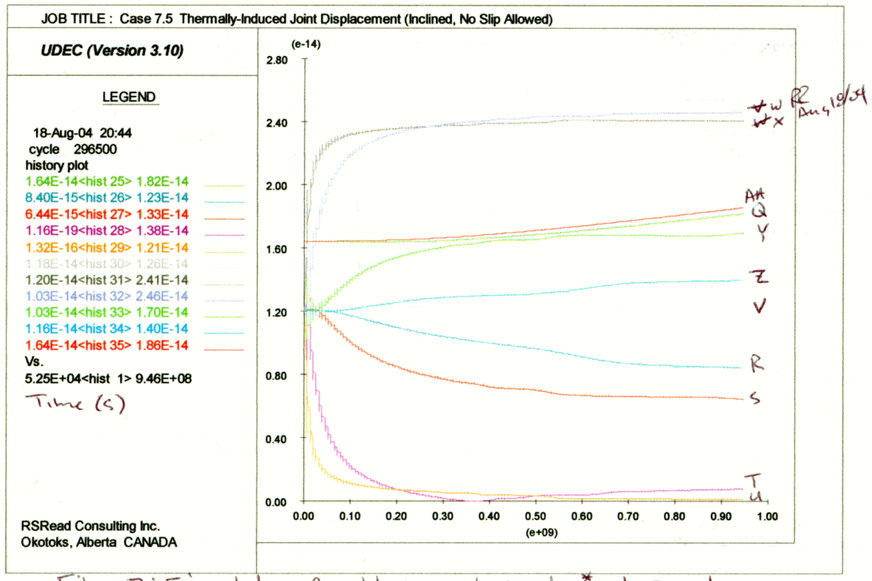

RR Aug 18/04

File 7.5jsrht.emf History of sratio* at points Q, R, S, T, U, V, W, X, Y, Z, AA

Sratio = $\frac{\text{stress}}{\text{strength}}$

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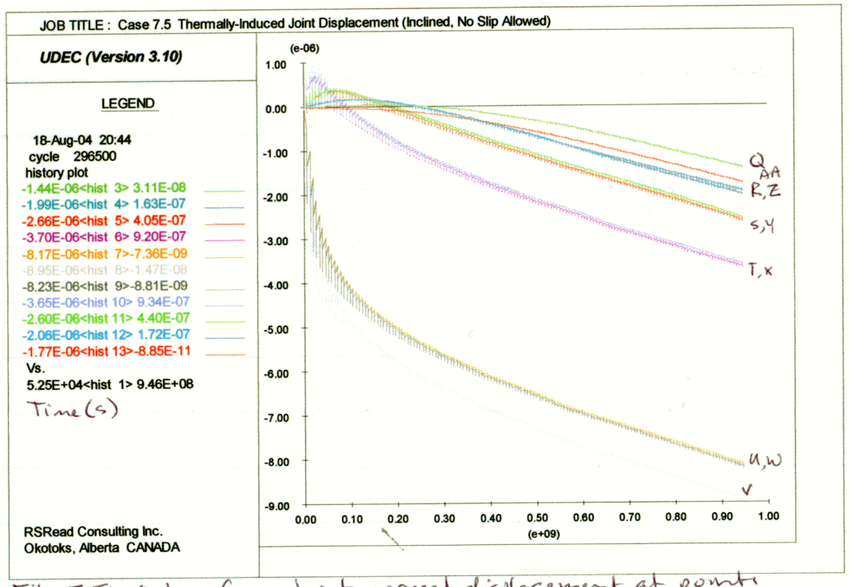
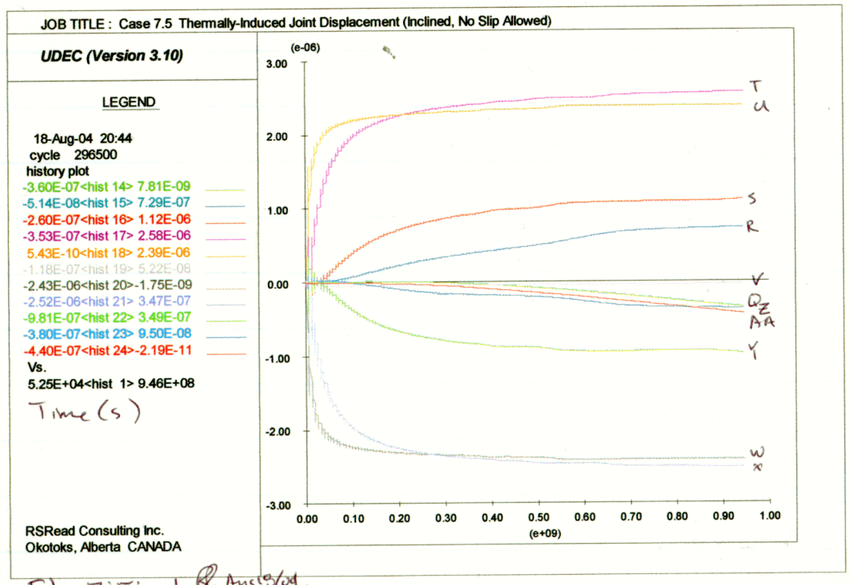


File 7.5jndht.emf Joint normal displacement at points Q,R,S,T,U,V,W,X,Y,Z,AA

R Aug 18/04



~~File 7.5jsdt~~ R Aug 18/04

File 7.5jsdht.emf Joint shear displacement at points Q,R,S,T,U,V,W,X,Y,Z,AA

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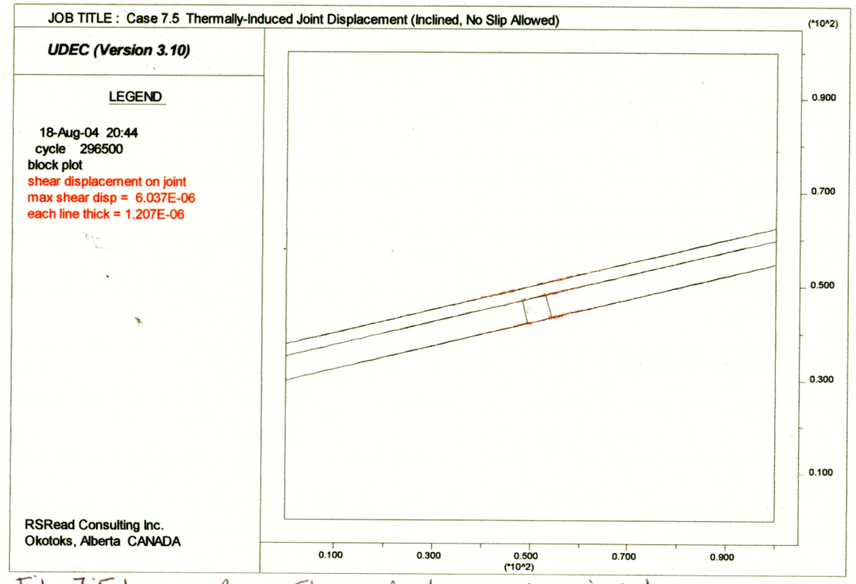
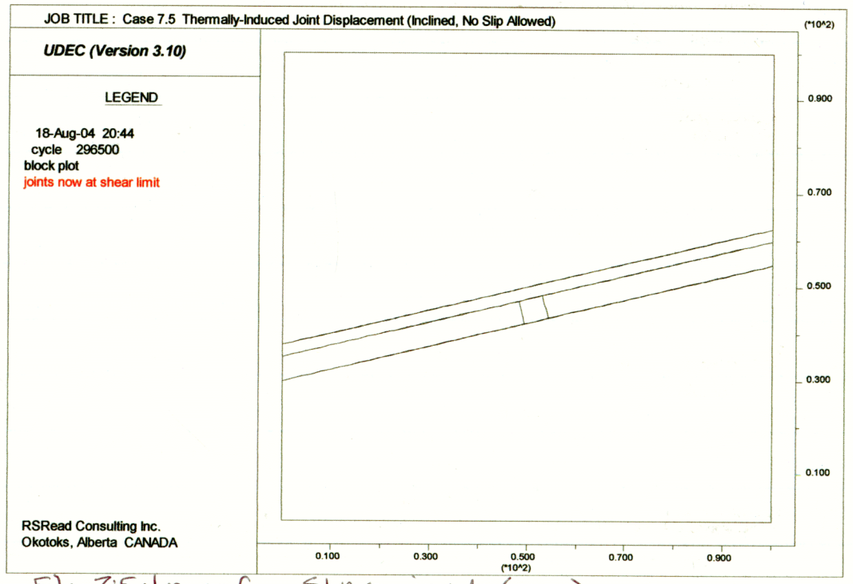


File 7.5shear.emf Shear displacement on joint

Aug 18/04 R



File 7.5slip.emf Slip on joint (none)

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Case 7.5 Summary of Results.

Case 7.5 demonstrates a maximum temperature increase of about 15°C at the heat source. This temperature increase results in small normal and shear displacements at points along the glued joint. The maximum shear displacement is $6.037e^{-6}$ m, and the maximum normal displacement is $-9.0e^{-6}$ m (closure). The maximum displacement vector in the model is $7.446e^{-4}$ m. No slip occurs along joints. Each of these plots on pages 110 - 113 represent conditions after 30 years of heating. Note that a dilation angle value of 15° was used in this case, but not activated.

The patterns of displacement in the vertical and horizontal direction (page 115) show that the presence of the joint does not affect the displacement patterns. Aug 18/2004

Case 7.6 - Base Case with Inclined Transgressing joint in a heated infinite rock mass (slip allowed on joint, typical Yucca Mountain properties and conditions used)

UDEC base case

Case 7.6 is identical to Case 7.5, except the joint properties are changed to reflect a compliant crack with high friction angle (41°) but relatively low cohesion (100 kPa) and tensile strength (40 kPa). The model is run to 30 years in thermal time. The input file for UDEC (INCLINED3B.TXT) is attached to page 116-117 and representative plots follow on pages 118-122.

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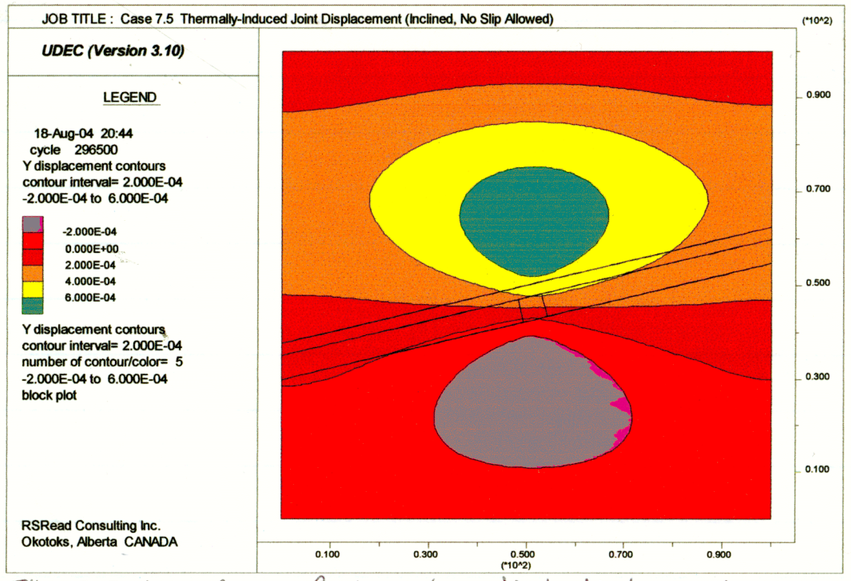

File 7.5ydc.emf Contours of vertical displacement

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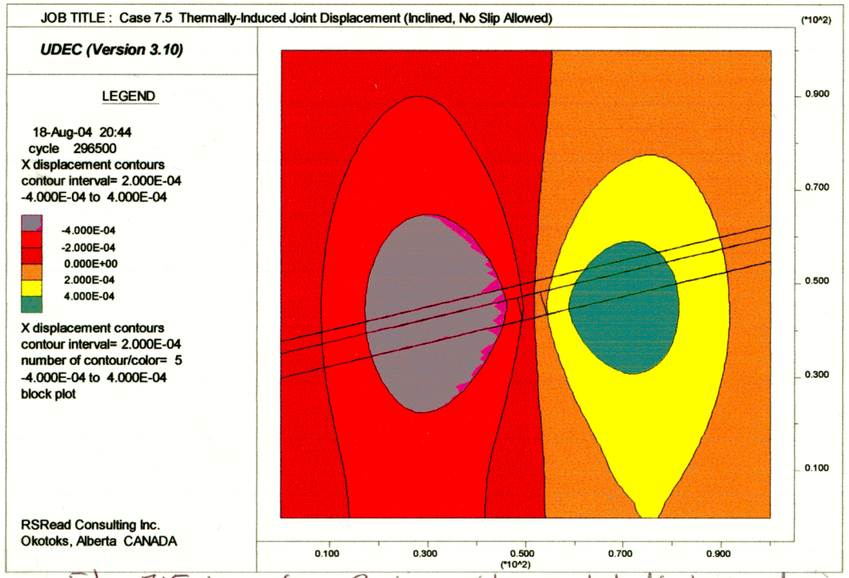

File 7.5xdc.emf Contours of horizontal displacement

```
; Case 7.6 Base case with inclined transgressing joint in a
heated
; infinite rock mass (slip allowed on joint, typical Yucca
Mountain
; properties and conditions used).
;
config thermal
set mech on
;
; Key Points
;
;A, 0.000, 37.534
;B, 100.000, 62.466
;C, 0.000, 34.957
;D, 100.000, 59.890
;E, 0.000, 29.804
;F, 100.000, 54.737
;G, 48.179, 46.969
;H, 49.389, 42.118
;I, 53.031, 48.179
;J, 54.240, 43.328
;K, 51.210, 45.149
;L, 50.605, 47.574
;M, 50.000, 50.000
;N, 48.790, 54.851
;O, 45.162, 69.406
;P, 37.534, 100.000
;Q, 0.000, 37.534
;R, 18.465, 42.138
;S, 30.594, 45.162
;T, 40.297, 47.581
;U, 47.574, 49.395
;V, 50.000, 50.000
;W, 52.426, 50.605
;X, 59.703, 52.419
;Y, 69.406, 54.838
;Z, 81.535, 57.862
;AA, 100.000, 62.466
;
; Geometry
;
rou 0.001
bl 0,0 0,100 100,100 100,0
crack 0.000 37.534 100.000 62.466 ; Main joint A-B
crack 0.000 34.957 100.000 59.890 ; Top C-D
crack 0.000 29.804 100.000 54.737 ; Bottom E-F
crack 48.179 46.969 49.389 42.118 ; Left side G-H
crack 53.031 48.179 54.240 43.328 ; Right side I-J
;
gen quad 2.0
;
; Material properties
;
prop m=1 de=2210.0 k=19.2e9 g=13.6e9
prop jm=1 jkn=5.0e11 jks=5.0e11
prop jm=1 jcoh=1.0e20 jfric=0.0 jten=1.0e20 jd=0
prop m=1 thexp=10.0e-6 cond=2.13 spec=990.0
prop jm=2 jkn=5.0e4 jks=5.0e4
prop jm=2 jcoh=100.0e3 jfric=41.0 jten=40.0e3 jd=0
;
; Initial conditions
;
initemp 25.0 0 100 0 100
ini syy -8.1e6 grad 0 0.022e6
ini sxx -2.1546e6 grad 0 0.005852e6
ini sxy 0.0
ini szz -2.1546e6 grad 0 0.005852e6
;
; Boundary conditions
;
bound yvel 0.0 range (0,100) (-0.1, 0.1)
bound yvel 0.0 range (0,100) (99.1, 100.1)
bound xvel 0.0 range (-0.1, 0.1) (0,100)
bound xvel 0.0 range (99.1, 100.1) (0,100)
;
; Apply heat source
;
thapp source 58 0 range 49.389 53.031 43.328 46.969
;
; Equilibrate model
;
set ovtol 0.1
step 4000
change jmat=2 range block 358 143
change jmat=2 range block 143 358
ini xd 0
ini yd 0
ini nd 0
ini sd 0
ini xv 0
ini yv 0
ini bxv 0
ini byv 0
ini brv 0
;
; Thermal histories
;
thist temp 51.210, 45.149  ; 1
thist temp 50.605, 47.574  ; 2
thist temp 50.000, 50.000  ; 3
thist temp 48.790, 54.851  ; 4
thist temp 45.162, 69.406  ; 5
thist temp 37.534, 100.000 ; 6
;
; Time and unbalanced force histories
;
hist thtime ; 1
hist unbal ; 2
;
; Histories of normal displacement along joint
;
hist ndis 0.000  37.534 ;3
hist ndis 18.465 42.138 ;4
hist ndis 30.594 45.162 ;5
hist ndis 40.297 47.581 ;6
hist ndis 47.574 49.395 ;7
hist ndis 50.000 50.000 ;8
hist ndis 52.426 50.605 ;9
hist ndis 59.703 52.419 ;10
hist ndis 69.406 54.838 ;11
hist ndis 81.535 57.862 ;12
hist ndis 100.000 62.466 ;13
;
; Histories of shear displacement along joint
;
hist sdis 0.000  37.534 ;14
hist sdis 18.465 42.138 ;15
hist sdis 30.594 45.162 ;16
hist sdis 40.297 47.581 ;17
hist sdis 47.574 49.395 ;18
hist sdis 50.000 50.000 ;19
hist sdis 52.426 50.605 ;20
hist sdis 59.703 52.419 ;21
hist sdis 69.406 54.838 ;22
hist sdis 81.535 57.862 ;23
hist sdis 100.000 62.466 ;24
;
; Histories of sratio along joint
;
hist srat 0.000  37.534 ;25
hist srat 18.465 42.138 ;26
hist srat 30.594 45.162 ;27
hist srat 40.297 47.581 ;28
hist srat 47.574 49.395 ;29
hist srat 50.000 50.000 ;30
hist srat 52.426 50.605 ;31
hist srat 59.703 52.419 ;32
hist srat 69.406 54.838 ;33
hist srat 81.535 57.862 ;34
hist srat 100.000 62.466 ;35
;
; Plot lines
;
set pline 0.000 37.534 100.000 62.466 100 ; 1
;
; Thermal mechanical analysis
;
damp auto
run age 50000
step 2000
set nther 2500
set nmech 2000
run age 315400000 temp 50 s 1000000
sav 7i6y10.sav
run age 630720000 temp 50 s 1000000
sav 7i6y20.sav
run age 946080000 temp 50 s 1000000
sav 7i6y30.sav
;run age 1261440000 temp 50 s 1000000
;sav 7i6y40.sav
;run age 1576899000 temp 50 s 1000000
;sav 7i6y50.sav
;run age 1892160000 temp 50 s 1000000
;sav 7i6y60.sav
;run age 2207520000 temp 50 s 1000000
;sav 7i6y70.sav
;run age 2522880000 temp 50 s 1000000
;sav 7i6y80.sav
;run age 2838240000 temp 50 s 1000000
;sav 7i6y90.sav
;run age 3153600000 temp 50 s 1000000
;sav 7i6y100.sav
step 2500
;
save 7i6final.sav
;
set plot emf color
title
```

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UDEC input file INCLINED3B.TXT (pg 1 of 2)


```
Case 7.6  Thermally-Induced Joint Displacement (Inclined,
Slip Allowed)
;
; Geometry
;
set out 7i6grid.emf
set color iw
plo zone green blo iw
copy

; Joint condition plots
;
set out 7i6jndl.emf
set color iw
plot joint 0 25 100 75 ndisp 5
copy
;
set out 7i6jnsl.emf
set color iw
plot joint 0 25 100 75 nstr 5
copy
;
set out 7i6jsdl.emf
set color iw
plot joint 0 25 100 75 sdisp 5
copy
;
set out 7i6jssl.emf
set color iw
plot joint 0 25 100 75 sstr 5
copy
;
set out 7i6shear.emf
set color iw
plo blo iw shear red
copy
;
set out 7i6slip.emf
set color iw
plo blo iw slip red
copy
;
; Contour plots
;
set out 7i6tempc.emf
set color iw
plot temp fill int 50 temp int 50 iw blo iw
copy
;
set out 7i6dispc.emf
set color iw
plot disp green blo iw
copy
;
set out 7i6xdc.emf
set color iw
plot xd fill xd iw blo iw
copy
;
set out 7i6ydc.emf
set color iw
plot yd fill yd iw blo iw
copy
;
set out 7i6sig1c.emf
set color iw
plot sig1 int 1e7 fill sig1 int 1e7 iw blo iw
copy
;
set out 7i6sig2c.emf
set color iw
plot sig2 int 1e7 fill sig2 int 1e7 iw blo iw
copy
;
set out 7i6sdifc.emf
set color iw
plot sdiff int 1e7 fill sdiff int 1e7 iw blo iw
copy
;
set out 7i6sevol.emf
set color iw
plot evol fill evol iw blo iw
copy
;
; History plots
;
set out 7i6thisth.emf
set color iw
plo thist 1 2 3 4 5 6
copy
;
set out 7i6unbalh.emf
set color iw
plo hist 2
copy
;
set out 7i6jndhs.emf
set color iw
plo hist 3 4 5 6 7 8 9 10 11 12 13
copy
;
set out 7i6jndht.emf
set color iw
plo hist 3 4 5 6 7 8 9 10 11 12 13 vs 1
copy
;
set out 7i6jsdhs.emf
set color iw
plo hist 14 15 16 17 18 19 20 21 22 23 24
copy
;
set out 7i6jsdht.emf
set color iw
plo hist 14 15 16 17 18 19 20 21 22 23 24 vs 1
copy
;
set out 7i6jsrhs.emf
set color iw
plo hist 25 26 27 28 29 30 31 32 33 34 35
copy
;
set out 7i6jsrht.emf
set color iw
plo hist 25 26 27 28 29 30 31 32 33 34 35 vs 1
copy
;
; Plot lines
;
set out 7i6pllss.emf
set color iw
plo pline 1 ss
copy
;
set out 7i6pllns.emf
set color iw
plo pline 1 nstr
copy
;
set out 7i6plld.emf
set color iw
plo pline 1 disp
copy
;
ret
```

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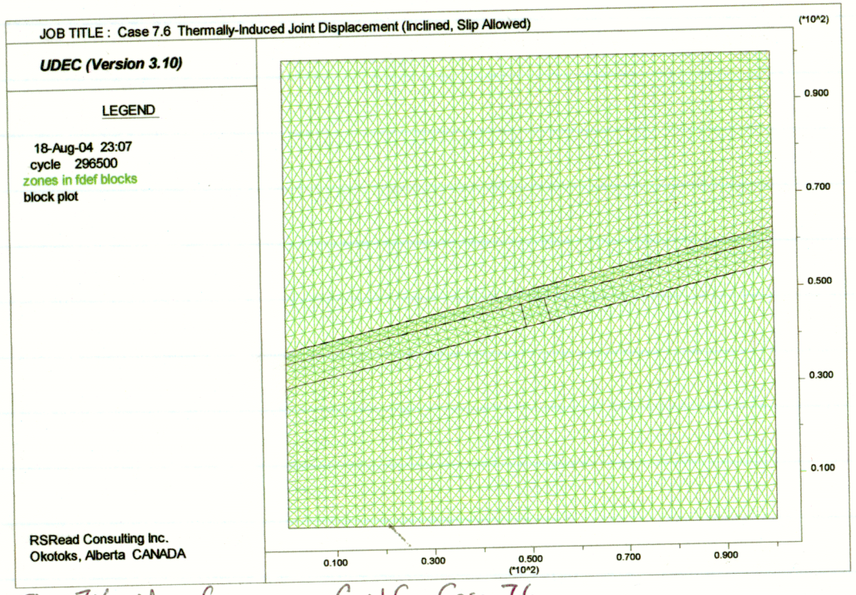

File 7.6grid.emf Grid for Case 7.6

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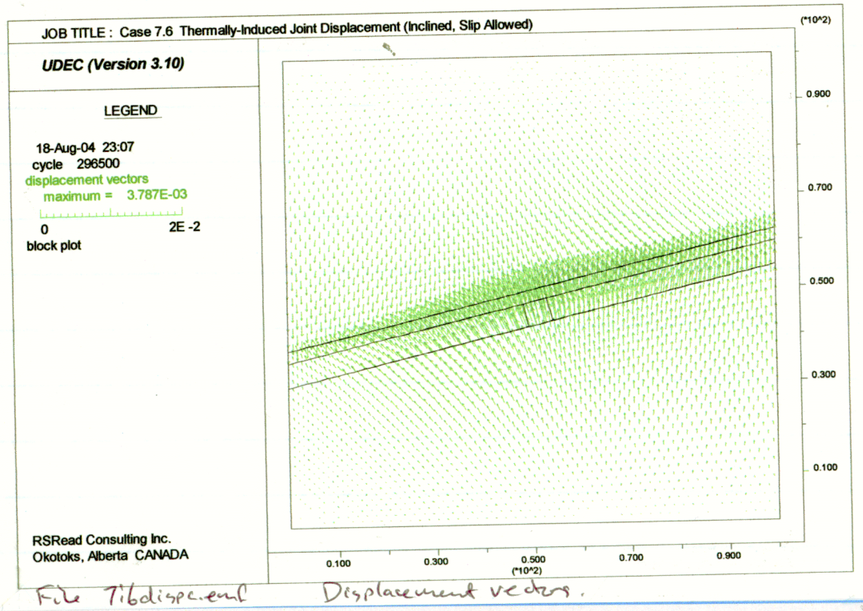
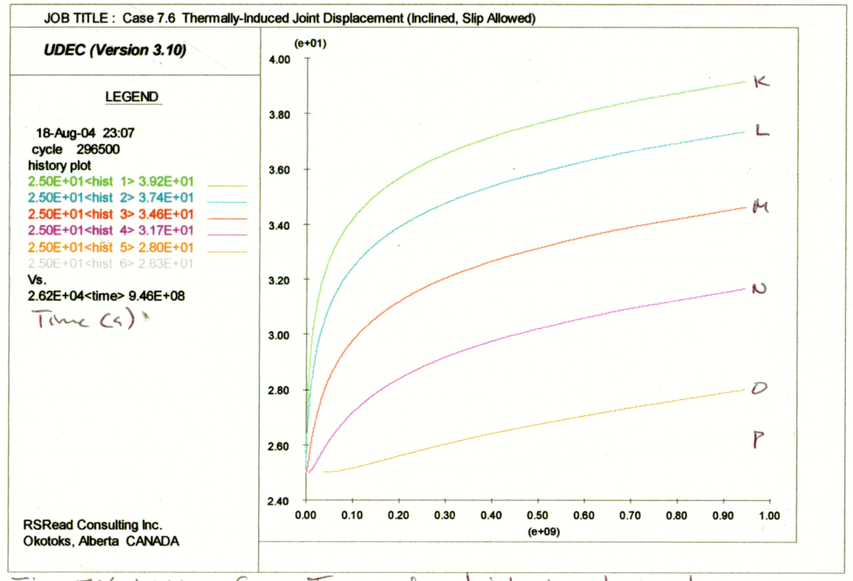


File 7.6displ.emf Displacement vectors.

SN654 Vol 1



File 7.6thisth.emf Temperature histories at points K, L, M, N, O, P

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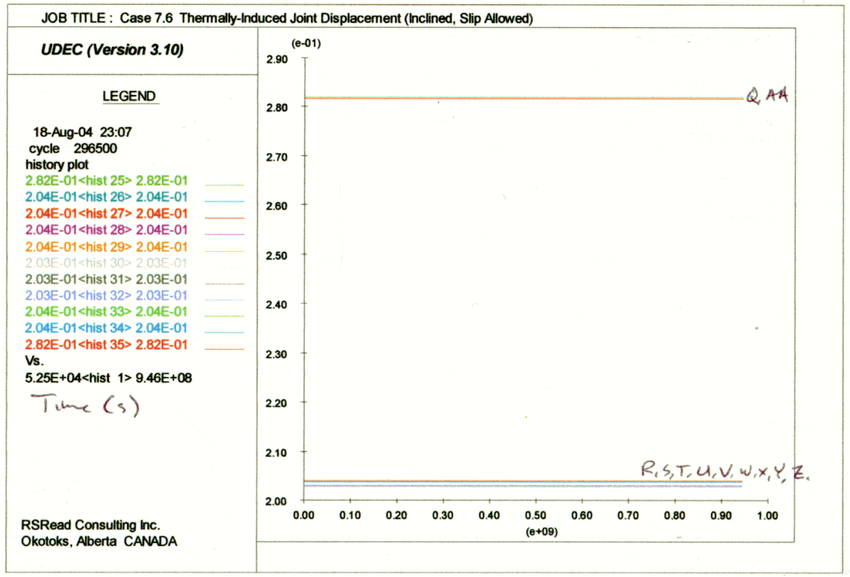
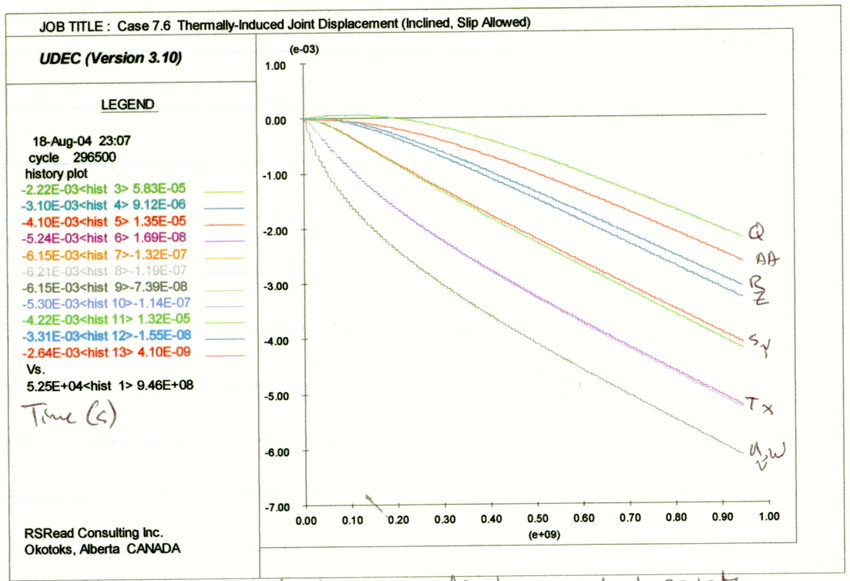


File 7.6jsrht.emf History of Sratio at points Q, R, S, T, U, V, W, X, Y, Z, AA.

SNG54 Vol 1



File Tibjndht.emf Joint normal displacement at points Q,R,S,T,U,V,W,X,Y,Z,AA.

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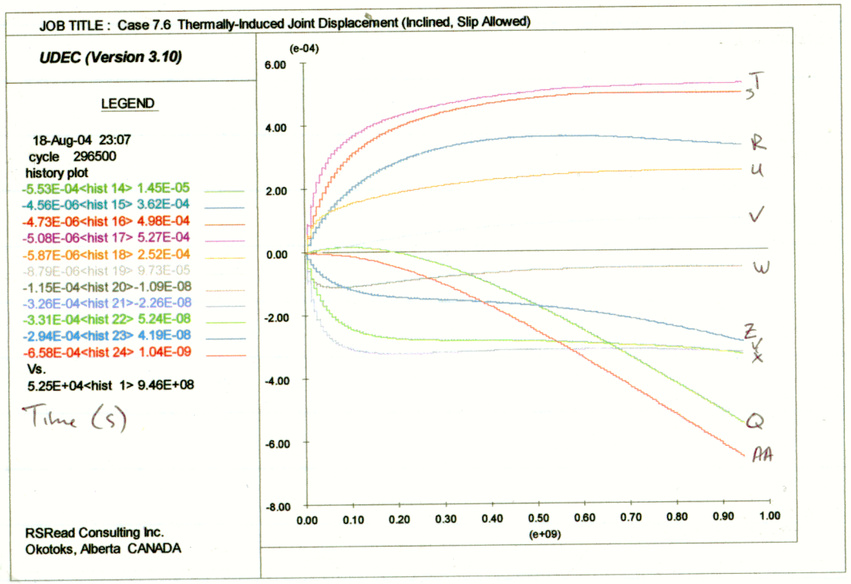
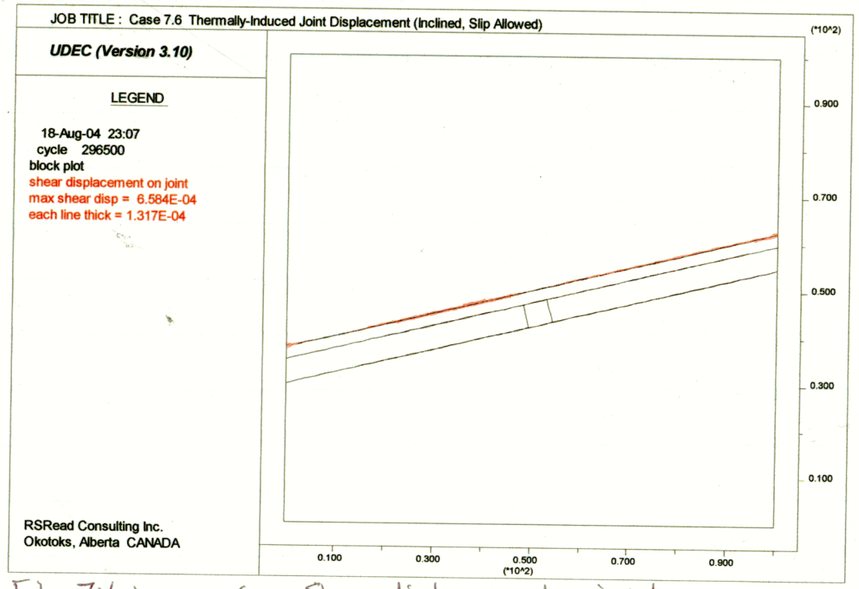


File Tibjsdht.emf Joint shear displacement at points Q,R,S,T,U,V,W,X,Y,Z,AA

SNG54 Vol 1.



File Tibshear.emf Shear displacement on joint.

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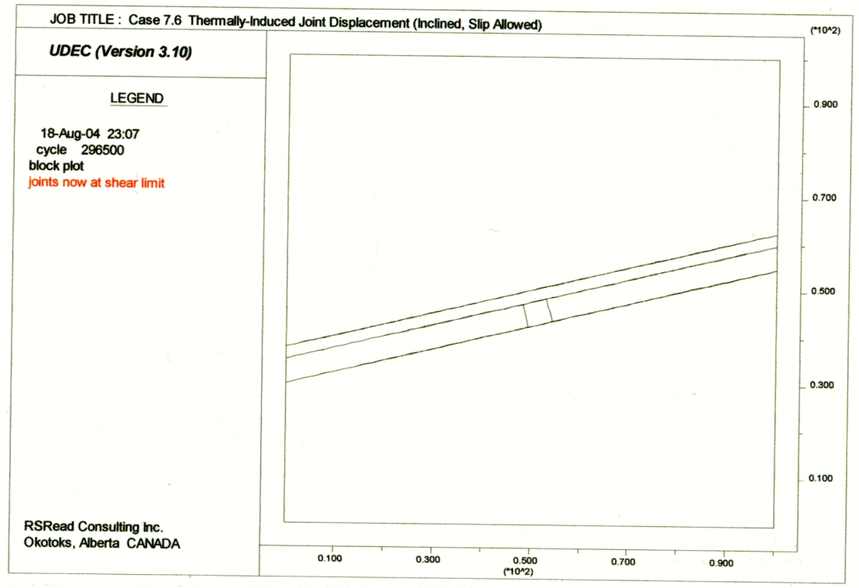

File Tibslip.emf Slip on joint. (none)