COMPUTER GENERATION OF TYPE CURVES

A REPORT
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by
BRENNA L. SURRITT
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To Timothy

ABSTRACT

Type curves are a useful tool for analyzing transient well test data. This paper presents some previously published type curves and the computer programs that were used to generate these type curves. The governing equations of the curves and their references the programs are presented as well. In addition, some previously unpublished type curves are developed. These include drawdown **type** curves for locating a sealed linear boundary, and **type** curves for a well located between two parallel sealing faults. The governing equations for these curves are derived.

The computer generated working type curves are included in the Appendix.

ACKNOWLEDGEMENTS

The author wishes to express appreciation to the following: to Avrami Sageev, for the guidance and supervision that made the completion of this research possible; to Stanford University, for financial assistance provided; and to the Stanford Geothermal Program, for financial assistance provided under Department of Energy Contract No. DE-ASO3-80SF11459.

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1: INTRODUCTION

Type curves are a useful tool for transient well test analysis. The curves are used to obtain quantitative answers to well test problems (using type-curve matching techniques). In addition, the curves are a meaningful qualitative picture of the reservoir behavior, an analogue for identifying an appropriate reservoir model. Many type curves are available. The curves are useful for drawdown, build-up, interference, constant pressure, constant rate, or any transient well test with a known P_D and t_D.

This research is part of a larger effort to produce a manual of type curves. The purpose of this research specifically, is to generate P_D versus t_D values using a computer. Some curves were first prepared by draftspersons, and have been re-done using computer graphics capabilities. Others have not been presented before.

Unless otherwise stated, t_D, and P_D are defined as:

$$t_D = \frac{0.000264\, k\, t}{\phi \mu c_t r_w^2} \tag{1}$$

$$P_D = \frac{k\, h}{141.2\, q\, B\, \mu} \left[p_i - p_{r,t} \right] \tag{2}$$

where the parameters are defined in the nomenclature.

In this report, twelve type curves are presented. Some of these are from the literature, others have not been presented before in their large scale form. These include:

1) Drawdown Build-Up Curve (Line Source Solution)
2) Pressure Distribution In A Square Reservoir
3) Finite Radius Wellbore, Infinite System, Constant Terminal Rate
4) Transient Linear Behavior
5) Hurst Simplified Water Influx, Constant Rate Inner Boundary
6) Linear Fault Type Curve For A Drawdown Interference Test
7) Semi-log Linear Fault Type Curve For **A** Drawdown Interference Test
8) Pressure Derivative For Linear Fault Type Curve
9) Parallel Sealing Faults, Well Located Midway Between Faults.
10) Shifted Parallel Sealing Faults Type Curve, Well Midway Between Faults.
11) Parallel Sealing Faults, Well At Various Locations.
12) Shifted Parallel Sealing Faults, Well At Various Locations.

The governing equations are presented for each of the type curves. The equations are programmed in Fortran to generate the curves. The complete, working type curves are in **Appendix** C; the report contains smaller versions **of** the working curves.

Of the type curves listed, **7** - 12 are previously unpublished in their large form. The first are a modification of the linear fault type curve ***(Stallman 1952)*** for a drawdown interference test, small r_2/r_1 ratios. The others are for the behavior of a well located between two parallel sealing faults. The locations of the well, in addition to the distance between the faults is varied.

2: DRAWDOWN BUILD-UP CURVE (LINE SOURCE SOLUTION)

The dimensionless pressure response to a diminishing radius constant rate well in an infinite reservoir , the line source, **is:**

$$P_D = -\frac{1}{2}\, Ei \left[\frac{-r_D^2}{4t_D} \right] \qquad (3)$$

For a production time t_p, the dimensionless pressure **is:**

$$P_D = -\frac{1}{2}\, Ei \left[\frac{-r_D^2}{4t_{pD}} \right] \qquad (4)$$

If the well is closed in for a time ***At,*** the pressure drop at time ***(t_p + At)*** is the difference between the pressure drop caused by rate **q** for a time (t_p+Δt) and the pressure increase caused by rate of **-q** for time ***At,*** yielding:

$$P_D = P_D\left[t_p+\Delta t \right] - P_D\left[\Delta t \right] \qquad (5)$$

$$P_D = -\frac{1}{2}\, Ei \left[\frac{-r_D^2}{4(t_p+\Delta t)_D} \right] + \frac{1}{2}\, Ei \left[\frac{-r_D^2}{4\Delta t_D} \right] \qquad (6)$$

Fig. 2.1 presents the log-log type curves for the drawdown-buildup tests.

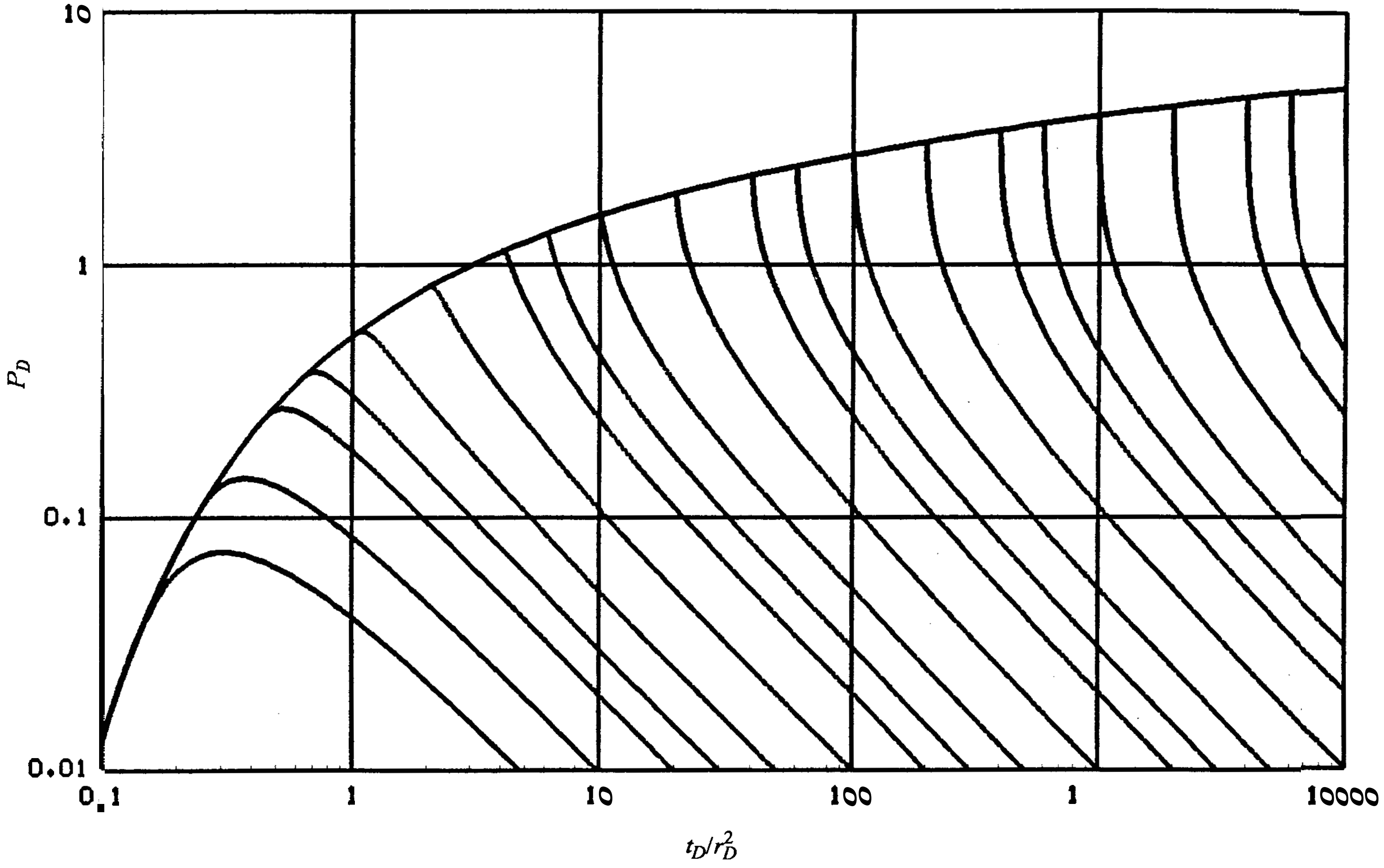

Fig. 2.1 - P_D versus t_D/r_D^2 for ≡ drawdown-buildup tests (After *Ramey* 1979).

3: PRESSURE DISTRIBUTION IN A SQUARE RESERVOIR WITH NO FLOW OUTER BOUNDARIES

Earlougher, ***Ramey, and Miller (1968)*** presented type curves for a constant terminal rate well in a closed square reservoir. The type curves show P_D versus t_{DA} functions at various locations within a bounded square that has a well at its center.

The analytical solution used **is** the line source solution.

$$P_D = -\frac{1}{2}\ Ei\left[\frac{-r_D^2}{4t_D}\right] \tag{3}$$

Matthews, Brons ***and Hazebroek (1954)*** demonstrated that solutions such as Eq. (3) can be superposed to generate the behavior of bounded geometric shapes. In this case, the behavior of a single well in a bounded square reservoir is calculated by adding the pressure disturbances together caused by the appropriate array of an infinite number of wells producing from an infinite system.

$$P_D\ (x_D, y_D, t_{DA}) = \sum_{i=1}^{\infty} P_D\ (a_{iD}^2\ ,\ t_{DA}) \tag{7}$$

$$P_D = -\frac{1}{2} \sum_{i=1}^{\infty} Ei\left[-\frac{((x_{iD}-x_D)^2 + (y_{iD}-y_D)^2)/4}{4t_D}\right] \tag{8}$$

Where: $a_{iD} = a_i/\sqrt{A}$

$a_i =$ distance from i^{th} well to (x,y).

$A =$ drainage area of the bounded system.

$x_D = x/L$

$y_D = y/L$

$L = \sqrt{A}/2$

Fig. 3.1 shows the square grid used to generate Fig. 3.2. Because of the symmetry of the square drainage region, it is necessary to compute pressures only within the octant shown in Fig. 3.1.

The summation of exponential integrals were carried out until the contribution from additional perimeter image wells was less than 10^{-9} of P_D. The results are graphed in Fig. 3.2. In the case of the pressures at the well, the calculations were carried out for $\sqrt{A}/r_w = 2000$.

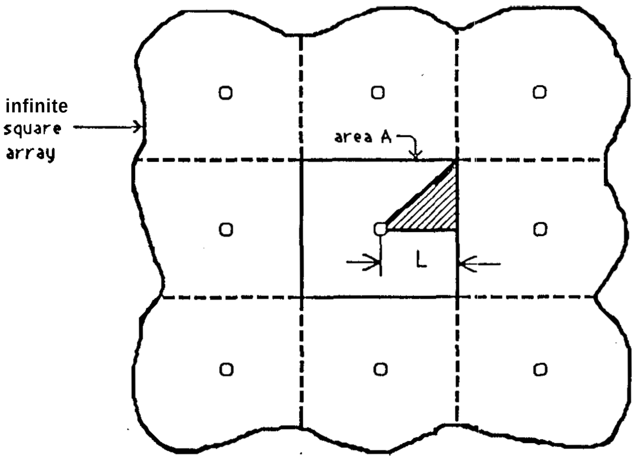

Fig. 3.1 - Octant of a square drainage system showing well and pressure point locations.

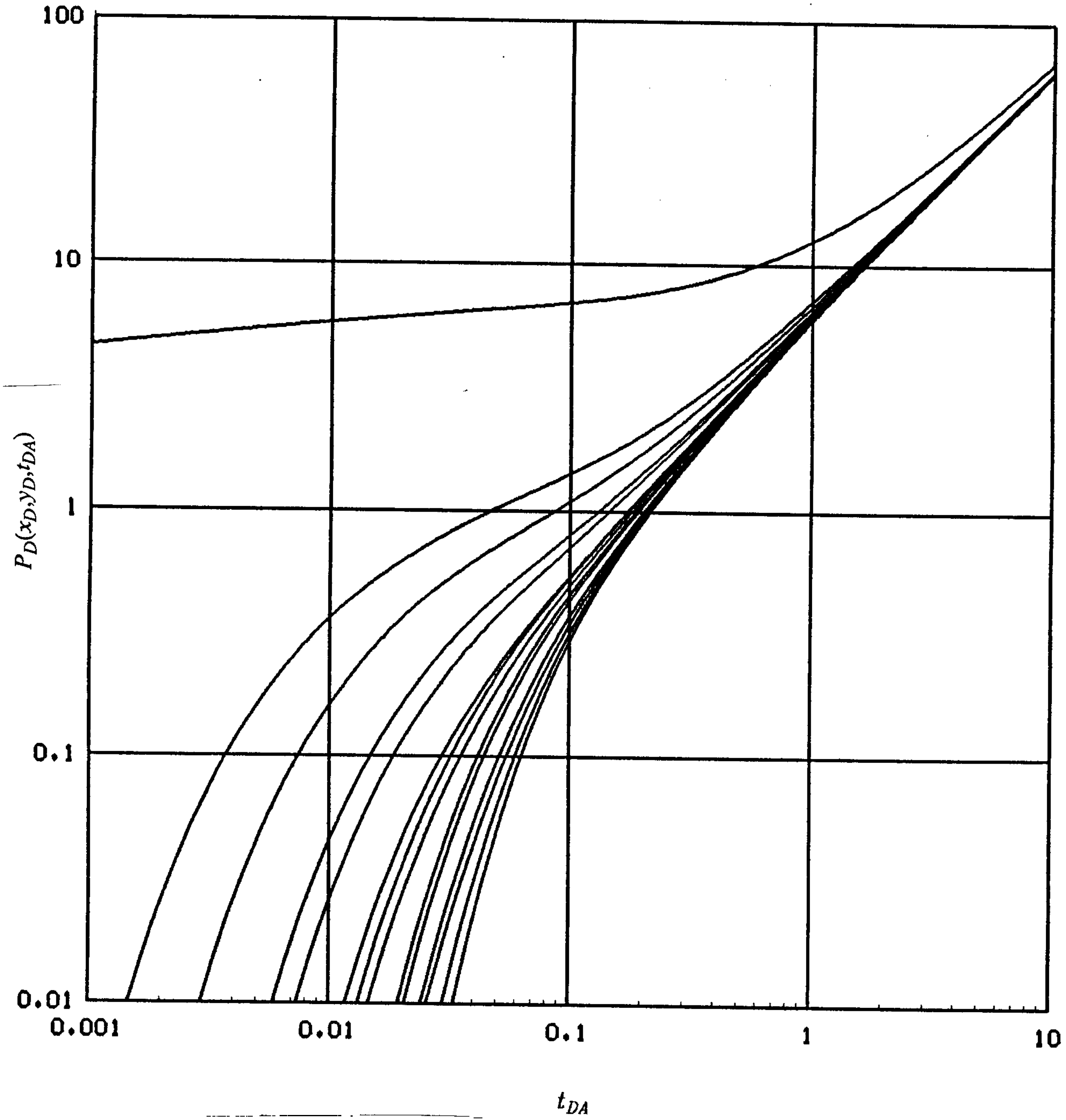

Fig. 3.2 - P_D versus t_{DA} at **various** points in **a** closed-square system with the well at the center, $\sqrt{A}/r_w = 2000$ (After ***Earlougher, Ramey, and Miller*** 1968).

4: FINITE RADIUS WELLBORE, INFINITE SYSTEM

CONSTANT TERMINAL RATE

Mueller and Witherspoon (1965) presented type curves for radial flow at constant terminal rate in an infinite medium, for a finite radius wellbore. They pointed out that at early times and at short distances from the inner boundary, the line source solution ($r_D = \infty$) is not valid. They concluded that for $t_D > 10$ and $r_D > 20$, all the dimensionless pressure responses are similar to the line-source response.

Van Everdingen and ***Hurst*** (1949) describe the governing equations for the finite radius constant terminal rate case. The Laplace transform solution **is:**

$$\bar{P}_D = \frac{K_0(r_D\sqrt{s})}{s\sqrt{s}\,K_1(r_D\sqrt{s})} \tag{9}$$

The Stehfest algorithm (1970) was used to invert the Laplace solution for various values of r_D, presented in Fig. 4.1.

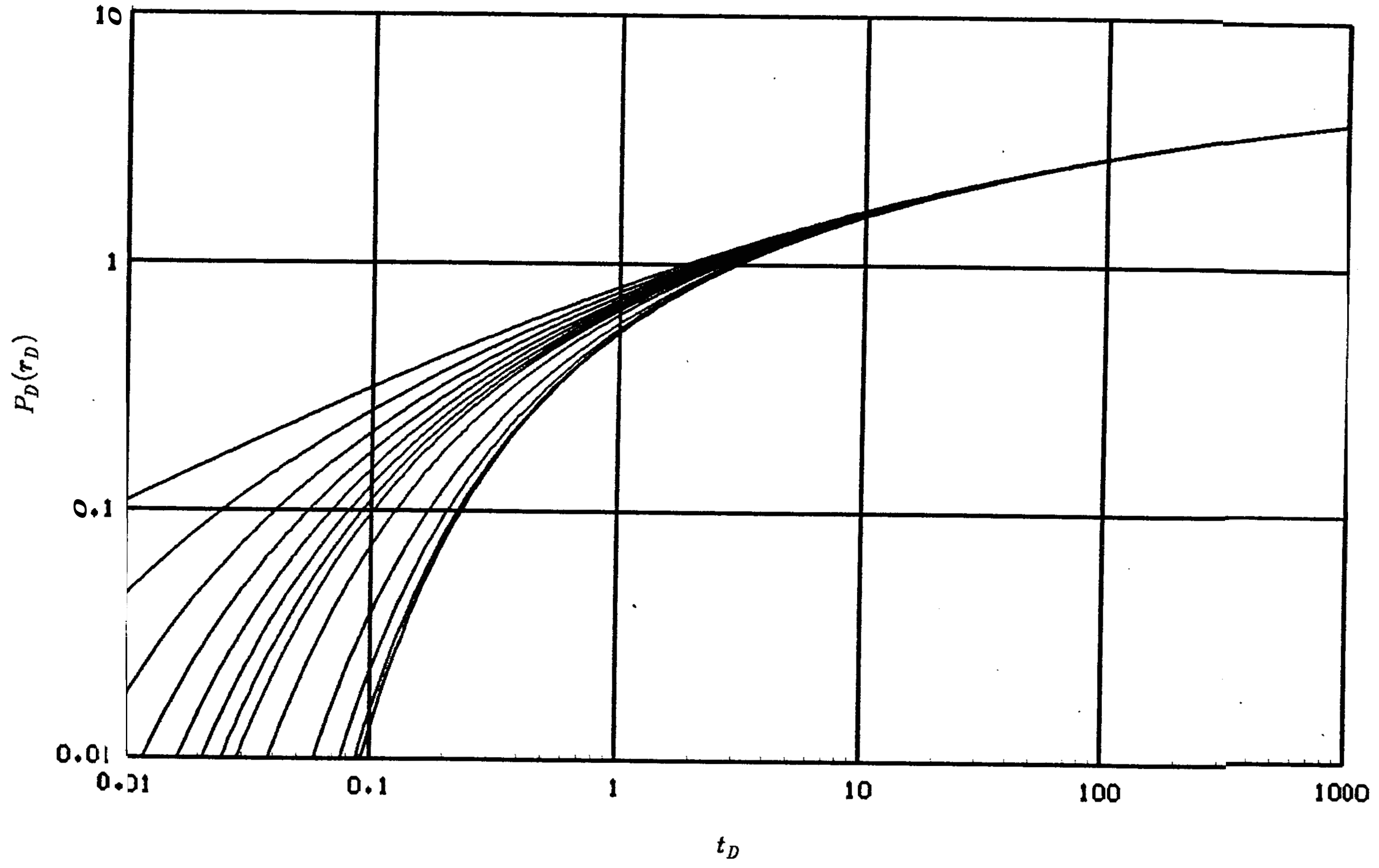

Fig. 4.1 - $P_D(r_D)$ versus t_D for finite radius wellbore in an infinite system, constant terminal rate, (After *Mueller and Witherspoon* 1965).

5: TRANSIENT LINEAR BEHAVIOR

Miller (1962) analyzed the performance of finite and infinite aquifers. His equations give pressure drop or cumulative influx at the linear aquifer-reservoir boundary as a function of time for an infinite aquifer, and a finite aquifer with a sealed outer boundary. *Nabor and Barham* **(1964)** developed the appropriate equations for a finite aquifer with constant pressure at the outer boundary.

The original curves developed by *Miller* were specific to a given size aquifer. *Nabor and Barham* modified his equations, reducing them to a form that yields a single working curve, applicable to any size aquifer.

For a constant rate of influx across the aquifer-reservoir boundary:

Infinite Linear Aquifer

$$\Delta p = \frac{kbh}{q\mu L} F_{1/2}(t_D) \tag{10}$$

Finite Linear Aquifer, Sealed Outer Boundary

$$\Delta p = \frac{kbh}{q\mu L} F_1(t_D) \tag{11}$$

Finite Linear Aquifer, Constant Pressure at Outer Boundary

$$\Delta p = \frac{kbh}{q\mu L} F_0(t_D) \tag{12}$$

For a constant pressure at the aquifer-reservoir boundary:

Infinite Linear Aquifer

$$W_e = \phi\ b\ h\ L\ c_t\ (\Delta p)\ F_{1/2}\ (t_D) \tag{13}$$

Finite Linear Aquifer, Sealed Outer Boundary

$$W_e = \phi\ b\ h\ L\ c_t\ (\Delta p)\ F_1\ (t_D) \tag{14}$$

Finite Linear Aquifer, Constant Pressure at Outer Boundary

$$W_e = \phi\ b\ h\ L\ c_t\ (\Delta p)\ F_0\ (t_D) \tag{15}$$

Fig. 5.1 shows the plotted functions of dimensionless time, $F_0\ (t_D)$, $F_{1/2}\ (t_D)$, and $F_1\ (t_D)$.

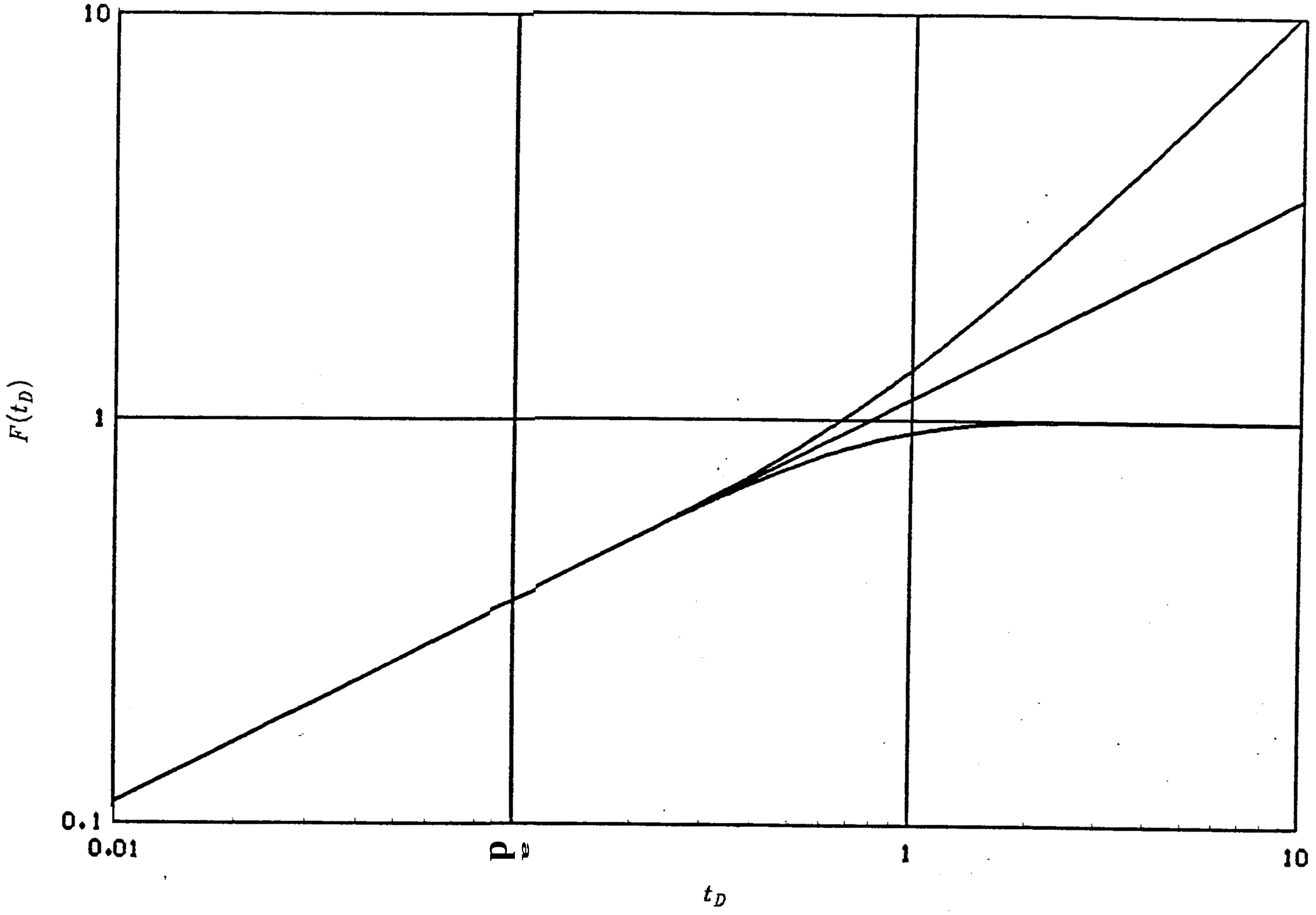

Fig. 5.1 - Dimensionless pressure change and efflux functions $F(t_D)$ for linear aquifers (After *Nabor and Barham* 1964).

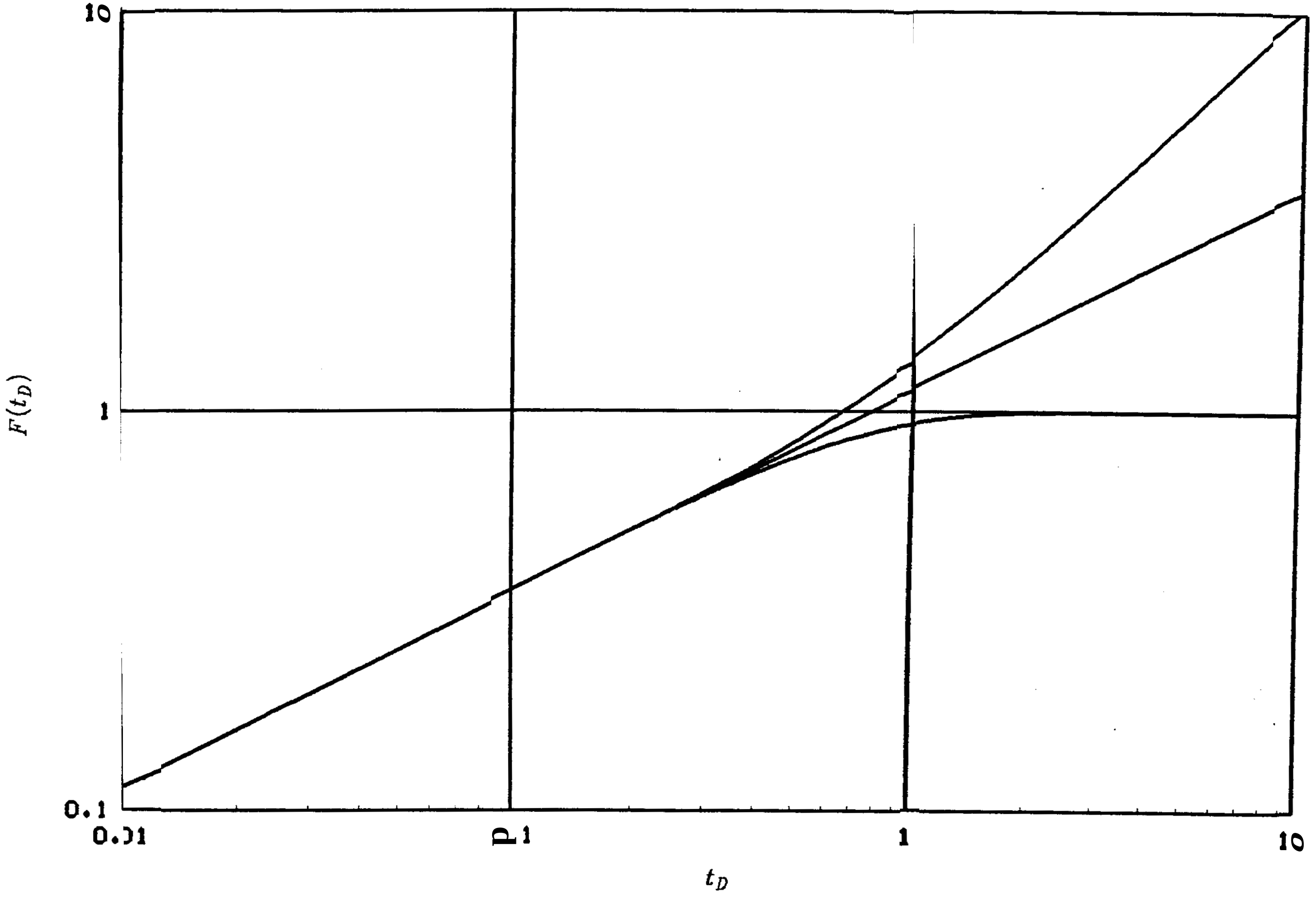

Fig. 5.1 - Dimensionless pressure change and efflux functions $F(t_D)$ for linear aquifers (After *Nabor and Barham* 1964).

6: HURST SIMPLIFIED WATER INFLUX

CONSTANT RATE INNER BOUNDARY, INFINITE RADIAL SYSTEM

For a constant rate at the reservoir-aquifer boundary, the Laplace space solution for dimensionless pressure is:

$$\overline{P}_D = \sigma N(\sigma, s) \tag{16}$$

where:

$$\sigma = \frac{2\pi\phi c_w h r_w^2}{N B_{oi} c_o} \tag{17}$$

and

$$N(\sigma, s) = \frac{K_0(s\sqrt{s}\,)}{s\sqrt{s}\left[\sigma K_1(s\sqrt{s}\,) + \sqrt{s}\,K_0(s\sqrt{s}\,)\right]} \tag{18}$$

This is the simplification of the material balance equation for an undersaturated oil reservoir, subject to radial water drive as developed **by *Hurst*** (1953).

Fig. 6.1 is a plot of p_D versus t_D for various O.

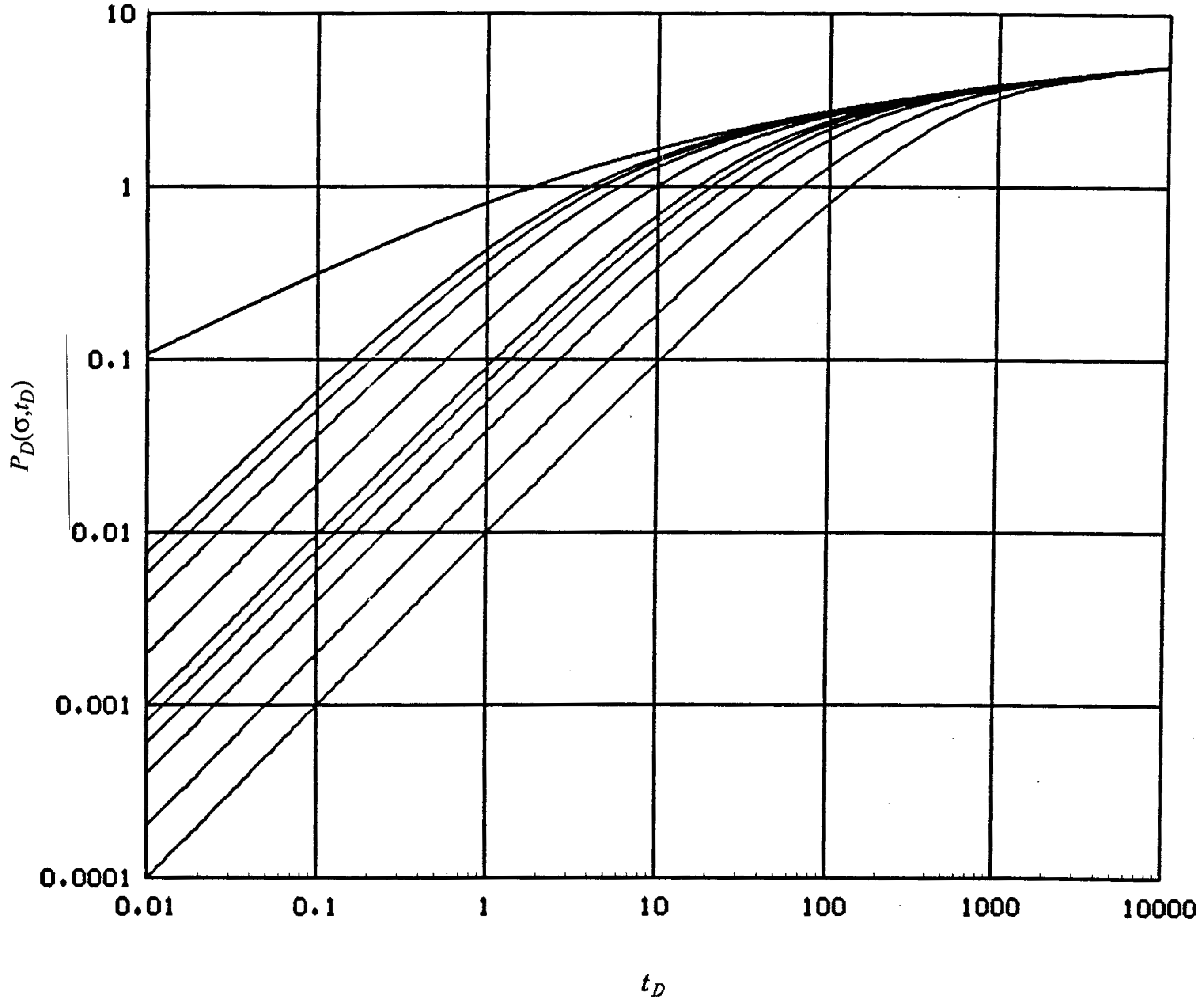

Fig. 6.1 - $P_D(\sigma,t_D)$ versus t_D for and undersaturated oil reservoir, subjected to radial water drive (After *Hurst* 1953).

7: LINEAR FAULT TYPE CURVE FOR A DRAWDOWN INTERFERENCE TEST (SMALL r_2/r_1 RATIOS)

The drawdown linear fault type curve uses superposition of the line source solution in space to produce the effect of a linear fault. Fig. 7.1 illustrates the well geometry,

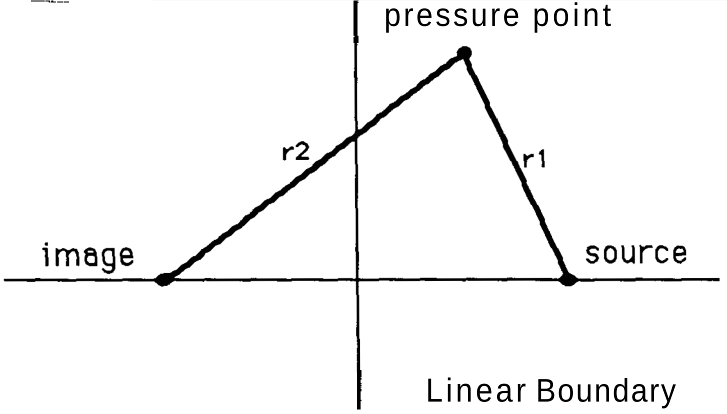

Fig. 7.1 - Well geometry for linear fault interference test

Production at the image well simulates the effect **of** a sealed linear fault halfway between the image **and** producing well. *Stallman* (1952) presented log-log type curves for a constant rate line source producing near a linear boundary.

The solution for dimensionless pressure is the sum of the individual effects of the producing and image wells.

$$p_D = p_D(r_{D1}, t_D) + p_D(r_{D2}, t_D) \tag{19}$$

Substitution of the exponential integral solution gives the sealed fault solution:

$$p_D = -\frac{1}{2}\left[Ei\left(\frac{-r_{D1}^2}{4t_D}\right) + Ei\left(\frac{-(r_2/r_1)^2\, r_{D1}^2}{4\, t_D}\right)\right] \tag{20}$$

Pressure-time responses can be matched to the type-curve and the ratio of r_2/r_1 may be estimated. The curves presented here are for small r_2/r_1 ranging from 1.0 to 10.0. Fig. 7.2 is a log log plot of the pressure response.

Fig. 7.3 is a semi-log plot of the same data.

Fig. 7.4 differs from most type curves presented; it is a plot of the dimensionless pressure derivative (denoted by P_D'), versus time.

P_D' **is** defined as follows:

$$P_D' = \frac{d\,P_D}{d\,(ln t_D)} \tag{21}$$

For the line-source solution,

$$P_D' = \frac{1}{2}\, e^{r_D^2/4t_D} \tag{22}$$

Thus, for a well near a sealed linear fault:

$$P_D' = \frac{1}{2}\left[e^{-r_{D1}^2/4t_D} + e^{-((r_2/r_1)^2 r_{D1}^2)/4t_D} \right] \tag{23}$$

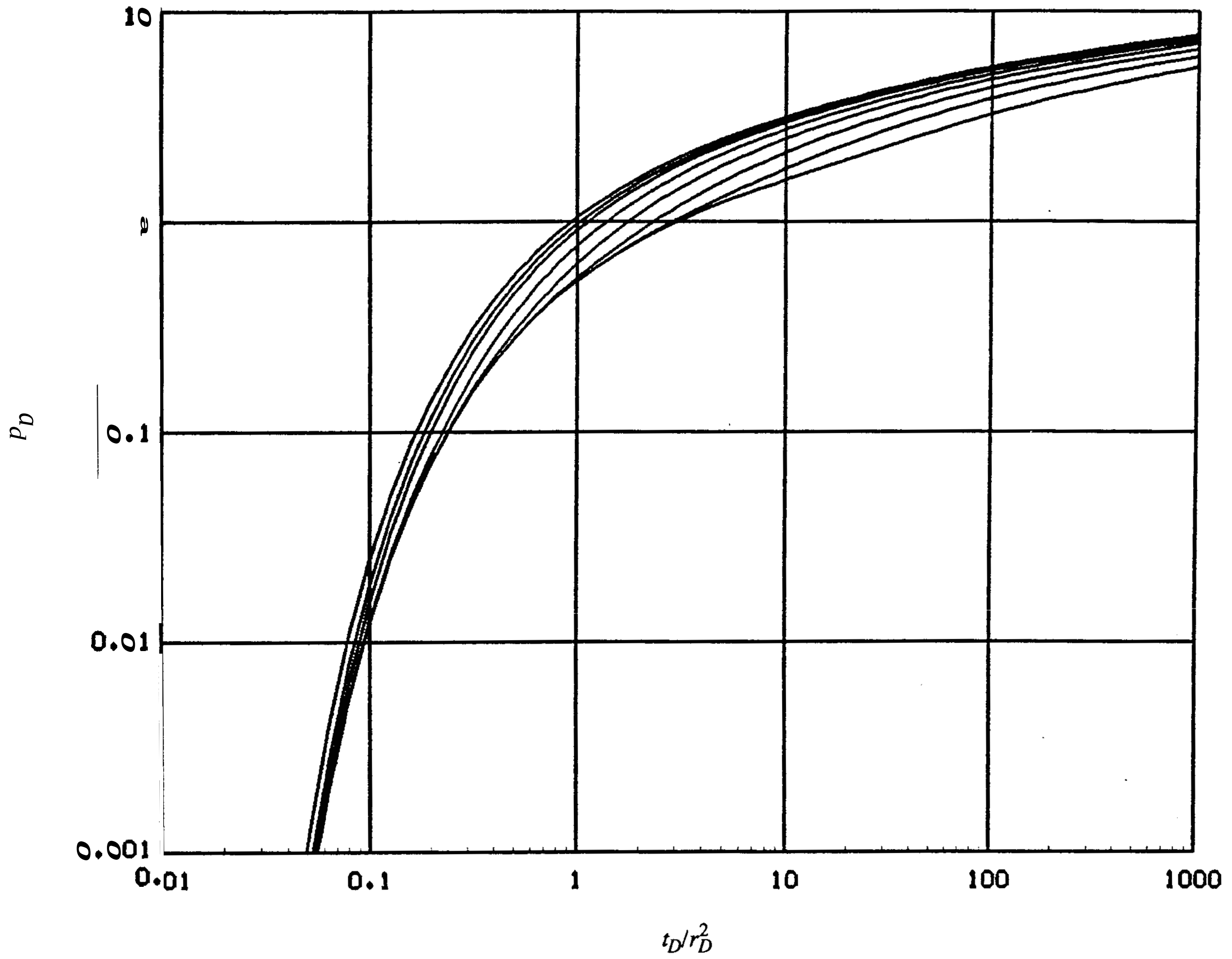

Fig. 7.2 - P_D versus t_D/r_D^2 for a well near a sealed linear fault, a drawdown interference test, with small r_2/r_1 ratios (After *Stallman* 1952).

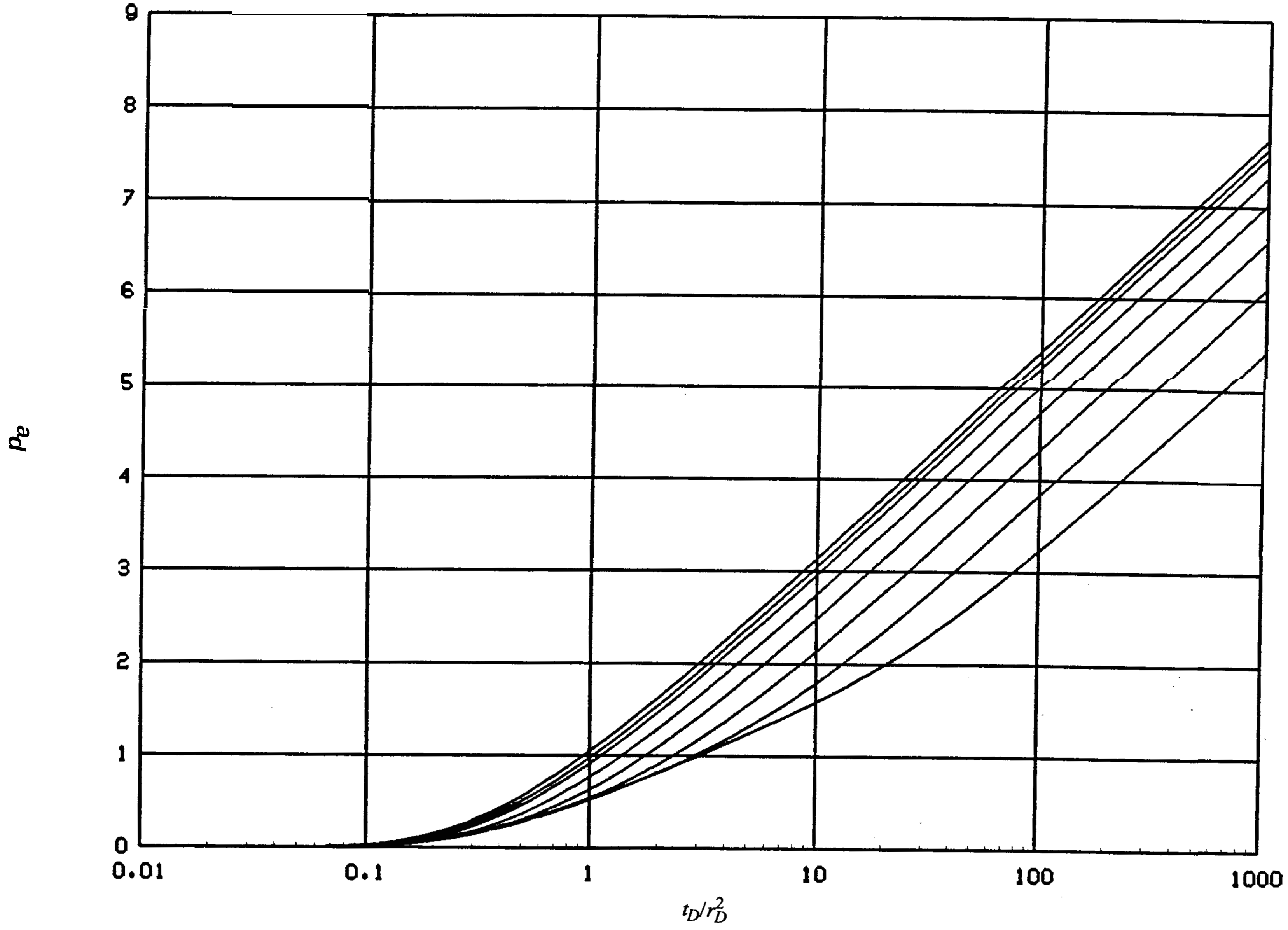

Fig. 7.3 - Semi-log plot of P_D versus t_D/r_D^2 for a well near a sealed linear fault, a drawdown interference test, with small r_2/r_1 ratios (After *Stallman* 1952).

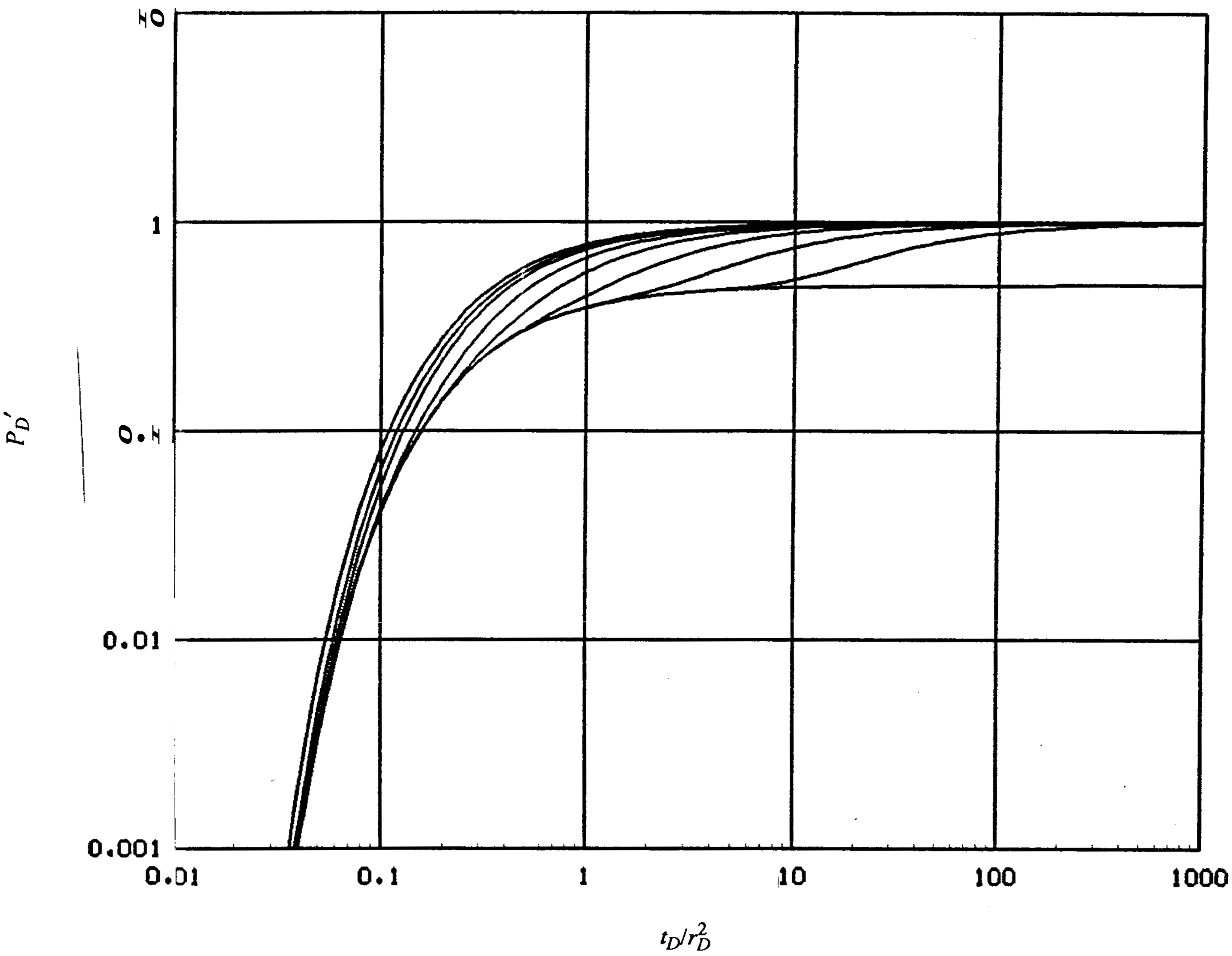

Fig. R - Dimensionless pressure derivative, P_D', versus t_D/r_D^2 for a well near a sealed linear fault, a drawdown interference test, with small r_2/r_1 ratios.

8: PRESSURE DISTRIBUTION FOR A WELL BETWEEN TWO PARALLEL SEALING FAULTS

Ramey, Kumar, and Gulati (1973) have tabulated dimensionless pressure data for the specific case of a well located midway between two parallel sealing faults. ***Tiab*** *and Kumar* expanded the pressure behavior to include off-center locations between the faults.

The analytical solution used is the line source solution.

$$P_D = -\frac{1}{2}\, Ei \left[\frac{-r_D^2}{4t_D}\right] \tag{3}$$

The line source solution can be superposed to generate the behavior bounded geometric shapes. In this case, the behavior of two parallel sealing faults is calculated by adding together the pressure disturbances caused by the appropriate combination of image wells, producing from an infinite system.

$$P_D\,(b_D, L_D) = \sum_{i=1}^{\infty} P_D\,(r_{iD}^2) \tag{24}$$

$$P_D = -\frac{1}{2} \sum_{i=1}^{\infty} Ei \left[-\frac{r_{iD}^2}{4t_D}\right] \tag{25}$$

Where:

L_D = dimensionless distance between faults, L/r_w

L = distance between faults

b_D = dimensionless distance to the nearest fault

b = distance to the nearest fault

r_{iD} = $r_i L_D$

r_i = distance from well to i^{th} image well

Figure 8.1 show the image well system used to generate figures 8.2-8.4. Because of the symmetry of the drainage region, it is necessary to compute pressures only within half of the area shown.

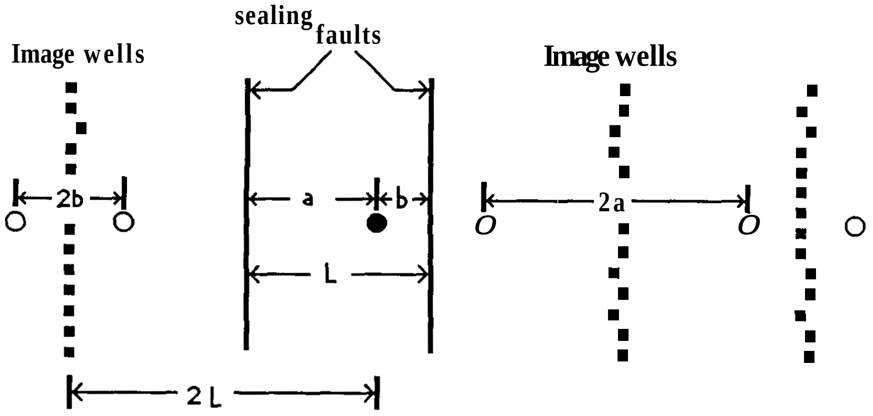

Fig. 8.1- Image well configuration for two parallel sealing faults.

The summation of exponential integrals were carried out until the contribution from additional perimeter image wells was less than 10e-09 of P_D. The pressure behavior of a well located midway between the faults (b_D=0.5 was generated for various L_D and presented in figure 8.2.

By redefining t_D it is possible to mathematically collapse the late time pressure response to one curve, figure **8.3,** representative of linear flow.

$$t_D^* = \frac{t_D}{L_D^2} \tag{26}$$

Moving the well closer to one of the faults causes an earlier deviation from line source behavior as expected. The curves shown in figure **8.4** are for b_D = 0.05, 0.1, 0.2 and 0.5 , L_D = 10, 100, 1000, 10000.

Again, it is possible to mathematically collapse the late time pressure response using the same definition of t_D^* (eqn. 26), as in figure **8.3.** Figure ***8.5*** shows the results.

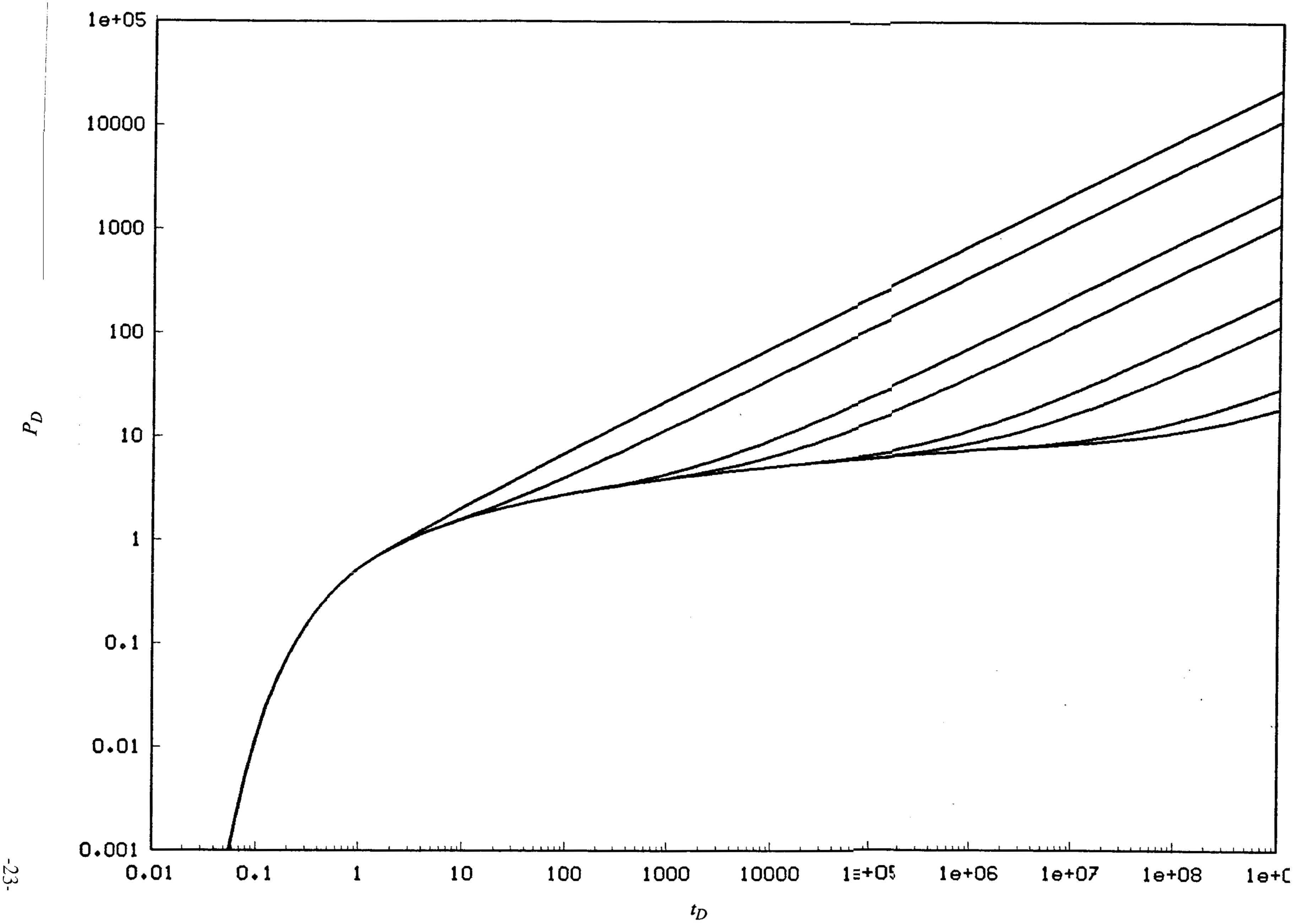

Fig. 8.2- P_D versus t_D for a well located midway between two parallel sealing faults, (L_D varies from 5 to 10,000).

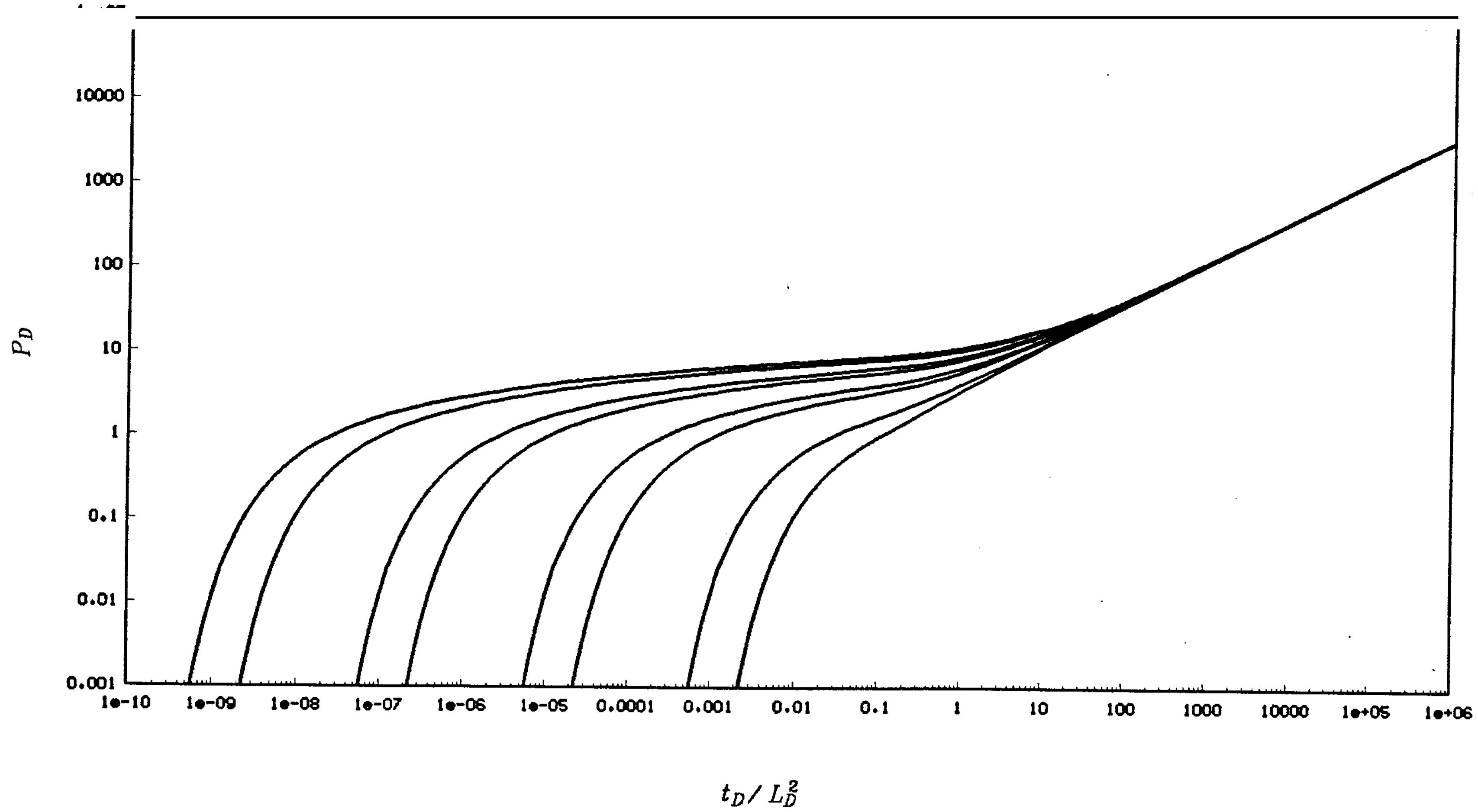

Fig. 8.3. P_D versus t_D/L_D^2 for a well located midway between two parallel sealing faults, L_D varies from 5 to 10,000.

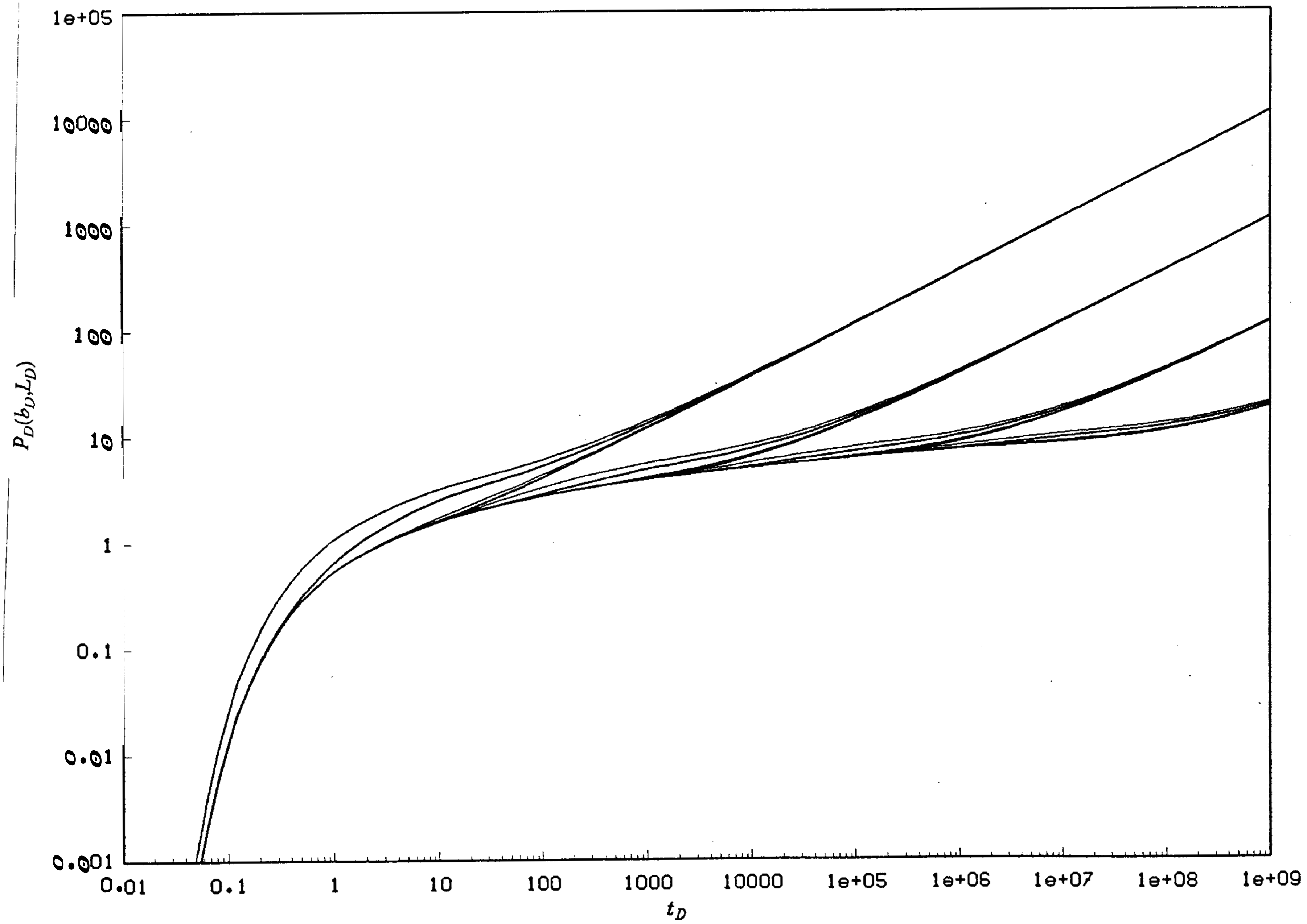

Fig. 8.4- P_D versus t_D for a well at various locations between two parallel sealing faults, $b_D = 0.05, 0.1, 0.2$, and 0.5 .($L_D = 10, 100, 1000, 10000$).

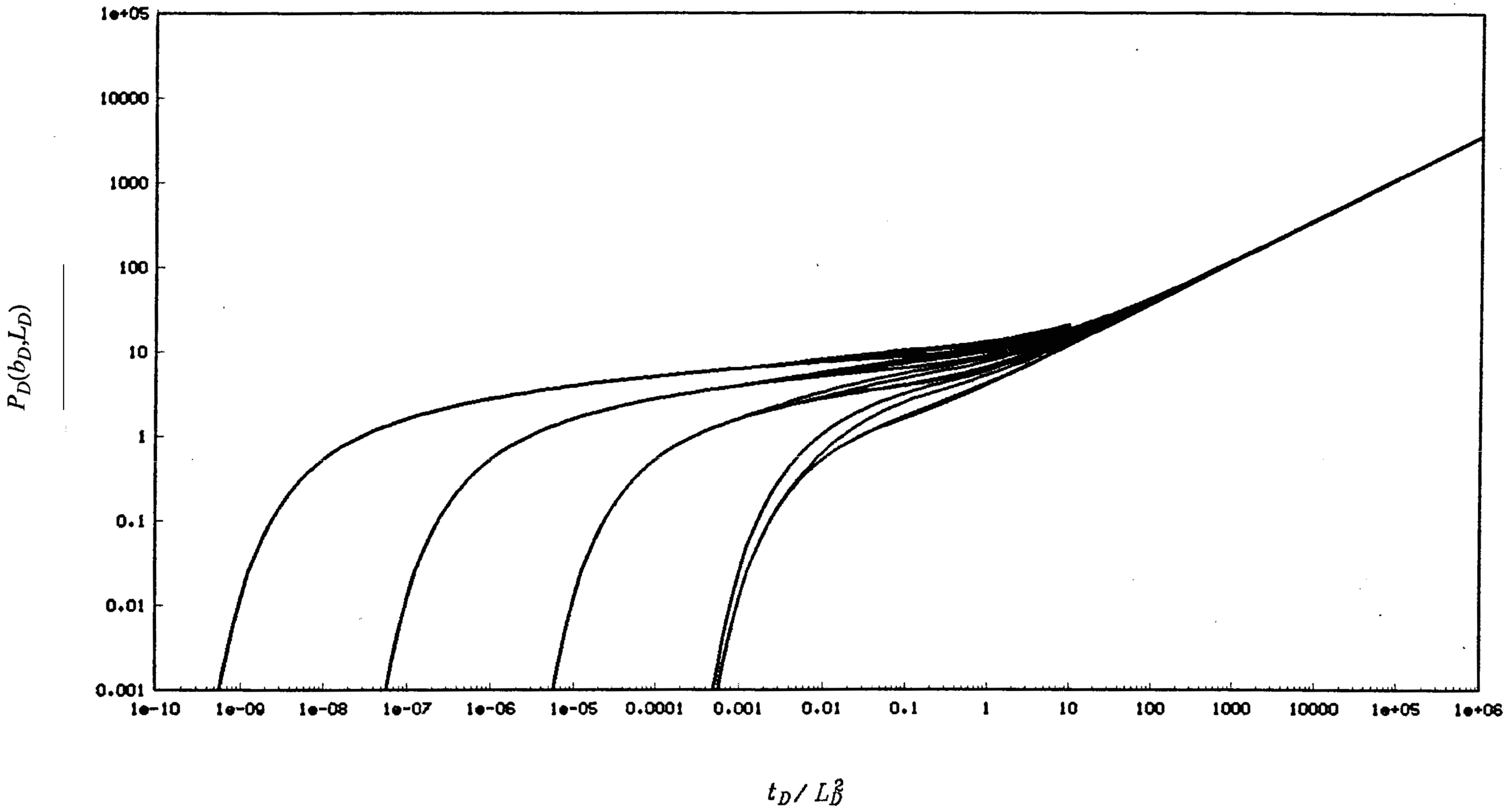

Fig. 8.5 P_D versus t_D/L_D^2 for a well at various locations between two parallel sealing faults, $b_D = 0.05, 0.1, 0.2$, and 0.5 . ($L_D = 10, 100, 1000, 10000$).

9: CONCLUSIONS

Type curves were generated using Fortran computer programs. The drawdown-buildup type curve was produced using superposition in time of the line source solution. The linear fault interference type curve, the pressure distribution in a closed square reservoir curves and the parallel sealing faults curves were generated using superposition in space of the line source solution.

The finite radius type curve, and ***Hurst'*** simplified water influx curves were generated by numerical inversion of their governing Laplace equations with the ***Stehfest*** algorithm (1970). This method was very efficient, reducing the required CPU time and the required programming.

The transient linear behavior type curve was generated 'by numerical integration of the published integral equations.

NOMENCLATURE

A = drainage area of the square bounded system

a_i = distance from i^{th} well to (x,y).

a_{iD} = $a_i/\sqrt{A}$

b = distance to nearest fault, parallel sealing faults section 8

b = aquifer width, chp.5

b_D = dimensionless distance to nearest fault, parallel faults

c_t = total formation compressibility (psi^{-1})

$F_{1/2}(t_D)$ = infinite linear aquifer flow

$F_1(t_D)$ = finite linear aquifer, sealed outer boundary

$F_0(t_D)$ = finite linear aquifer, constant pressure outer boundary

h = formation sand thickness (ft)

K_0 = modified Bessel function of the second kind of order zero

K_1 = modified Bessel function of the second kind of order one

L = 1/4 the drainage area of the square bounded system, chp.3

L = distance between faults, parallel sealing faults, section 8

L_D = dimensionless distance between faults, L/r_w

P_D = dimensionless pressure

$\overline{P}_D$ = Laplace transform of dimensionless pressure

P_{wf} = flowing pressure in the wellbore (psia)

P_i = static initial reservoir pressure (psia)

r_D = dimensionless radial distance

r_i = distance from with to i^{th} image well

r_{iD} = $r_i\, L_D$

r_w = wellbore radius (ft)

s = Laplace space variable

t = time (hours)

t_D = dimensionless time

t_D^* = redefined dimensionless time t_D/L_D^2

t_{DA} = dimensionless time based on **a** square drainage area

t_{pD} = dimensionless producing time

W_e = water influx

(x,y) = location of pressure point in square bounded system

(x_D,y_D) = dimensionless location of pressure point in square

μ = fluid viscosity (centipoise)

ϕ = formation porosity (fraction)

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APPENDIX A

COMPUTER PROGRAMS

DRAWDOWN BUILD-UP CURVE (LINE SOURCE SOLUTION)

```
c  This program calculates pD vs tD during the buildup
c  portion of the drawdown buildup test.
c
c  Dimensionless shut-in times considered are .1,.2,.4,.6, 1,2,4,6,
c  10,20,40,60,   100,200,400,600,  1000,2000,4000,6000
c
c  Variables used:
c    mmdei= imsl routine to calculate the exponential integral
c    tpd   = dimensionless shut-in time
c    pd    = dimensionless pressure
c    td    = dimensionless time

      implicit real*8(a-h,o-z)
      dimension tdd(10000),pdd( 10000)
      double precision mmdei
      iopt = 1
c
c  This loop calculates pD vs tD for the various shut-in times.
c
      do 70 kk=1,5
        aaa=kk
        do 80 ll=1,6
          bbb=ll
          if(ll.eq.3.or.ll.eq.5) go to 80
          tpd=0.001*(bbb*(10.0**aaa))

          nn=1
c
c  Calculate the initial pD value at the shut-in time, tpd.
c
          arg=(-1.0)/(4.0*tpd)
          pd=-0.5*(mmdei(iopt,arg,ier))
          pdd(1)=pd
          tdd(1)=tpd
```

DRAWDOWN BUILD-UP CURVE (LINE SOURCE SOLUTION) cont.

```
c
c   Generate values of tD between 0.1 and 10000 and calculate
c   the corresponding pD values.
c
         do 30 i=1,15
           aa=i
           do 40 j=1,36
             bb=j
             dt= 0.0001*(1.+(bb-1)*.25)* (10.**(aa))
             td= tpd + dt
             if (dt.lt.0.01.or.td.gt. 10000000)go to 40
             arg1=(-1.0)/(4.0*td)
             arg2=(-1.0)/(4.0*dt)
             pd=-0.5*(mmdei(iopt,arg1,ier)-mmdei(iopt,arg2,ier))
             if (pd.lt.0.0001) go to 50
             nn=nn+1
             pdd(nn)=pd
             tdd(nn)=td
 40        continue
 30      continue
c
c Output the data for plotting
c
 50      write(6,1000) nn
         do 60 m=1,nn
             time=tdd(m)
             pres=pdd(m)
             write(6,2000) time,pres
 60      continue

  1000format(5x,i3)
  2000 format(5x,e10.5,5x,e15.7)

  80     continue
  70   continue

       stop
       end
```

PRESSURE DISTRIBUTION IN A SQUARE RESERVOIR WITH NO FLOW BOUNDARIES

```
c   Dimensionless pressure at various points in a closed-
c   square system with the well at the center, no wellbore
c   storage, no skin, srt(A)/rw = 2,000.    Log-log plot.
c
c   Variables used:
c      mmdei= imsl routine to calculate the exponential integral
c      pd    = dimensionless pressure
c      td    = dimensionless time
c      (xd,yd) = coordinates of pressure point (well is at the origin)
c       (xi,yi) = coordinates of image well
c      ri2  = the distance from pressure point to image well (squared).
c       n     = half the length of the image well grid... it increases as
c                td increases to achieve the pD error tolerance.
c      err  = the percentage error in pD caused by a finite grid of
c                image wells rather than an infinite grid.

      implicit real*8(a-h,o-z)
      dimension tdd(10000),pdd(10000)
      dimension ri2(80000)
      double precision rnmdei

      iopt = 1
      error= 10e-9

 80   write(0,*)'input xd (type 0.0 to quit)'
      read(5,*)xd
      if(xd.eq.0.0)go to 90
      write(0,*)'input yd'
      read(5,*)yd

      n=1
      nn=1
      np=0

      do 10 i=1,5
        do 20 j=1,50
          tdlog= -4.+i+(j-1)/50.
          if(tdlog.gt.1.) go to 10
          tdA=10.**tdlog
          pdsum=0.0
          if(xd.eq.0.0.and.yd.eq.0.0)
     @          pdsum=-0.5*(dlog(1./(4.*2000.*2000.*tdA))+0.5772)
          ri2(nn)= (xd**2. + yd**2.)
```

PRESSURE DISTRIBUTION IN A SQUARE RESERVOIR WITH NO FLOW BOUNDARIES (cont.)

```
c calculate the distance to the producing well
c
          ri2(nn)= (xd**2. + yd**2.)
c
c calculate the distances to the image wells for layer n
c
 1        do 30 ii=1,8
           signx= 1.
           signy= 1.
           if(ii.ge.3.and.ii.le.6) signx= -1.
           if(ii.gt.4) signy= -1.
           do 40 jj=1,n
             an=n
             aj=jj
             if(ii.eq. 1.or.ii.eq.5) then
               xi= signx * an * 2.
               yi= signy * (aj-1.) * 2.
             elseif(ii.eq.2.or.ii.eq.6)then
               xi= signx * (an-aj+1.) * 2.
               yi= signy * an * 2.
             elseif(ii.eq.3.or.ii.eq.7)then
               xi= signx * (aj-1.) * 2.
               yi= signy * an * 2.
             else
               xi= signx * an * 2.
               yi= signy * (an-aj+1.) * 2.
             endif
             nn= nn+1
             ri2(nn)= (xi-xd)**2. + (yi-yd)**2.
 40        continue
 30       continue
c
c calculate the pD
c
          dpd= 0.0
          do 50 k=1,nn
            arg1=-(ri2(k)/4.) /(4.*tdA)
            if(arg1.eq.0.0)go to 50
            if(arg1.lt.-50.)go to 50
            pd=-0.5*(mmdei(iopt,arg1,ier))
            pdsum=pdsum +pd
            if(pdsum.lt.0.001)go to 21
            dpd=dpd + pd
 50       continue
```

PRESSURE DISTRIBUTION IN A SQUARE RESERVOIR WITH NO FLOW BOUNDARIES (cont.)

```
c
c check to see if this layer has a significant effect
c on the pd summation
c
           if(pdsum.gt.0.0) err=dpd/pdsum
           if(dpd.lt.error)  go to 60
           nn= 0
           n=n+1
           go to 1
c
c assign data pts to array for plotting
 60        np=np+1
           pdd(np)=pdsum
           tdd(np)=tdA

c set counter of outer layer back to 0 and n to 1 for next td value
 21        nn= 1
           n=1

 20      continue
 10    continue
c
c write results to output file
c
       write(6,1000)np
       do 70 m=1,np
         time=tdd(m)
         pres=pdd(m)
         write(6,2000) time,pres
 70    continue

 1000format(5x,i3)
 2000format(5x,e10.5,5x,e15.7)

       go to 80
 90    continue

       stop
       end
```

CONSTANT TERMINAL RATE

```
c  This program calculates the complete solution ffor
c  an infinite radial system operating at constant
c  terminal rate.(Mueller and Witherspoon)JPT 4/65.
c
c  Rd values: 1., 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7,
c                             2.0, 3.0, 5.0, 10.0, 20.
c  Variables used:
c      mmbsk0= IMSL routine to calculate modified Bessel function, KO
c      mmbsk1= IMSL routine to calculate modified Bessel function, K1
c      FA( ) = stehfest algoritm to invert solution
c      N     = number of iterations used in stehfest
c      rd    = radius of well, divided by ratius of reservoir
c      td    = dimensionless time
c      pd    = dimensionless pressure

      implicit real*8(a-h,o-z)
      dimension tdd(1000),pdd(1000)
      common rd

      write (0,888)
888   format ('enter N')
      read (5,*)N
      M=N+1
c
c  rD loop
c
 10   write(0,*)'what rd value do you want?'
      write(0,*)' (type 0.0 to quit)'
      read(5,*) rd
      if(rd.eq.0.0)go to 70
      nn=0

      do 20 i=1,26
         aa=i
         do 30 j=1,36
              bb=j
              dt=0.000001*(1.+(bb-1)*0.25)* (10.**aa)
              td=dt/(rd**2)
              T=dt
              if(td.lt.0.006.or.td.gt.1100) go to 30
              pd=FA(T,N,M)
              if (pd.lt.0.006) go to 30
              nn=nn+1
              pdd(nn)=pd
              tdd(nn)=td
 30      continue
 20   continue
```

FINITE RADIUS WELLBORE, INFINITE SYSTEM, CONSTANT TERMINAL RATE ,INCLUDING THE STEHFEST SUBROUTINE

```
c
c write results to output file
c
 50    write(6,1000) nn
       do 60 k=1,nn
          time=tdd(k)
          pres=pdd(k)
          write(6,2000) time,pres
 60    continue

 1000format(5x,i3)
 2000format(5x,e10.5,5x,e15.7)

       go to 10
 70    stop
       end
c
c  THE STEHFEST ALGORITHM
c  ---------------------
c
      FUNCTION FA(TD,N,M)
c          THIS FUNTION COMPUTES NUMERICALLY THE LAPLACE TRNSFORM
c          INVERSE OF F(S).
      IMPLICIT  REAL*8 (A-H,O-Z)
      DIMENSION G(50),V(50),H(25)
c
c          NOW IF THE ARRAY V(I) WAS COMPUTED BEFORE THE PROGRAM
c          GOES DIRECTLY TO THE END OF THE SUBRUTINE TO CALCULATE
c          F(S).
      IF (N.EQ.M) GO TO 17
      M=N
      DLOGTW=0.6931471805599
      NH=N/2
c
c          THE FACTORIALS OF 1 TO N ARE CALCULATED INTO ARRAY G.
      G(1)=1
      DO 1 I=2,N
      G(I)=G(I-1)*I
 1    CONTINUE
```

THE STEHFEST SUBROUTINE (cont.)

```
C        TERMS WITH K ONLY ARE CALCULATED INTO ARRAY H.
      H(1)=2./G(NH-1)
      DO 6 I=2,NH
      FI=I
      IF(I-NH) 4,5,6
4     H(I)=FI**NH*G(2*I)/(G(NH-I)*G(I)*G(I-1))
      GO TO 6
5     H(I)=FI**NH*G(2*I)/(G(I)*G(I-1))
6     CONTINUE
C
C        THE TERMS (-1)**NH+ 1 ARE CALCULATED.
C        FIRST THE TERM FOR 1=1
      SN=2*(NH-NH/2*2)-1
C
C        THE REST OF THE SN'S ARECALCULATED IN THE MAIN RUTINE.
C
C
C        THE ARRAY V(I) IS CALCULATED.
      DO 7 I=1,N
C
C        FIRST SET V(I)=0
      V(I)=0.
C
C        THE LIMITS FOR K ARE ESTABLISHED.
C        THE LOWER LIMIT IS K1=INTEG((I+1/2))
      K 1=(I+1)/2
C
C        THE UPPER LIMIT IS K2=MIN(I,N/2)
      K2=I
      IF (K2-NH) 8,8,9
9     K2=NH
C
C        THE SUMMATION TERM IN V(I) IS CALCULATED.
8     DO 10 K=K1,K2
      IF (2*K-I) 12,13,12
12    IF (I-K) 11,14,11
11    V(I)=V(I)+H(K)/(G(I-K)*G(2*K-I))
      GO TO 10
13    V(I)=V(I)+H(K)/G(I-K)
      GO TO 10
14    V(I)=V(I)+H(K)/G(2*K-I)
10    CONTINUE
```

THE STEHFEST SUBROUTINE (cont.)

```
C
C       THE V(I) ARRAY IS FINALLY CALCULATED BY WEIGHTING
C       ACCORDING TO SN.
      V(I)=SN*V(I)
C
C       THE TERM SN CHANGES ITS SIGN EACH ITERATION.
      SN=-SN
7     CONTINUE
C
C       THE NUMERICAL APPROXIMATION IS CALCULATED.
17     fa=0.
      A=DLOGTW/TD
      DO 15 I=1,N
      ARG=A*I
      fa=fa+V(I)* p(arg)
15     CONTINUE
      fa=fa*A
18     RETURN
      END
```

TRANSIENT LINEAR BEHAVIOR

```
c  Constant Rate of Influx Across Aquifer-Reservoir Boundary
c
c  Variables used:
c        td    =      dimensionless time
c        pd     = dimensionless pressure
c
        implicit real*8(a-h,o-z)
        dimension tdd(10000),Fdd( 10000)

        pi=3.141592654
        error=1Oe-9

c Calculate F1/2(td)
c Constant We inner boundary, infinite outer boundary.
c Constant P inner boundary, infinite outer boundary.

        nn=0
        do 10 i=1,10
          aa=i
          do 20 j=1,36
            bb–j
            dt= 0.0001*(1. +(bb-1)*0.25)*(10.**(aa))
            td= dt
            if(td.lt.0.006.or.td.gt.10)  go to 20
            F=2.*((td/pi)**0.5)
            if(F.lt.0.01)go to 20
            nn=nn+1
            Fdd(nn)=F
            tdd(nn)=td
 20         continue
 10       continue

          write(6,1000) nn
          do 30 m=1,nn
             time=tdd(m)
             efff=Fdd(m)
             write(6,2000) time,efff
 30       continue

 1000 format(5x,i3)
 2000 format(5x,e10.5,5x,e15.7)
```

```
c Calculate F1(td)...finite linear aquifer
c Constant We inner boundary, sealed outer boundary.
c Constant P inner boundary, constant pressure outer boundary.

      nn=0
      do 40 i=1,10
        aa=i
        do 50 j=1,72
          bb=j
          dt= 0.001*(1. +(bb-1)*0.25)*(10.**(aa))
          td= 0.25 + dt
          if(td.gt.10) go to 50
          sum=0.0
          do 60 k=1,1000
            sum1=sum
            sum=sum+(1./k**2)*dexp(-(k**2.)*(pi**2.)*td)
            err=dabs(sum1-sum)
            if (err.lt.error)go to 70
 60       continue
 70       F1=(td+1./3.) - (2./(pi**2.))*sum
          if(F1.lt.0.01)go to 50
          nn=nn+1
          Fdd(nn)=F1
          tdd(nn)=td
 50     continue
 40   continue

      write(6,1000) nn
      do 80 m=1,nn
          time=tdd(m)
          eff2=Fdd(m)
          write(6,2000) time,eff2
 80   continue
```

```
c Calculate F0(td) ...finite linear aquifer
c Constant We inner boundary, constant pressure outer boundary.
c Constant P inner boundary, sealed outer boundary.

      nn=0
      do 81 i=1,10
        aa=i
        do 82 j=1,36
          bb=j
          dt= 0.001*(1. +(bb-1)*0.25)*(10.**(aa))
          td= 0.25 + dt
          if(td.gt.10) go to 82
          sum=0.0
          do 83 k=1,1000
            ak=(2.*k) - 1
            sum1=sum
            sum=sum+(1./ak**2)*dexp((-(ak**2.)*(pi**2.)*td)/4.)
            err=dabs(sum1-sum)
            if (err.lt.error)go to 84
 83       continue
 84       F0= 1. - (8./pi**2.)*sum
          if(F0.lt.0.01)go to 82
          nn=nn+1
          Fdd(nn)=F0
          tdd(nn)=td
 82     continue
 81   continue

      write(6,1000) nn
      do 85 m=1,nn
          time=tdd(m)
          eff2=Fdd(m)
          write(6,2000) time,eff2
 85   continue

      stop
      end
```

CONSTANT RATE INNER BOUNDARY, INFINITE RADIAL SYSTEM

```
c  Variables used:
c      td       = dimensionless time
c      pd       = dimensionless pressure
c      sigma  = spunginess ratio relating aquifer compressibility
c                    to reservoir compressibility.
c      FA       = stehfest algorithm to invert Laplace: space solution.

       implicit real*8(a-h,o-z)
       dimension tdd(1000),pdd( 1000)
       common sigma

       N=10
       M=N+1
 10    write(0,*)'enter sigma (type 0.0 to quit)'
       read(5,*) sigma
       if(sigma.eq.0.0)go to 70

       nn=0
       dt=0.0
       do 20 i=1,15
          aa=i
          do 30 j=1,36
             bb–j
             tdlog=-4.+ aa +(bb-1)/36.
             td=10.**tdlog
             if(td.lt..001.or.td.gt.10000.) go to 30
             pd=FA(td,N,M)
             if (pd.lt.0.00006.or.pd.gt.10) go to 30
             nn=nn+1
             pdd(nn)=pd
             tdd(nn)= td
 30       continue
 20    continue

 40    write(6,1000) nn
       do 50 k=1,nn
          time=tdd(k)
          pres=pdd(k)
          write(6,2000) time,pres
 50    continue

 1000      format(5x,i3)
 2000      format(5x,e17.5,5x,e15.7)
       go to 10
 70    stop
       end
```

LINEAR FAULT, DRAWDOWN INTERFERENCE TEST (SMALL R2/R1 RATIOS)

```
c  This program calculates pD and pD' versus tD for the sealed linear
c  fault type curve.
c  R2/R1 ratios used were: 1.0, 1.1, 1.2, 1.5, 2.0, 3.0, 5.0 and 10.0.
c
c  Variables used:
c       mmdei- IMSL routine to calculate the exponential integral
c       rd    = r2/r1 ratios desired
c       pd    = dimensionless pressure
c       dpd   = dimensionless pressure derivative
c       td    = dimensionless time

        implicit real*8(a-h,o-z)
        dimension tdd(1000),pdd(1000)
        double precision mmdei
        iopt=1

 10     write(0,*)'input r2/r1'
        write(0,*)' (type 0.0 to quit)'
        read(5,*)rd
        if(rd.eq.0.0)go to 90
        nn=0
c
c calculate dimensionless pressure
c
        do 20 i=1,15
          aa=i
          do 25 j=1,20
            bb=j
            tdlog=-3.+aa+(bb-1.)/20.
            td=10.**tdlog
            if(td.gt.1000) go to 40
            arg1=-1./(4.*td)
            arg2=-(rd*rd)/(4.*td)
            if(arg2.lt.-50.) go to 30
            pd=-0.5*(mmdei(iopt,arg1,ier)+mmdei(iopt,arg2,ier))
            go to 35
 30         pd=-0.5*mmdei(iopt,arg1,ier)
 35         if (pd.lt.O.00001) go to 25
            nn=nn+1
            pdd(nn)=pd
            tdd(nn)=td
 25       continue
 20     continue
```

LINEAR FAULT, DRAWDOWN INTERFERENCE TEST (SMALL R2/R1 RATIOS)

```
 40   write(6,1000) nn
      do 45 k=1,nn
        time=tdd(k)
        pres=pdd(k)
        write(6,2000) time,pres
 45   continue

 1000format(5x,i3)
 2000format(5x,e10.5,5x,e15.7)
c
c calculate the dimensionless pressure derivative
c
      do 50 i=1,15
        aa=i
        do 55 j=1,20
          bb=j
          tdlog=-3.+aa+(bb-1.)/20.
          td=10.**tdlog
          if(td.gt.1000) go to 60
          arg1=-1./(4.*td)
          arg2=-(rd*rd)/(4.*td)
          dpd= 0.5*(dexp(arg1)+dexp(arg2))
          nn=nn+1
          dpdd(nn)=dpd
          tdd(nn)=td
 55     continue
 50   continue

 60   write(6,1000) nn
      do 65 k=1,nn
        time=tdd(k)
        deriv=dpdd(k)
        write(6,2000) time,deriv
 65   continue

      go to 10
 90   stop
      end
```

PRESSURE DISTRIBUTION, RESERVOIR BETWEEN TWO PARALLEL SEALING FAULTS

```
c   Dimensionless pressure at various points between two
c   parallel linear faults, no wellbore storage, no skin.
c
c   Variables used:
c      mmdei= imsl routine to calculate the exponential integral
c      pd    = dimensionless pressure
c      td    = dimensionless time
c      bd    = dimensionless location of well
c      rd1   = the distance from well to image well (in positive direction)
c      rd2   = the distance from well to image well (in negative direction)
c      Ld    = the ratio of L to rw    Where L is the actual distance
c                between faults.
c      n     = half the length of the image well grid.... it increases as
c                td increases to achieve the pD error tolerance.
c      err   = the percentage error in pD caused by a finite grid of
c                image wells rather than an infinite grid.

       implicit real*8(a-h,o-z)
       real*8 Ld
       dimension tdd(10000),pdd( 10000)
       double precision mmdei

       iopt = 1
       error= 10e-9
       err = 10

 80    write(0,*)'Input bd (type 0.0 to quit)'
       read(5,*)bd
       if(bd.eq.0.0) go to 90
       write(0,*)'Input Ld'
       read(5,*)Ld

       dr2= bd
       dr1= 1.-bd

       np = 0
```

PRESSURE DISTRIBUTION, RESERVOIR BETWEEN TWO PARALLEL SEALING FAULTS (cont.)

```
c Time Loop
c
      do 10 i=1,12
        do 20 j=1,10
          tdlog= -3+i+(j-1)/10.
          if(tdlog.gt.9.1) go to 10
          td=10.**tdlog
          if(td.lt.0.035) go to 20
c
c calculate pd at well
c
          arg0 = -1./(4.*td)
          pdsum= -0.5*mmdei(iopt,arg0,ier)
c
c initialize rdl and rd2
c
 21       rdl = 0.0
          rd2 = 0.0

c Loop to calculate the pD contribution from image wells
c switch drl and dr2 to alternate a and b
c
 30       dummy = drl
          drl = dr2
          dr2 = dummy
c
c    calculate distance to next two image wells
c
          rdl = rdl + 2.*dr1
          rd2 = rd2 + 2.*dr2
c
          dpd = 0.0
          argl = -(rd1*rd1*Ld*Ld)/(4.*td)
          if(arg1.eq.0.0.or.arg1.lt.-50.0)go to 40
          pd= -0.5*mmdei(iopt,arg1,ier)
          pdsum=pdsum+pd
          dpd=pd
 40       arg2 = -(rd2*rd2*Ld*Ld)/(4.*td)
          if(arg2.eq.0.0.or.arg2.lt.-50.0)go to 41
          pd= -0.5*mmdei(iopt,arg2,ier)
          pdsum=pdsum+pd
          dpd=dpd+pd
```

PRESSURE DISTRIBUTION, RESERVOIR BETWEEN TWO PARALLEL SEALING FAULTS (cont.)

```
c     check error
c
 41          if(pdsum.lt.0.0001) go to 20
             if(pdsum.ne.0.0) err=dpd/pdsum
             if(err.lt.error) go to 50
             go to 30

 50          np=np+1
             pdd(np)=pdsum
             tdd(np)=td

 20        continue
 10     continue
c
c write results to output file
c
        write(6,1000)np
        do 70 m=1,np
          time=tdd(m)
          pres=pdd(m)
          write(6,2000) time,pres
 70     continue

 1000format(5x,i3)
 2000format(5x,e10.5,5x,e15.7)

        go to 80
 90     stop
        end
```

APPENDIX B

SELECTED DATA FROM THAT GENERATED BY THE COMPUTER PROGRAMS

SELECTED BUILDUP TEST VALUES (LINE SOURCE SOLUTION)

$\frac{t_{pD}}{r_D^2}$	$\frac{t_D}{r_D^2}$	p_D
0.1	0.1000	0.0125
	0.1600	0.0440
	0.2500	0.0705
	0.4000	0.0698
	0.6250	0.0563
	1.0000	0.0405
	1.6000	0.0275
	2.6000	0.0178
	4.1000	0.0116
	6.3500	0.0076
	10.1000	0.0049
1.0	1.0000	0.5221
	1.6000	0.3771
	2.5000	0.2242
	4.0000	0.1338
	6.2500	0.0834
	10.0000	0.0513
	16.0000	0.0318
	26.0000	0.0194
	41.0000	0.0123
	63.5000	0.0079
	101.0000	0.0050
10.0	10.0000	1.5683
	16.0000	0.4776
	25.0000	0.2521
	40.0000	0.1428
	62.5000	0.0868
	100.0000	0.0525
	160.0000	0.0322
	260.0000	0.0196
	410.0000	0.0123
	635.0000	0.0079
	1010.0000	0.0050

SELECTED BUILDUP TEST VALUES
(LINE SOURCE SOLUTION - CONTINUED)

$\frac{t_{pD}}{r_D^2}$	$\frac{t_D}{r_D^2}$	p_D
100.0	100.0000	2.7084
	160.0000	0.4891
	250.0000	0.2551
	400.0000	0.1437
	625.0000	0.0871
	1000.0000	0.0527
	1600.0000	0.0323
	2600.0000	0.0196
	4100.0000	0.0123
	6350.0000	0.0079
	10100.0000	0.0050
1000.0	1000.0000	3.8585
	1600.0000	0.4903
	2500.0000	0.2554
	4000.0000	0.1438
	6250.0000	0.0872
	10000.0000	0.0527
	16000.0000	0.0323
	26000.0000	0.0196
	41000.0000	0.0123
	63500.0000	0.0079
	101000.0000	0.0050

PRESSURE DISTRIBUTIONS IN A CLOSED SQUARE RESERVOIR

SELECTED TYPE-CURVE VALUES

(x_D,y_D)	t_{DA}	p_D
(0.0,0.0)	0.0010	4.5516
	0.0016	4.7818
	0.0025	5.0121
	0.0040	5.2423
	0.0063	5.4726
	0.0100	5.7029
	0.0158	5.9331
	0.0251	6.1634
	0.0398	6.3942
	0.0631	6.6319
	0.1000	6.9063
	0.1585	7.2850
	0.2512	7.8686
	0.3981	8.7918
	0.6310	10.2548
	1.0000	12.5736
	1.5849	16.2486
	2.5119	22.0730
	3.9811	31.3042
	6.3096	45.9346
	10.0000	69.1222
(.25,.25)	0.0025	0.0057
	0.0040	0.0258
	0.0063	0.0746
	0.0100	0.1607
	0.0158	0.2842
	0.0251	0.4396
	0.0398	0.6204
	0.0631	0.8287
	0.1000	1.0902
	0.1585	1.4656
	0.2512	2.0489
	0.3981	2.9720
	0.6310	4.4351
	1.0000	6.7538
	1.5849	10.4288
	2.5119	16.2533
	3.9811	25.4845
	6.3096	40.1149
	10.0000	63.3025

PRESSURE DISTRIBUTIONS IN A CLOSED SQUARE RESERVOIR

SELECTED TYPE-CURVE VALUES (CONTINUED)

(x_D, y_D)	t_{DA}	p_D
(.50,.50)	0.0100	0.0056
	0.0158	0.0254
	0.0251	0.0742
	0.0398	0.1638
	0.0631	0.3098
	0.1000	0.5417
	0.1585	0.9092
	0.2512	1.4916
	0.3981	2.4147
	0.6310	3.8778
	1.0000	6.1965
	1.5849	9.8715
	2.5119	15.6960
	3.9811	24.9272
	6.3096	39.5576
	10.0000	62.7452
(1.0,1.0)	0.0251	0.0024
	0.0398	0.0219
	0.0631	0.1004
	0.1000	0.2939
	0.1585	0.6505
	0.2512	1.2317
	0.3981	2.1548
	0.6310	3.6178
	1.0000	5.9366
	1.5849	9.6116
	2.5119	15.4361
	3.9811	24.6672
	6.3096	39.2976
	10.0000	62.4853

FINITE RADIUS WELLBORE, INFINITE SYSTEM

SELECTED TYPE-CURVE VALUES

r_D	$\frac{t_D}{r_D^2}$	p_D
1.0	0.0100	0.1081
	0.0150	0.1312
	0.0250	0.1669
	0.0400	0.2077
	0.0625	0.2546
	0.1000	0.3142
	0.1250	0.3466
	0.1500	0.3751
	0.2500	0.4659
	0.4000	0.5646
	0.6250	0.6727
	1.0000	0.8021
1.2	0.0104	0.0188
	0.0156	0.0344
	0.0260	0.0638
	0.0417	0.1021
	0.0625	0.1449
	0.1042	0.2129
	0.1562	0.2790
	0.2604	0.3789
	0.4167	0.4879
	0.6250	0.5953
1.5	0.0200	0.0093
	0.0256	0.0162
	0.0400	0.0376
	0.0667	0.0789
	0.1000	0.1266
	0.1556	0.1950
	0.2556	0.2929
	0.4000	0.4004
	0.6667	0.5446
	1.0000	0.6744

FINITE RADIUS WELLBORE, INFINITE SYSTEM

SELECTED TYPE-CURVE VALUES (CONTINUED)

r_D	$\frac{t_D}{r_D^2}$	p_D
3.0	0.0556	0.0087
	0.0639	0.0131
	0.1000	0.0386
	0.1667	0.0961
	0.2500	0.1673
	0.4167	0.2897
	0.6389	0.4179
	1.0000	0.5738
20.0	0.0875	0.0087
	0.1000	0.0136
	0.1625	0.0494
	0.2500	0.1124
	0.4375	0.2435
	0.6250	0.3537
	1.0000	0.5242

PRESSURE DROP AND CUMULATIVE INFLUX, LINEAR AQUIFERS

F-FUNCTIONS

t_D	$F_0(t_D)$	$F_{\frac{1}{2}}(t_D)$	$F_1(t_D)$
0.2500	0.5622	0.5642	0.5661
0.3000	0.6132	0.6180	0.6228
0.3500	0.6582	0.6676	0.6769
0.4000	0.6979	0.7136	0.7294
0.4500	0.7330	0.7569	0.7809
0.5000	0.7640	0.7979	0.8319
0.5500	0.7913	0.8368	0.8824
0.6000	0.8156	0.8740	0.9328
0.6500	0.8370	0.9097	0.9830
0.7000	0.8559	0.9441	1.0331
0.7500	0.8726	0.9772	1.0832
0.8000	0.8874	1.0093	1.1333
0.8500	0.9005	1.0403	1.1833
0.9000	0.9120	1.0705	1.2333
0.9500	0.9222	1.0998	1.2833
1.2500	0.9629	1.2616	1.5833
1.7500	0.9892	1.4927	2.0833
2.2500	0.9969	1.6926	2.5833
2.7500	0.9991	1.8712	3.0833

SELECTED HURST WATER INFLUX TYPE CURVE VALUES

(CONSTANT RATE INNER-BOUNDARY,,INFINITE SYSTEM)

σ	t_D	p_D
.01	1.0000	0.0099
	1.5849	0.0156
	2.5119	0.0247
	3.9811	0.0389
	6.3096	0.0611
	10.0000	0.0958
	15.8489	0.1494
	25.1189	0.2314
	39.8107	0.3549
	63.0957	0.5371
	100.0000	0.7976
	158.4893	1.1536
	251.1886	1.6110
	398.1072	2.1516
	630.9573	2.7259
	1000.0000	3.2676
.02	1.0000	0.0196
	1.5849	0.0309
	2.5119	0.0485
	3.9811	0.0760
	6.3096	0.1186
	10.0000	0.1837
	15.8489	0.2821
	25.1189	0.4278
	39.8107	0.6375
	63.0957	0.9274
	100.0000	1.3069
	158.4893	1.7679
	251.1886	2.2774
	398.1072	2.7826
	630.9573	3.2351
	1000.0000	3.6166

SELECTED HURST WATER INFLUX TYPE CURVE VALUES

(CONSTANT RATE INNER-BOUNDARY, INFINITE SYSTEM) - cont.

σ	t_D	p_D
.04	1.0000	0.0385
	1.5849	0.0602
	2.5119	0.0939
	3.9811	0.1454
	6.3096	0.2234
	10.0000	0.3390
	15.8489	0.5062
	25.1189	0.7394
	39.8107	1.0489
	63.0957	1.4335
	100.0000	1.8731
	158.4893	2.3289
	251.1886	2.7582
	398.1072	3.1362
	630.9573	3.4631
	1000.0000	3.7532
.06	1.0000	0.0567
	1.5849	0.0882
	2.5119	0.1363
	3.9811	0.2089
	6.3096	0.3163
	10.0000	0.4710
	15.8489	0.6861
	25.1189	0.9708
	39.8107	1.3242
	63.0957	1.7291
	100.0000	2.1520
	158.4893	2.5563
	251.1886	2.9190
	398.1072	3.2386
	630.9573	3.5256
	1000.0000	3.7918

SELECTED HURST WATER INFLUX TYPE CURVE VALUES

(CONSTANT RATE INNER-BOUNDARY, INFINITE SYSTEM) - cont.

σ	t_D	P_D
.10	1.0000	0.0910
	1.5849	0.1400
	2.5119	0.2132
	3.9811	0.3204
	6.3096	0.4728
	10.0000	0.6811
	15.8489	0.9518
	25.1189	1.2811
	39.8107	1.6513
	63.0957	2.0336
	100.0000	2.3993
	158.4893	2.7328
	251.1886	3.0339
	398.1072	3.3104
	630.9573	3.5707
	1000.0000	3.8205
.20	0.1000	0.0190
	0.1585	0.0297
	0.2512	0.0462
	0.3981	0.0714
	0.6310	0.1096
	1.0000	0.1666
	1.5849	0.2498
	2.5119	0.3682
	3.9811	0.5308
	6.3096	0.7440
	10.0000	1.0079
	15.8489	1.3131
	25.1189	1.6410
	39.8107	1.9697
	63.0957	2.2832
	100.0000	2.5758

SELECTED HURST WATER INFLUX TYPE CURVE VALUES

(CONSTANT RATE INNER-BOUNDARY, INFINITE SYSTEM) - cont.

σ	t_D	P_D
.40	0.1000	0.0362
	0.1585	0.0558
	0.2512	0.0853
	0.3981	0.1291
	0.6310	0.1929
	1.0000	0.2835
	1.5849	0.4080
	2.5119	0.5721
	3.9811	0.7779
	6.3096	1.0215
	10.0000	1.2923
	15.8489	1.5760
	25.1189	1.8593
	39.8107	2.1343
	63.0957	2.3987
	100.0000	2.6534
.60	0.1000	0.0517
	0.1585	0.0788
	0.2512	0.1187
	0.3981	0.1763
	0.6310	0.2576
	1.0000	0.3685
	1.5849	0.5138
	2.5119	0.6956
	3.9811	0.9111
	6.3096	1.1527
	10.0000	1.4097
	15.8489	1.6717
	25.1189	1.9314
	39.8107	2.1857
	63.0957	2.4341
	100.0000	2.6775

SELECTED VALUES FROM LINEAR FAULT CURVES

SMALL R2/R1 RATIOS, INTERFERENCE TEST

	r_2/r 1.0		r_2/r 1.1	
t_D	p_D	p_D'	p_D	p_D'
0.1000	0.0249	0.0821	0.0188	0.0653
0.1259	0.0499	0.1373	0.0391	0.1139
0.1585	0.0892	0.2065	0.0724	0.1774
0.1995	0.1457	0.2857	0.1217	0.2526
0.2512	0.2211	0.3696	0.1892	0.3348
0.3162	0.3160	0.4536	0.2760	0.4189
0.3981	0.4297	0.5337	0.3820	0.5007
0.5012	0.5612	0.6072	0.5062	0.5771
0.6310	0.7088	0.6729	0.6471	0.6460
0.7943	0.8704	0.7300	0.8030	0.7066
1.0000	1.0443	0.7788	0.9719	0.7589
1.2589	1.2285	0.8199	1.1519	0.8031
1.5849	1.4213	0.8541	1.3412	0.8402
1.9953	1.6213	0.8822	1.5383	0.8708
2.5119	1.8272	0.9053	1.7418	0.8959
3.1623	2.0379	0.9240	1.9505	0.9164
3.9811	2.2525	0.9391	2.1635	0.9330
5.0119	2.4702	0.9513	2.3799	0.9464
6.3096	2.6904	0.9612	2.5991	0.9572
7.9433	2.9126	0.9690	2.8206	0.9658
10.0000	3.1365	0.9753	3.0438	0.9728
12.5893	3.3617	0.9803	3.2684	0.9783
15.8489	3.5879	0.9843	3.4942	0.9827
19.9526	3.8149	0.9875	3.7209	0.9863
25.1189	4.0426	0.9901	3.9484	0.9891
31.6228	4.2708	0.9921	4.1764	0.9913
39.8107	4.4995	0.9937	4.4048	0.9931
50.1187	4.7285	0.9950	4.6337	0.9945
63.0957	4.9577	0.9960	4.8628	0.9956
79.4328	5.1871	0.9969	5.0922	0.9965
100.0000	5.4167	0.9975	5.3217	0.9972
125.8925	5.6465	0.9980	5.5514	0.9978
158.4893	5.8763	0.9984	5.7812	0.9983
199.5262	6.1063	0.9987	6.0111	0.9986
251.1886	6.3363	0.9990	6.2411	0.9989
316.2278	6.5663	0.9992	6.4711	0.9991
398.1072	6.7964	0.9994	6.7012	0.9993
501.1872	7.0266	0.9995	6.9313	0.9994
630.9573	7.2567	0.9996	7.1614	0.9996
794.3282	7.4869	0.9997	7.3916	0.9997
1000.0000	7.7171	0.9998	7.6218	0.9997

SELECTED VALUES FROM LINEAR FAULT CURVES

SMALL R2/R1 RATIOS, INTERFERENCE TEST (cont.)

	r_2/r_1=1.2		r_2/r_1=1.5	
t_D	p_D	p_D'	p_D	p_D'
0.1000	0.0155	0.0547	0.0127	0.0428
0.1259	0.0327	0.0973	0.0260	0.0744
0.1585	0.0615	0.1548	0.0479	0.1176
0.1995	0.1050	0.2251	0.0811	0.1727
0.2512	0.1658	0.3041	0.1282	0.2381
0.3162	0.2454	0.3870	0.1913	0.3112
0.3981	0.3440	0.4693	0.2718	0.3886
0.5012	0.4611	0.5474	0.3703	0.4664
0.6310	0.5956	0.6190	0.4864	0.5414
0.7943	0.7456	0.6828	0.6192	0.6113
1.0000	0.9094	0.7382	0.7674	0.6743
1.2589	1.0850	0.7856	0.9292	0.7298
1.5849	1.2706	0.8254	1.1029	0.7777
1.9953	1.4646	0.8586	1.2867	0.8183
2.5119	1.6655	0.8859	1.4792	0.8523
3.1623	1.8722	0.9082	1.6788	0.8805
3.9811	2.0834	0.9263	1.8843	0.9037
5.0119	2.2985	0.9410	2.0946	0.9226
6.3096	2.5166	0.9528	2.3089	0.9379
7.9433	2.7371	0.9624	2.5263	0.9503
10.0000	2.9596	0.9700	2.7464	0.9603
12.5893	3.1837	0.9761	2.9684	0.9683
15.8489	3.4090	0.9809	3.1922	0.9747
19.9526	3.6353	0.9848	3.4172	0.9799
25.1189	3.8625	0.9879	3.6433	0.9840
31.6228	4.0903	0.9904	3.8703	0.9872
39.8107	4.3185	0.9924	4.0979	0.9899
50.1187	4.5472	0.9939	4.3261	0.9919
63.0957	4.7762	0.9952	4.5547	0.9936
79.4328	5.0055	0.9962	4.7836	0.9949
100.0000	5.2350	0.9970	5.0128	0.9959
125.8925	5.4646	0.9976	5.2423	0.9968
158.4893	5.6944	0.9981	5.4719	0.9974
199.5262	5.9242	0.9985	5.7016	0.9980
251.1886	6.1542	0.9988	5.9314	0.9984
316.2278	6.3842	0.9990	6.1614	0.9987
398.1072	6.6142	0.9992	6.3914	0.9990
501.1872	6.8443	0.9994	6.6214	0.9992
630.9573	7.0745	0.9995	6.8515	0.9994
794.3282	7.3046	0.9996	7.0816	0.9995
1000.0000	7.5348	0.9997	7.3118	0.9996

SELECTED VALUES FROM LINEAR FAULT CURVES

SMALL R2/R1 RATIOS, INTERFERENCE TEST (cont.)

	r_2/r_1 2.0		r_2/r_1 3.0	
t_D	P_D	P_D'	P_D	P_D'
0.1000	0.0125	0.0411	0.0125	0.0410
0.1259	0.0250	0.0688	0.0249	0.0686
0.1585	0.0447	0.1042	0.0446	0.1033
0.1995	0.0734	0.1462	0.0729	0.1428
0.2512	0.1125	0.1941	0.1106	0.1849
0.3162	0.1633	0.2480	0.1580	0.2272
0.3981	0.2271	0.3074	0.2151	0.2686
0.5012	0.3052	0.3716	0.2817	0.3092
0.6310	0.3985	0.4389	0.3576	0.3506
0.7943	0.5074	0.5070	0.4433	0.3944
1.0000	0.6318	0.5733	0.5395	0.4421
1.2589	0.7711	0.6359	0.6472	0.4937
1.5849	0.9243	0.6931	0.7671	0.5479
1.9953	1.0898	0.7440	0.8996	0.6030
2.5119	1.2664	0.7884	1.0447	0.6568
3.1623	1.4524	0.8264	1.2018	0.7074
3.9811	1.6465	0.8585	1.3701	0.7537
5.0119	1.8474	0.8852	1.5485	0.7948
6.3096	2.0538	0.9073	1.7357	0.8306
7.9433	2.2649	0.9254	1.9306	0.8612
10.0000	2.4797	0.9401	2.1319	0.8869
12.5893	2.6976	0.9520	2.3387	0.9083
15.8489	2.9179	0.9616	2.5500	0.9260
19.9526	3.1403	0.9693	2.7649	0.9405
25.1189	3.3642	0.9755	2.9829	0.9522
31.6228	3.5894	0.9805	3.2032	0.9617
39.8107	3.8157	0.9845	3.4256	0.9694
50.1187	4.0427	0.9876	3.6495	0.9756
63.0957	4.2705	0.9902	3.8748	0.9805
79.4328	4.4987	0.9922	4.1010	0.9845
100.0000	4.7273	0.9938	4.3281	0.9876
125.8925	4.9563	0.9951	4.5558	0.9902
158.4893	5.1856	0.9961	4.7840	0.9922
199.5262	5.4150	0.9969	5.0127	0.9938
251.1886	5.6446	0.9975	5.2416	0.9950
316.2278	5.8744	0.9980	5.4709	0.9961
398.1072	6.1042	0.9984	5.7003	0.9969
501.1872	6.3342	0.9988	5.9299	0.9975
630.9573	6.5642	0.9990	6.1597	0.9980
794.3282	6.7942	0.9992	6.3895	0.9984
1000.0000	7.0243	0.9994	6.6195	0.9988

SELECTED VALUES FROM LINEAR FAULT CURVES

SMALL R2/R1 RATIOS, INTERFERENCE TEST (cont.)

	r_2/r_1=5.0		r_2/r_1=10.0	
t_D	p_D	p_D'	p_D	p_D'
0.1000	0.0125	0.0410	0.0125	0.0410
0.1259	0.0249	0.0686	0.0249	0.0686
0.1585	0.0446	0.1033	0.0446	0.1033
0.1995	0.0729	0.1428	0.0729	0.1428
0.2512	0.1106	0.1848	0.1106	0.1848
0.3162	0.1580	0.2268	0.1580	0.2268
0.3981	0.2149	0.2668	0.2149	0.2668
0.5012	0.2806	0.3036	0.2806	0.3036
0.6310	0.3544	0.3365	0.3544	0.3364
0.7943	0.4352	0.3652	0.4352	0.3650
1.0000	0.5223	0.3904	0.5221	0.3894
1.2589	0.6148	0.4134	0.6142	0.4099
1.5849	0.7127	0.4367	0.7107	0.4270
1.9953	0.8162	0.4629	0.8107	0.4411
2.5119	0.9263	0.4942	0.9136	0.4527
3.1623	1.0442	0.5313	1.0190	0.4622
3.9811	1.1713	0.5736	1.1264	0.4705
5.0119	1.3086	0.6193	1.2357	0.4791
6.3096	1.4566	0.6663	1.3472	0.4901
7.9433	1.6154	0.7122	1.4617	0.5060
10.0000	1.7844	0.7553	1.5807	0.5287
12.5893	1.9629	0.7945	1.7058	0.5588
15.8489	2.1499	0.8292	1.8386	0.5954
19.9526	2.3444	0.8593	1.9803	0.6366
25.1189	2.5453	0.8849	2.1319	0.6799
31.6228	2.7516	0.9064	2.2934	0.7229
39.8107	2.9624	0.9242	2.4646	0.7637
50.1187	3.1770	0.9389	2.6448	0.8011
63.0957	3.3946	0.9509	2.8332	0.8345
79.4328	3.6147	0.9606	3.0288	0.8634
100.0000	3.8368	0.9685	3.2305	0.8882
125.8925	4.0606	0.9748	3.4375	0.9090
158.4893	4.2856	0.9799	3.6488	0.9262
199.5262	4.5118	0.9840	3.8638	0.9405
251.1886	4.7387	0.9872	4.0817	0.9521
316.2278	4.9663	0.9898	4.3021	0.9616
398.1072	5.1945	0.9919	4.5244	0.9693
501.1872	5.4231	0.9936	4.7484	0.9754
630.9573	5.6520	0.9949	4.9735	0.9804
794.3282	5.8812	0.9959	5.1998	0.9844
1000.0000	6.1106	0.9968	5.4268	0.9875

SELECTED VALUES FROM PARALLEL SEALING FAULTS, b_D=0.5

	L_D=5	L_D=10	L_D=50	L_D=100
t_D	P_D	P_D	P_D	P_D
.1000e+01	0.5224	0.5221	0.5221	0.5221
.1334e+01	0.6396	0.6380	0.6380	0.6380
.1778e+01	0.7671	0.7603	0.7603	0.7603
.2371e+01	0.9085	0.8876	0.8876	0.8876
.3162e+01	1.0695	1.0190	1.0189	1.0189
4217e+01	1.2564	1.1537	1.1533	1.1533
5623e+01	1.4748	1.2922	1.2900	1.2900
7499e+01	1.7296	1.4370	1.4285	1.4285
1000e+02	2.0260	1.5932	1.5683	1.5683
1334e+02	2.3699	1.7674	1.7091	1.7091
1778e+02	2.7683	1.9664	1.8507	1.8507
2371e+02	3.2293	2.1962	1.9928	1.9928
3162e+02	3.7624	2.4621	2.1354	2.1354
4217e+02	4.3785	2.7697	2.2783	2.2783
5623e+02	5.0904	3.1252	2.4215	2.4215
.7499e+02	5.9128	3.5361	2.5649	2.5649
1000e+03	6.8626	4.0109	2.7086	2.7084
1334e+03	7.9597	4.5592	2.8536	2.8520
.1778e+03	9.2267	5.1926	3.0025	2.9957
.2371e+03	10.6899	5.9241	3.1602	3.1394
.3162e+03	12.3796	6.7689	3.3337	3.2832
.4217e+03	14.3310	7.7446	3.5301	3.4274
.5623e+03	16.5844	8.8712	3.7556	3.5730
.7499e+03	19.1866	10.1723	4.0158	3.7232
.1000e+04	22.1917	11.6748	4.3163	3.8835
.1334e+04	25.6618	13.4099	4.6633	4.0607
.1778e+04	29.6691	15.4135	5.0640	4.2621
.2371e+04	34.2967	17.7273	5.5267	4.4936
.3162e+04	39.6406	20.3992	6.0611	4.7608
.4217e+04	45.8115	23.4847	6.6782	5.0693
.5623e+04	52.9377	27.0478	7.3908	5.4256
.7499e+04	61.1668	31.1624	8.2137	5.8371
.1000e+05	70.6697	35.9138	9.1640	6.3122
.1334e+05	81.6435	41.4007	10.2613	6.8609
.1778e+05	94.3158	47.7368	11.5286	7.4945
.2371e+05	108.9495	55.0537	12.9919	8.2262
.3162e+05	125.8483	63.5031	14.6818	9.0711
.4217e+05	145.3627	73.2603	16.6333	10.0469
.5623e+05	167.8976	84.5277	18.8867	11.1736
.7499e+05	193.9204	97.5392	21.4890	12.4747

PARALLEL SEALING FAULTS, b_D=0.5 (cont.)

	L_D=5	L_D=10	L_D=50	L_D=100
t_D	p_D	p_D	p_D	p_D
.1000e+06	223.9712	112.5645	24.4941	13.9773
.1334e+06	258.6732	129.9156	27.9643	15.7124
.1778e+06	298.7465	149.9522	31.9716	17.7160
.2371e+06	345.0225	173.0902	36.5992	20.0298
.3162e+06	398.4611	199.8095	41.9431	22.7018
.4217e+06	460.1710	230.6645	48.1141	25.7873
.5623e+06	531.4325	266.2952	55.2403	29.3504
.7499e+06	613.7240	307.4410	63.4694	33.4649
.1000e+07	708.7527	354.9554	72.9723	38.2164
.1334e+07	818.4901	409.8241	83.9461	43.7032
.1778e+07	945.2129	473.1856	96.6183	50.0394
.2371e+07	1091.5501	546.3542	111.2521	57.3563
.3162e+07	1260.5375	630.8480	128.1509	65.8057
.4217e+07	1455.6812	728.4200	147.6653	75.5629
.5623e+07	1681.0294	841.0942	170.2001	86.8303
.7499e+07	1941.2574	971.2084	196.2230	99.8417
.1000e+08	2241.7638	1121.4619	226.2738	114.8671
.1334e+08	2588.7831	1294.9719	260.9758	132.2181
.1778e+08	2989.5143	1495.3381	301.0491	152.2548
.2371e+08	3452.2713	1726.7172	347.3250	175.3928
.3162e+08	3986.6541	1993.9095	400.7636	202.1121
.4217e+08	4603.7491	2302.4582	462.4736	232.9670
.5623e+08	5316.3585	2658.7645	533.7351	268.5978
.7499e+08	6139.2657	3070.2203	616.0266	309.7436
.1000e+09	7089.5427	3545.3617	711.0553	357.2580
.1334e+09	8186.9031	4094.0458	820.7927	412.1267
.1778e+09	9454.1124	4727.6557	947.5155	475.4882
.2371e+09	10917.4591	5459.3362	1093.8527	548.6568
.3162e+09	12607.3003	6304.2663	1262.8401	633.1506
.4217e+09	14558.6915	7279.9746	11457.9837	730.7225
.5623e+09	16812.1137	8406.7028	11683.3320	843.3968
.7499e+09	19414.3125	9707.8252	1943.5600	973.5110
.1000e+10	22419.2680	11210.3339	2244.0664	1123.7645

PARALLEL SEALING FAULTS,,b_D=0.5 (cont.)

	L_D=500	L_D=1000	L_D=5000	L_D=10000
t_D	p_D	p_D	p_D	p_D
.1000e+01	0.5221	0.5221	0.5221	0.5221
.1334e+01	0.6380	0.6380	0.6380	0.6380
.1778e+01	0.7603	0.7603	0.7603	0.7603
.2371e+01	0.8876	0.8876	0.8876	0.8876
.3162e+01	1.0189	1.0189	1.0189	1.0189
.4217e+01	1.1533	1.1533	1.1533	1.1533
.5623e+01	1.2900	1.2900	1.2900	1.2900
.7499e+01	1.4285	1.4285	1.4285	1.4285
.1000e+02	1.5683	1.5683	1.5683	1.5683
.1334e+02	1.7091	1.7091	1.7091	1.7091
.1778e+02	1.8507	1.8507	1.8507	1.8507
.2371e+02	1.9928	1.9928	1.9928	1.9928
.3162e+02	2.1354	2.1354	2.1354	2.1354
.4217e+02	2.2783	2.2783	2.2783	2.2783
.5623e+02	2.4215	2.4215	2.4215	2.4215
.7499e+02	2.5649	2.5649	2.5649	2.5649
.1000e+03	2.7084	2.7084	2.7084	2.7084
.1334e+03	2.8520	2.8520	2.8520	2.8520
.1778e+03	2.9957	2.9957	2.9957	2.9957
.2371e+03	3.1394	3.1394	3.1394	3.1394
.3162e+03	3.2832	3.2832	3.2832	3.2832
.4217e+03	3.4270	3.4270	3.4270	3.4270
.5623e+03	3.5708	3.5708	3.5708	3.5708
.7499e+03	3.7147	3.7147	3.7147	3.7147
.1000e+04	3.8585	3.8585	3.8585	3.8585
.1334e+04	4.0024	4.0024	4.0024	4.0024
.1778e+04	4.1463	4.1463	4.1463	4.1463
.2371e+04	4.2902	4.2902	4.2902	4.2902
.3162e+04	4.4341	4.4341	4.4341	4.4341
.4217e+04	4.5780	4.5780	4.5780	4.5780
.5623e+04	4.7219	4.7219	4.7219	4.7219
.7499e+04	4.8658	4.8658	4.8658	4.8658
.1000e+05	5.0100	5.0097	5.0097	5.0097
.1334e+05	5.1553	5.1536	5.1536	5.1536
.1778e+05	5.3044	5.2975	5.2975	5.2975
.2371e+05	5.4623	5.4415	5.4414	5.4414
.3162e+05	5.6359	5.5854	5.5854	5.5854
.4217e+05	5.8324	5.7297	5.7293	5.7293
.5623e+05	6.0580	5.8754	5.8732	5.8732
.7499e+05	6.3182	6.0257	6.0171	6.0171

PARALLEL SEALING FAULTS,,b_D=0.5 (cont.)

	L_D=500	L_D=1000	L_D=5000	L_D=10000
t_D	p_D	p_D	p_D	p_D
.1000e+06	6.6187	6.1859	6.1610	6.1610
.1334e+06	6.9657	6.3632	6.3049	6.3049
.1778e+06	7.3665	6.5646	6.4488	6.4488
.2371e+06	7.8292	6.7961	6.5927	6.5927
.3162e+06	8.3636	7.0633	6.7366	6.7366
.4217e+06	8.9807	7.3719	6.8806	6.8806
.5623e+06	9.6933	7.7282	7.0245	7.0245
.7499e+06	10.5163	8.1396	7.1684	7.1684
.1000e+07	11.4665	8.6148	7.3126	7.3123
.1334e+07	12.5639	9.1635	7.4579	7.4562
.1778e+07	13.8312	9.7971	7.6070	7.6001
.2371e+07	15.2945	10.5288	7.7649	7.7440
.3162e+07	16.9844	11.3737	7.9385	7.8880
.4217e+07	18.9358	12.3494	8.1350	8.0322
.5623e+07	21.1893	13.4762	8.3606	8.1780
.7499e+07	23.7916	14.7773	8.6208	8.3282
.1000e+08	26.7967	16.2799	8.9213	8.4885
.1334e+08	30.2669	18.0150	9.2683	8.6658
.1778e+08	34.2742	20.0186	9.6691	8.8672
.2371e+08	38.9018	22.3324	10.1318	9.0987
.3162e+08	44.2457	25.0044	10.6662	9.3659
.4217e+08	50.4167	28.0899	11.2833	9.6745
.5623e+08	57.5428	31.6529	11.9959	10.0308
.7499e+08	65.7720	35.7675	12.8188	10.4422
.1000e+09	75.2749	40.5190	13.7691	10.9174
.1334e+09	86.2486	46.0058	14.8665	11.4661
.1778e+09	98.9209	52.3420	16.1337	12.0997
.2371e+09	113.5547	59.6589	17.5971	12.8314
.3162e+09	130.4534	68.1082	19.2870	13.6763
.4217e+09	149.9678	77.8654	21.2384	14.6520
.5623e+09	172.5027	89.1329	23.4919	15.7788
.7499e+09	198.5256	102.1443	26.0942	17.0799
.1000e+10	228.5763	117.1697	29.0993	18.5824