# APPENDIX

## CONTENT

# APPENDIX

## FLUSH MODEL FORMULAE

| | | | |
|---|---|---|---|
| **#1** | **r** | $(0 < r < 1)$ :constant | Solids content of aqueous pigment |
| **#2** | **r** | $\sum_{i=1}^{n} \frac{P_i}{P_i + W_i} = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} PW_i}$ | Calculation of **solids content** |
| **#3** | **i** | $(0 \le i \le n)$:integer | Incremental flush stages |
| **#4** | **P** | $P_i$ | Pigment charge at stage, **(i)** |
| **#5** | **V** | $V_i$ | Vehicle charge at stage, **(i)** |
| **#6** | **W** | $W_i = \frac{P_i}{r} - P_i$ | Water displacement at stage, **(i)** |
| **#7** | | $W_n = B - (\sum_{i=1}^{n} P_i + \sum_{i=1}^{n} V)_i$ | Water displacement at last stage, **(n)** |
| **#8** | | $n = \frac{(1-E_0)\frac{x_p}{r} + x_v}{x_{v_n}} = \frac{1/r \sum_{i=1}^{n} (P_i + V_i)}{x_{p_n} B}$ | Calculation of the number of stages required to flush the total charge of pigment and vehicle. ($E_0$ is in decimal format) |
| #9 | | $\sum_{i=1}^{n} (P_i + V_i)$ | Total charge after water displacement |
| **#10** | | $B = \frac{\sum_{i=1}^{n} (P_i + V_i)}{\%Eff} = \frac{\sum_{i=1}^{n} (P_i + V_i)}{1 - E_0}$ | Bulk capacity or working mixer capacity at % Effective, ***%Eff*** (~ 80% to 90%; decimal) and Allowance, **$E_o$** is in Decimal format |

# APPENDIX

## FLUSH MODEL FORMULAE

**#11** $$x_p = \frac{\sum_{i=1}^{n} P_i}{(\% Eff)(B)} = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} (P_i + V_i)}$$ % pigment in total charge

**#12** $$x_p = 1 - x_v$$ % pigment in total charge

**#13** $$x_v = \frac{\sum_{i=1}^{n} V_i}{(\% Eff)(B)}$$ % vehicle in total charge

**#14** $$x_v = 1 - x_p$$ % vehicle in total charge

**#15** $$k_v = \ln(\tfrac{\eta_v}{\eta_p})$$ Viscosity constant in the Exponential Viscosity Distribution

**#16** $$\eta_n = \eta_p e^{k_v x_v}$$ Relative End-Viscosity of the mix at stage (n)

**#17** $$k_{vn} = \ln\left(\frac{\eta_v}{\eta_n}\right)$$ Mix Viscosity Distribution Constant

**#18** $$\eta_j = \eta_n\left(1 - e^{k_{vn}\left(j/n\right)}\right) + \eta_v$$ Viscosity Distribution Function $0 \le i \le n$

**#19** $$P_i = \frac{Bx_{p_i} - \sum_{i=1}^{i-1} Pi}{\frac{1}{r} + x_{v_i}(1 - \frac{1}{r})}$$ Pigment Charge Distribution given $1 \le i \le n$

# APPENDIX

## FLUSH MODEL FORMULAE

**#20** $$V_i = B - \sum_{i=1}^{i-1}(P_i + V_i) - \frac{P_i}{r}$$ Vehicle Charge Distribution given $1 \le i \le n$

**#21** $$P_n = \frac{w_n r}{1 - r}$$ Final (nth) Pigment Charge given $\frac{P_n}{r} = P_n + w_n$

**#22** $$E_0 = \frac{w_n}{B}$$ Allowance = ***(100 - % Effective)***

**#23** $$PW + V \longrightarrow P + V + W \longrightarrow PV + W$$ Physical reaction of presscake ***(PW)***, mixing to a slurry ***(P+V+W)***, to produce a paste of wetted pigment, ***(PV)***, with displaced water, ***(W)***.

**#24** $$B \ge \sum_{i=1}^{i-1}(P + V)_i + PW_i + V_i$$ Expression of capacity (B), before

mixing and water displacement.

**#25** $$B \ge \sum_{i=1}^{i-1}(P + V)_i + PV_i + W_i$$ Expression of capacity (B), after

mixing and water displacement.

**#26** $$x_{v_i} = \frac{\ln(\frac{\eta_i}{\eta_p})}{k_v}$$ % Vehicle Distribution (Decimal Format)

**#27** $$y = \frac{1}{e^{kx^2}}$$ Error Function: y = % (the amount remaining)

$x \ge 0$: k = 1 standard error constant

**#28** $$y = 1 - \frac{1}{e^{kx^2}}$$ Error Function: y = % the amount displaced

$x \ge 0$: k = 1 standard error constant

# APPENDIX

**#29** $W_D$ — Water Displaced in stage (i): $W_i = \frac{P_i}{r} - P_i$

**#30** $w_i(t) = W_D\left(1 - e^{-kt^2}\right)$ — Water Displacement Function: t (hours)

**#31** $P_i(t) = \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1 - r)}$ — Pigment Wetting Function: t (hours)

**#32** $t = \sqrt{\left(\frac{1}{-k}\right)\ln\left(1 - \frac{w_i(t)}{W_D}\right)}$ — Time required to displace water, $w_i$: t (hours)

**#33** $T_{95_i} = \sqrt{\left(\frac{1}{-k}\right)\ln\left(1 - \frac{W_i}{W_D}\right)}$ — Time required to displace 95% water, $w_i$: t (hours)

**#34** $\frac{w(t)}{dt} = 2W_D kte^{-kt^2}$ — Water Displacement Rate

**#35** Paste Formation Rate

$$\frac{dP(t)}{dt} = \frac{r}{1 - r}\left[\frac{dw(t)}{dt}\right]$$

$$\frac{dP(t)}{dt} = \frac{r}{1 - r}\left[2W_D kte^{-kt^2}\right]$$

**#36** % Pigment with respect to mix time

$$\boxed{x_{P_i}(t) = \frac{\sum_{j=1}^{i-1} P_j + P_i(t)}{\sum_{j=1}^{i}(P_j + V_j)} = \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1 - r)}}{\sum_{j=1}^{i}(P_j + V_j)}}$$

**#37** % Vehicle with respect to mix time

$$x_{V_i}(t) = 1 - x_{P_i}(t)$$

$$x_{V_i}(t) = 1 - \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1 - r)}}{\sum_{j=1}^{i}(P_j + V_j)}$$

**#38** Viscosity with respect to mix time

$$\eta_i(t) = \eta_p e^{k_v x_v(t)}$$

$$\eta_i(t) = \eta_p e^{k_v[1 - x_p(t)]}$$

$$\eta_i(t) = \eta_p e^{k_v\left[1 - \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1 - r)}}{\sum_{j=1}^{i}(P_j + V_j)}\right]}$$

# APPENDIX

## BASIC PROGRAMS

### MODEL-A0

```
REM Pigment Distribution Based On Viscosity Function Algorithm
REM Created by Herb Norman Sr. for Mixer Problem Thesis (Treatment-1)
REM 05/28/2009 - 2nd Edition Revision to MIX00_A.BAS
REM MODEL_A.BAS - Revise Viscosity Distribution Page 65 Steps #5 & #6
REM MDL_A0.BAS - 06/15/2010 - Zero References to Residual
REM MDL_A0.BAS - 06/16/2010 - Create INDAT_A0.TXT and OUTDT_A0
REM*****************************************************************
CLS
F1$ = "C:\Herb\QBASIC\Mixer_3\INDAT_A0.TXT"
F2$ = "C:\Herb\QBASIC\Mixer_3\OUTDT_A0.TXT"

REM Input Parameters
REM ================
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Batch Nbr (NB$) ............... NB$ ="; nb$


W = 0: xv(0) = 0
xv(0) = 0


REM Calculate Constants
REM ===================
P(0) = W * (1 - xv(0))
V(0) = W * xv(0)
kv = LOG(nv / np)
xv = V / (P + V): xp = (1 - xv)
nmix = np * EXP(kv * xv)
n = INT((P / r + V) / (xv * B) + .5)
n0 = (P / r + V) / (xv * B)
a = LOG(nv / nmix)

REM 06/16/2010 - APPEND to Input File - INDAT_A0.TXT
REM ================================================

OPEN F1$ FOR APPEND AS #1
PRINT #1, nb$; CHR$(44); B; CHR$(44); P; CHR$(44); V; CHR$(44); r; CHR$(44); nv; CHR
$(44); np; CHR$(44); kv; CHR$(44); xv; CHR$(44); xp; CHR$(44); nmix; CHR$(44); a; CHR
$(44); n0; CHR$(44); n
CLOSE #1
```

# APPENDIX

## BASIC PROGRAMS

### MODEL-A0
### (Continued)

```
REM 06/16/2010 APPEND to Output File - OUTDT_A0.TXT
REM ==================================
OPEN F2$ FOR APPEND AS #1


REM Calculate Viscosity Distribution n(j)
REM ====================================PRINT "#  "; "Viscosity", "% Pgmt",
"Pigment", "Vehicle", "Water"
PRINT "== "; "=========", "======", "=======", "=======", "====="

FOR j = 1 TO n
    REM 05/28/2009 n(j) = INT(a * LOG(j + 1))
    n(j) = nmix * (1 - EXP(a * j / n)) + nv
    xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    xp(j) = 1 - xv(j)
    K1 = K1 + P(j - 1): K2 = K2 + V(j - 1)
    P(j) = INT((B * xp(j) - K1) / ((1 / r) + xv(j) * (1 - 1 / r)) + .5)
    V(j) = INT(B - (K1 + K2) - P(j) / r + .5)
    wd(j) = P(j) * (1 / r - 1)
    SumP = SumP + P(j): SumV = SumV + V(j): SumW = SumW + wd(j)
    PRINT j; n(j), xp(j), P(j), V(j), wd(j)
    PRINT #1, nb$; CHR$(44); n; CHR$(44); j; CHR$(44); n(j); CHR$(44); xp(j); CHR
$(44); xv(j); CHR$(44); P(j); CHR$(44); V(j); CHR$(44); wd(j)

NEXT j

CLOSE #1


PRINT : PRINT "Pigment Charge (INPUT)"; P
PRINT "Vehicle Charge (INPUT)"; V
PRINT "Sum of Optimized Pigment Charge"; SumP
PRINT "Sum of Optimized Vehicle Charges"; SumV
PRINT "Sum of Optimized Water Displacement"; SumW
PRINT "Original n .... n0"; n0
REM PRINT SumP, SumV, SumW
```

# APPENDIX

## MODEL-A1

```
REM Pigment Distribution Based On Viscosity Function Algorithm
REM Created by Herb Norman Sr. for Mixer Problem Thesis (Treatment-1)
REM 05/28/2009 - 2nd Edition Revision to MIX00_A.BAS
REM MODEL_A.BAS - Revise Viscosity Distribution Page 65 Steps #5 & #6
REM MODEL_A2.BAS - 06/10/2009  Input Nbr of Mix Stages & Calc V/P Ratio
REM MDL-A1.BAS
REM*****************************************************************
CLS
REM Input Parameters
REM ================
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Nbr of Mix Stages (n) .........  n ="; n
INPUT "Prior Residual (W) ............. W ="; W
INPUT "W Vehicle Content [xv(0)] ... xv(0) ="; xv(0)

REM B = 3000
REM P = 1350
REM V = 1200
REM r = .2
REM nv = 100
REM np = 240000
REM W = 0: xv(0) = 0
REM xv(0) = 0


REM Calculate Constants
REM ===================
P(0) = W * (1 - xv(0))
V(0) = W * xv(0)
kv = LOG(nv / np)
xv = V / (P + V): xp = (1 - xv)
nmix = np * EXP(kv * xv)
REM  06/10/2009  n = INT((P / r + V) / (xv * B) + .5)
n0 = (P / r + V) / (xv * B)
REM  05/28/2009 a = nmix / (LOG(n + 1))
a = LOG(nv / nmix)



REM Calculate Viscosity Distribution n(j)
REM =====================================
PRINT "#  "; "Viscosity", "% Pgmt", "Pigment", "Vehicle", "Water"; "  "; "V/P Ratio"
PRINT "== "; "=========", "======", "=======", "=======", "====="; "  "; "========="
```

# APPENDIX

## MODEL-A1
## (Continued)

```
FOR j = 1 TO n
    REM 05/28/2009 n(j) = INT(a * LOG(j + 1))
    n(j) = nmix * (1 - EXP(a * j / n)) + nv
    xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    xp(j) = 1 - xv(j)
    K1 = K1 + P(j - 1): K2 = K2 + V(j - 1)
    P(j) = INT((B * xp(j) - K1) / ((1 / r) + xv(j) * (1 - 1 / r)) + .5)
    V(j) = INT(B - (K1 + K2) - P(j) / r + .5)
    wd(j) = P(j) * (1 / r - 1)
    SumP = SumP + P(j): SumV = SumV + V(j): SumW = SumW + wd(j)
    vp = INT((SumV / SumP) * 100 + .5) / 100
    PRINT j; n(j), xp(j), P(j), V(j), wd(j); "    "; vp
NEXT j

PRINT : PRINT "Pigment Charge (INPUT)"; P
PRINT "Vehicle Charge (INPUT)"; V
PRINT "Sum of Optimized Pigment Charge"; SumP
PRINT "Sum of Optimized Vehicle Charges"; SumV
PRINT "Sum of Optimized Water Displacement"; SumW
PRINT "Calculated n .... n0"; n0
REM PRINT SumP, SumV, SumW
```

# APPENDIX

## MODEL-A3

```
REM Pigment Distribution Based On Viscosity Function Algorithm
REM Created by Herb Norman Sr. for Mixer Problem Thesis (Treatment-1)
REM 05/28/2009 - 2nd Edition Revision to MIX00_A.BAS
REM MODEL_A.BAS - Revise Viscosity Distribution Page 65 Steps #5 & #6
REM MODEL_AN.BAS - 06/10/2009  Input Nbr of Mix Stages & Calc V/P Ratio
REM MODEL_A3.BAS - 06/15/2009  Report C:\Herb\Mixer\MODEL_R3.TXT
REM MDL-A3.BAS
REM*****************************************************************
RP$ = "C:\Herb\Mixer\MODEL_R3.txt"
CLS
REM Input Parameters
REM ================
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Nbr of Mix Stages (n) .........  n ="; n
INPUT "Prior Residual (W) ............. W ="; W
INPUT "W Vehicle Content [xv(0)] ... xv(0) ="; xv(0)

REM B = 3000
REM P = 1350
REM V = 1200
REM r = .2
REM nv = 100
REM np = 240000
REM W = 0: xv(0) = 0
REM xv(0) = 0

REM Calculate Constants
REM ===================
P(0) = W * (1 - xv(0))
V(0) = W * xv(0)
kv = LOG(nv / np)
xv = V / (P + V): xp = (1 - xv)
nmix = np * EXP(kv * xv)
REM  06/10/2009  n = INT((P / r + V) / (xv * B) + .5)
n0 = (P / r + V) / (xv * B)
REM  05/28/2009 a = nmix / (LOG(n + 1))
a = LOG(nv / nmix)

OPEN RP$ FOR APPEND AS #1

REM Calculate Viscosity Distribution n(j)
REM ======================================
PRINT "#  "; "Viscosity", "% Pgmt", "Pigment", "Vehicle", "Water"; "  "; "V/P Ratio"
PRINT "== "; "=========", "======", "=======", "=======", "====="; "  "; "========="

PRINT #1, "#  "; "Viscosity", "% Pgmt", "Pigment", "Vehicle", "Water"; "  "; "V/P
Ratio"
PRINT #1, "== "; "=========", "======", "=======", "=======", "====="; "  ";
"========="
```

## MODEL-A3
## (Continued)

```
FOR j = 1 TO n
    REM 05/28/2009 n(j) = INT(a * LOG(j + 1))
    n(j) = nmix * (1 - EXP(a * j / n)) + nv
    xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    xp(j) = 1 - xv(j)
    K1 = K1 + P(j - 1): K2 = K2 + V(j - 1)
    P(j) = INT((B * xp(j) - K1) / ((1 / r) + xv(j) * (1 - 1 / r)) + .5)
    V(j) = INT(B - (K1 + K2) - P(j) / r + .5)
    wd(j) = P(j) * (1 / r - 1)
    SumP = SumP + P(j): SumV = SumV + V(j): SumW = SumW + wd(j)
    vp = INT((SumV / SumP) * 100 + .5) / 100
    PRINT j; n(j), xp(j), P(j), V(j), wd(j); "    "; vp
    PRINT #1, j; n(j), xp(j), P(j), V(j), wd(j); "    "; vp
NEXT j

PRINT : PRINT "Pigment Charge (INPUT)"; P
PRINT "Vehicle Charge (INPUT)"; V
PRINT "Sum of Optimized Pigment Charge"; SumP
PRINT "Sum of Optimized Vehicle Charges"; SumV
PRINT "Sum of Optimized Water Displacement"; SumW
PRINT "Calculated n .... n0"; n0
REM PRINT SumP, SumV, SumW

PRINT #1, : PRINT #1, "Pigment Charge (INPUT)"; P
PRINT #1, "Vehicle Charge (INPUT)"; V
PRINT #1, "Sum of Optimized Pigment Charge"; SumP
PRINT #1, "Sum of Optimized Vehicle Charges"; SumV
PRINT #1, "Sum of Optimized Water Displacement"; SumW
PRINT #1, "Calculated n .... n0"; n0


CLOSE #1
```

# APPENDIX

## MODEL-AN

```
REM Pigment Distribution Based On Viscosity Function Algorithm
REM Created by Herb Norman Sr. for Mixer Problem Thesis (Treatment-1)
REM 05/28/2009 - 2nd Edition Revision to MIX00_A.BAS
REM MODEL_A.BAS - Revise Viscosity Distribution Page 65 Steps #5 & #6
REM MODEL_AN.BAS - 06/10/2009  Input Nbr of Mix Stages & Calc V/P Ratio
REM*******************************************************************

CLS
REM Input Parameters
REM =================
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Nbr of Mix Stages (n) ..........  n ="; n
INPUT "Prior Residual (W) ............. W ="; W
INPUT "W Vehicle Content [xv(0)] ... xv(0) ="; xv(0)

REM B = 3000
REM P = 1350
REM V = 1200
REM r = .2
REM nv = 100
REM np = 240000
REM W = 0: xv(0) = 0
REM xv(0) = 0



REM Calculate Constants
REM ===================
P(0) = W * (1 - xv(0))
V(0) = W * xv(0)
kv = LOG(nv / np)
xv = V / (P + V): xp = (1 - xv)
nmix = np * EXP(kv * xv)
REM  06/10/2009  n = INT((P / r + V) / (xv * B) + .5)
n0 = (P / r + V) / (xv * B)
REM  05/28/2009 a = nmix / (LOG(n + 1))
a = LOG(nv / nmix)


REM Calculate Viscosity Distribution n(j)
REM =====================================
PRINT "#  "; "Viscosity", "% Pgmt", "Pigment", "Vehicle", "Water"; "  "; "V/P Ratio"
PRINT "== "; "=========", "======", "=======", "=======", "====="; "  "; "========="
```

# APPENDIX

## MODEL-AN
## (Continued)

```
FOR j = 1 TO n
    REM 05/28/2009 n(j) = INT(a * LOG(j + 1))
    n(j) = nmix * (1 - EXP(a * j / n)) + nv
    xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    xp(j) = 1 - xv(j)
    K1 = K1 + P(j - 1): K2 = K2 + V(j - 1)
    P(j) = INT((B * xp(j) - K1) / ((1 / r) + xv(j) * (1 - 1 / r)) + .5)
    V(j) = INT(B - (K1 + K2) - P(j) / r + .5)
    wd(j) = P(j) * (1 / r - 1)
    SumP = SumP + P(j): SumV = SumV + V(j): SumW = SumW + wd(j)
    vp = INT((SumV / SumP) * 100 + .5) / 100
    PRINT j; n(j), xp(j), P(j), V(j), wd(j); "    "; vp
NEXT j

PRINT : PRINT "Pigment Charge (INPUT)"; P
PRINT "Vehicle Charge (INPUT)"; V
PRINT "Sum of Optimized Pigment Charge"; SumP
PRINT "Sum of Optimized Vehicle Charges"; SumV
PRINT "Sum of Optimized Water Displacement"; SumW
PRINT "Calculated n .... n0"; n0
REM PRINT SumP, SumV, SumW
```

# APPENDIX

## MODEL-B0

```
REM Pigment Distribution Based On Viscosity Function Algorithm
REM Created by Herb Norman Sr. for Mixer Problem Thesis (Treatment-1)
REM 06/01/2009 - 2nd Edition Revision to Refer to MIX00_B.BAS
REM MDL-B0.BAS - Revise Viscosity Distribution
REM*******************************************************

CLS
REM Input Parameters
REM =================
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "% Pigment Charge (xp) ...........xp ="; xp
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Prior Residual (W) ............. W ="; W
INPUT "W Vehicle Content [xv(0)] ... xv(0) ="; xv(0)


REM B = 3000
REM P = 1350
REM V = 1200
REM r = .2
REM nv = 100
REM np = 250000
REM W = 0: xv(0) = 0
REM xv(0) = 0


REM Calculate Constants
REM ===================
xv = 1 - xp
P = B * .85 * xp
V = B * .85 - P
P(0) = W * (1 - xv(0))
V(0) = W * xv(0)
kv = LOG(nv / np)
nmix = np * EXP(kv * xv)
n = INT((P / r + V) / (xv * B) + .5)
n0 = (P / r + V) / (xv * B)
REM 06/01/2009 a = nmix / (LOG(n + 1))
a = LOG(nv / nmix)


REM Calculate Viscosity Distribution n(j)
REM ======================================
PRINT "#  "; "Viscosity", "% Pgmt", "Pigment", "Vehicle", "Water"
PRINT "== "; "=========", "======", "=======", "=======", "====="
```

# APPENDIX

## MODEL-B0
## (Continued)

```
FOR j = 1 TO n
    REM 06/01/2009 n(j) = INT(a * LOG(j + 1))
    n(j) = nmix * (1 - EXP(a * j / n)) + nv
    xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    xp(j) = 1 - xv(j)
    K1 = K1 + P(j - 1): K2 = K2 + V(j - 1)
    P(j) = INT((B * xp(j) - K1) / ((1 / r) + xv(j) * (1 - 1 / r)) + .5)
    V(j) = INT(B - (K1 + K2) - P(j) / r + .5)
    wd(j) = P(j) * (1 / r - 1)
    SumP = SumP + P(j): SumV = SumV + V(j): SumW = SumW + wd(j)
    PRINT j; n(j), xp(j), P(j), V(j), wd(j)
NEXT j


PRINT : PRINT "Pigment Charge (INPUT)"; P
PRINT "Vehicle Charge (INPUT)"; V
PRINT "Sum of Pigment Charge"; SumP
PRINT "Sum of Vehicle Charges"; SumV
PRINT "Sum of Water Displacement"; SumW
PRINT "Original n .... n0"; n0
REM PRINT SumP, SumV, SumW
```

# APPENDIX

## MODEL-C0

```
REM Iteration o find R factor in an infinite series
REM Created by Herb Norman Sr. for Mixer Problem Thesis
REM 12/26/1998 - MIX00_C.BAS
REM 06/03/2009 - MDL-C0.BAS:MODEL_C.BAS Modified Iteration to DO WHILE
REM*******************************************************

CLS
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np

e = 2.7183
ex = .5
kv = LOG(nv / np)
xp = P / (P + V)
n = INT((((P / r) + V) / (xp * B)) + .5)
pn = (r / (1 - r)) * (B - (P + V))

start:
REM Iteration Loop
REM FOR x = 1 TO 1000
REM     Ri = 1 + (x / 1000)
REM     y = (pn * ((Ri ^ n) - 1)) / (Ri - 1)
REM     IF y >= (P - ex) THEN
REM        IF y <= (P + ex) THEN
REM           Rx = Ri
REM        END IF
REM     END IF
REM NEXT x

REM 06/03/2009 Modify Iteration to DO WHILE (4 Place Accuracy)
y = -10
x% = 0
DO WHILE y < 0
   x% = x% + 1
   Ri = 1 + (x% / 10000)
   y = Ri ^ n - (P / pn) * (Ri - 1) - 1
LOOP
Rx = Ri
IF y > 0 THEN
   Rx = 1 + (x% - 1) / 10000
END IF


px = pn
P(n) = pn
xp(n) = P / (P + V): xv(n) = 1 - xp(n)
nj(n) = np * e ^ (kv * xv(n))
tp = tp + pn
```

# APPENDIX

## MODEL-C0
## (Continued)

```
CLS
PRINT "Total Pigment Charge ... (P) ="; P, "Total Vehicle Charge (V) ="; V
PRINT "Mixer Capacity ......... (B) ="; B, "% Solids of Pigment  (r) ="; r
PRINT "Calculated Series Ratio (Ri) ="; Rx, "Pigment Viscosity  (Np) ="; np
PRINT "Number of Mixing Stages  (n) ="; n, "Vehicle Viscosity   (Nv) ="; nv

FOR s = 1 TO n - 1
    px = px * Rx
    P(n - s) = px
    tp = tp + px
    xp(s) = (tp / (P + V)): xv(s) = 1 - xp(s)
    nj(s) = np * e ^ (kv * xv(s))
NEXT s
V(0) = 0
P(0) = 0
wd(0) = 0
tp = 0
tv = 0
Wx = 0
PRINT
PRINT " j"; "  Pigment  ", "  Vehicle  ", "Cum Pigment", "Cum Vehicle", " Wtr-Dsp "; "
"; "Cum Wtr"
PRINT "=="; "  =========", " ==========", "===========", "===========", " ========"; "
"; "======="

FOR s = 1 TO n
     tp = tp + P(s - 1)
     tv = tv + V(s - 1)
     Wx = INT(Wx + wd(s - 1))
     wd(s) = (P(s) / r) - P(s) + .0011
     V(s) = B - (tp + tv + P(s) / r)
     PRINT s; P(s), V(s), tp + P(s), tv + V(s), wd(s); "   "; INT(Wx + wd(s))

NEXT s

PRINT
PRINT " j"; "   Pigment ", " Vehicle   ", " % Pigment ", " % Vehicle ", "Viscosity"
PRINT "=="; "  =========", " ==========", "===========", " ==========", "========="

tp = 0: tv = 0
FOR s = 1 TO n
     tp = tp + P(s)
     tv = tv + V(s)

     PRINT s; P(s), V(s), tp / (tp + tv), tv / (tp + tv), nj(s)
NEXT s
BEEP: BEEP: PRINT
INPUT a$
SYSTEM
```

# APPENDIX

## MODEL-D0

```
REM Iteration o find R factor in an infinite series
REM Created by Herb Norman Sr. for Mixer Problem Thesis
REM 06/09/2009 - MODEL_D.BAS INPUT(n)
REM MDL-D0.BAS
REM*********************************************************
CLS
INPUT "Mixer Capacity (B) ............. B ="; B
INPUT "Total Pigment Charge (P) ........ P ="; P
INPUT "Total Vehicle Charge (V) ........ V ="; V
INPUT "% Solids of Pigment (r) ......... r ="; r
INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
INPUT "Pigment Viscosity (np) ......... np ="; np
INPUT "Number of Stages (n) ...........  n ="; n

e = 2.7183
ex = .5
kv = LOG(nv / np)
xp = P / (P + V)
REM 06/09/2009  n = INT((((P / r) + V) / (xp * B)) + .5)
pn = (r / (1 - r)) * (B - (P + V))

start:
REM Iteration Loop
REM FOR x = 1 TO 1000
REM     Ri = 1 + (x / 1000)
REM     y = (pn * ((Ri ^ n) - 1)) / (Ri - 1)
REM     IF y >= (P - ex) THEN
REM        IF y <= (P + ex) THEN
REM           Rx = Ri
REM        END IF
REM     END IF
REM NEXT x

REM 06/03/2009 Modify Iteration to DO WHILE (4 Place Accuracy)
y = -10
x% = 0
DO WHILE y < 0
   x% = x% + 1
   Ri = 1 + (x% / 10000)
   y = Ri ^ n - (P / pn) * (Ri - 1) - 1
LOOP
Rx = Ri
IF y > 0 THEN
   Rx = 1 + (x% - 1) / 10000
END IF


px = pn
P(n) = pn
xp(n) = P / (P + V): xv(n) = 1 - xp(n)
nj(n) = np * e ^ (kv * xv(n))
tp = tp + pn
```

# APPENDIX

## MODEL-D0
## (Continued)

```
CLS
PRINT "Total Pigment Charge ... (P) ="; P, "Total Vehicle Charge (V) ="; V
PRINT "Mixer Capacity ......... (B) ="; B, "% Solids of Pigment  (r) ="; r
PRINT "Calculated Series Ratio (Ri) ="; Rx, "Pigment Viscosity  (Np) ="; np
PRINT "Number of Mixing Stages  (n) ="; n, "Vehicle Viscosity   (Nv) ="; nv


FOR s = 1 TO n - 1
    px = px * Rx
    P(n - s) = px
    tp = tp + px
    xp(s) = (tp / (P + V)): xv(s) = 1 - xp(s)
    nj(s) = np * e ^ (kv * xv(s))
NEXT s

V(0) = 0
P(0) = 0
wd(0) = 0
tp = 0
tv = 0
Wx = 0


PRINT
PRINT " j"; "  Pigment  ", "  Vehicle  ", "Cum Pigment", "Cum Vehicle", " Wtr-Dsp "; "
"; "Cum Wtr"
PRINT "=="; "  =========", " ==========", "===========", "===========", " ========"; "
"; "======="


FOR s = 1 TO n
     tp = tp + P(s - 1)
     tv = tv + V(s - 1)
     Wx = INT(Wx + wd(s - 1))
     wd(s) = (P(s) / r) - P(s) + .0011
     V(s) = B - (tp + tv + P(s) / r)
     PRINT s; P(s), V(s), tp + P(s), tv + V(s), wd(s); "    "; INT(Wx + wd(s))

NEXT s
```

# APPENDIX

## MODEL-D0
## (Continued)

```
PRINT
PRINT " j"; "   Pigment ", " Vehicle   ", " % Pigment ", " % Vehicle ", "Viscosity"; "
"; "V/P Ratio"
PRINT "=="; "  =========", " ==========", "===========", " ==========", "========="; "
"; "========="

tp = 0: tv = 0

FOR s = 1 TO n
     tp = tp + P(s)
     tv = tv + V(s)
     vp = tv / tp

     PRINT s; P(s), V(s), tp / (tp + tv), tv / (tp + tv), nj(s); "  "; vp
NEXT s
BEEP: BEEP: PRINT
INPUT a$
SYSTEM
```

# APPENDIX

## BASIC PROGRAM REPORTS

```
Mixer Capacity (B) ............... B =? 3000
Total Pigment Charge (P) ........ P =? 1350
Total Vehicle Charge (V) ........ V =? 1200
% Solids of Pigment (r) ......... r =? .2
Vehicle Viscosity (nv) .......... nv =? 100
Pigment Viscosity (np) .......... np =? 240000
Prior Residual (W) ............... W =? 0
W Vehicle Content [xv(0)] ... xv(0) =? 0
#  Viscosity  % Pgmt       Pigment      Vehicle      Water
== =========  ======       =======      =======      =====
 1  3159.846   .4437         480          600         1920
 2  4699.581   .4947         337          235         1348
 3  5474.384   .5143         237          163         948
 4  5864.271   .5231         167          113         668
 5  6060.464   .5273         116          88          464
 6  6159.189   .5294         81           59          324

Pigment Charge (INPUT) 1350
Vehicle Charge (INPUT) 1200
Sum of Pigment Charge 1418
Sum of Vehicle Charges 1258
Sum of Water Displacement 5672
Original n .... n0 5.63125
```

**REPORT-MODEL-A1 (Non-Optimized Input)**

```
Mixer Capacity (B) ............... B =? 3000
Total Pigment Charge (P) ........ P =? 1393
Total Vehicle Charge (V) ........ V =? 1239
% Solids of Pigment (r) ......... r =? 0.2
Vehicle Viscosity (nv) .......... nv =? 100
Pigment Viscosity (np) .......... np =? 240000
Prior Residual (W) ............... W =? 0
W Vehicle Content [xv(0)] ... xv(0) =? 0
#  Viscosity  % Pgmt       Pigment      Vehicle      Water
== =========  ======       =======      =======      =====
 1  2191       .3966         460          700         1840
 2  3473       .4558         321          235         1284
 3  4382       .4857         230          134         920
 4  5087       .5048         167          85          668
 5  5664       .5186         123          53          492
 6  6151       .5292         92           32          368

Pigment Charge (INPUT) 1393
Vehicle Charge (INPUT) 1239
Sum of Pigment Charge 1393
Sum of Vehicle Charges 1239
Sum of Water Displacement 5572
Original n .... n0 5.809236
```

**REPORT MODEL-A2 (Optimized A1-Input)**

# APPENDIX

## BASIC PROGRAM REPORTS

```
Mixer Capacity (B) ............... B =? 3000
% Pigment Charge (xp) ...........xp =? .5294
% Solids of Pigment (r) ......... r =? .20
Vehicle Viscosity (nv) ......... nv =? 100
Pigment Viscosity (np) ......... np =? 240000
Prior Residual (W) .............. W =? 0
W Vehicle Content [xv(0)] ... xv(0) =? 0
#  Viscosity  % Pgmt        Pigment        Vehicle       Water
== =========  ======        =======        =======       =====
 1  3159.519   .4436         480            600           1920
 2  4699.112   .4946         337            235           1348
 3  5473.856   .5143         237            163           948
 4  5863.719   .5231         167            113           668
 5  6059.903   .5273         116            88            464
 6  6158.625   .5294         81             59            324

Pigment Charge (INPUT) 1349.97
Vehicle Charge (INPUT) 1200.03
Sum of Pigment Charge 1418
Sum of Vehicle Charges 1258
Sum of Water Displacement 5672
Original n .... n0 5.631024
```

**REPORT MODEL-B1**

```
Mixer Capacity (B) ............... B =? 3000
% Pigment Charge (xp) ...........xp =? .52926
% Solids of Pigment (r) ......... r =? 0.2
Vehicle Viscosity (nv) ......... nv =? 100
Pigment Viscosity (np) ......... np =? 240000
Prior Residual (W) .............. W =? 0
W Vehicle Content [xv(0)] ... xv(0) =? 0
#  Viscosity  % Pgmt        Pigment        Vehicle       Water
== =========  ======        =======        =======       =====
 1  2191       .3966         460            700           1840
 2  3473       .4558         321            235           1284
 3  4382       .4857         230            134           920
 4  5088       .5049         167            85            668
 5  5664       .5186         123            53            492
 6  6151       .5292         92             32            368

Pigment Charge (INPUT) 1349.613
Vehicle Charge (INPUT) 1200.387
Sum of Pigment Charge 1393
Sum of Vehicle Charges 1239
Sum of Water Displacement 5572
Original n .... n0 5.628338
```

**REPORT MODEL-B2 (INPUT: Xp = 0.52926 vs 0.5294, B1)**

**BASIC PROGRAM REPORTS**

# APPENDIX

Total Pigment Charge ... (P) = 1350 Total Vehicle Charge (V) = 1200
Mixer Capacity ......... (B) = 3000 % Solids of Pigment (r) = .2
Calculated Series Ratio (Ri) = 1.449 Pigment Viscosity (Np) = 240000
Number of Mixing Stages (n) = 5 Vehicle Viscosity (Nv) = 100

| j | Pigment | Vehicle | Cum Pigment | Cum Vehicle | Wtr-Dsp | Cum Wtr |
|---|---|---|---|---|---|---|
| 1 | 495.9365 | 520.3176 | 495.9365 | 520.3176 | 1983.747 | 1983 |
| 2 | 342.2612 | 272.44 | 838.1977 | 792.7576 | 1369.046 | 3352 |
| 3 | 236.2051 | 188.0192 | 1074.403 | 980.7768 | 944.8215 | 4296 |
| 4 | 163.0125 | 129.7579 | 1237.415 | 1110.535 | 652.0511 | 4948 |
| 5 | 112.5 | 89.55006 | 1349.915 | 1200.085 | 450.0011 | 5398 |

| j | Pigment | Vehicle | % Pigment | % Vehicle | Viscosity |
|---|---|---|---|---|---|
| 1 | 495.9365 | 520.3176 | .4880044 | .5119956 | 231.8418 |
| 2 | 342.2612 | 272.44 | .5139305 | .4860695 | 476.7612 |
| 3 | 236.2051 | 188.0192 | .5227781 | .4772219 | 1355.177 |
| 4 | 163.0125 | 129.7579 | .5270194 | .4729806 | 6157.445 |
| 5 | 112.5 | 89.55006 | .5293785 | .4706215 | 6159.04 |

**REPORT MODEL-C2 (Geometric Non-Optimized n = 5)**

Total Pigment Charge ... (P) = 1393 Total Vehicle Charge (V) = 1239
Mixer Capacity ......... (B) = 3000 % Solids of Pigment (r) = .2
Calculated Series Ratio (Ri) = 1.5759 Pigment Viscosity (Np) = 240000
Number of Mixing Stages (n) = 5 Vehicle Viscosity (Nv) = 100

| j | Pigment | Vehicle | Cum Pigment | Cum Vehicle | Wtr-Dsp | Cum Wtr |
|---|---|---|---|---|---|---|
| 1 | 567.4171 | 162.9145 | 567.4171 | 162.9145 | 2269.669 | 2269 |
| 2 | 360.0591 | 469.373 | 927.4762 | 632.2875 | 1440.237 | 3709 |
| 3 | 228.4784 | 297.8444 | 1155.955 | 930.1318 | 913.9147 | 4622 |
| 4 | 144.9828 | 188.9996 | 1300.937 | 1119.131 | 579.9323 | 5201 |
| 5 | 92 | 119.9313 | 1392.937 | 1239.063 | 368.0011 | 5569 |

| j | Pigment | Vehicle | % Pigment | % Vehicle | Viscosity |
|---|---|---|---|---|---|
| 1 | 567.4171 | 162.9145 | .7769308 | .2230692 | 201.5257 |
| 2 | 360.0591 | 469.373 | .5946261 | .4053739 | 396.0604 |
| 3 | 228.4784 | 297.8444 | .5541259 | .4458741 | 1148.627 |
| 4 | 144.9828 | 188.9996 | .5375622 | .4624378 | 6150.405 |
| 5 | 92 | 119.9313 | .5292315 | .4707685 | 6151.543 |

**REPORT MODEL-C2 (Geometric Optimized Ref: n = 5)**

# APPENDIX – B

## FLUSH FORMULA DERIVATIONS

**Solids Content of Pigment Presscake (r)**
**Formula #2**

**Given the total pigment charge, $\sum_{i=1}^{n} P_i$ , the presscake is;**

$$\frac{\sum_{i=1}^{n} P_i}{r} = \sum_{i=1}^{n} P_i + \sum_{i=1}^{n} W_i$$

$$\frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} (P_i + W_i)} = r$$

**Water Displacement at stage (i)**
**Formula #6**

**Given the charge of presscake at stage (i), $\frac{P_i}{r}$**

$$\frac{P_i}{r} = W_i + P_i$$

$$\frac{P_i}{r} - P_i = W_i$$

$$P_i(\frac{1}{r} - 1) = W_i$$

**Water Displacement (W) at stage (n)**
**Formula #7**

**Given the capacity, B:** $B = \sum_{i=1}^{n-1} (P_i + V_i) + P_n + W_n + V_n$

$$B = \sum_{i=1}^{n} (P_i + V_i) + W_n$$

$$W_n = B - (\sum_{i=1}^{n} P_i + \sum_{i=1}^{n} V_i)$$

**Bulk Capacity, Allowance & % Effective (B), ($E_0$) & (%Eff)**
**Formula #10**

**Given capacity,** $B = \sum_{i=1}^{n} (P_i + V_i) + W_n$ **and** $\%Eff = 1 - Eo)$

$$B = \frac{\sum_{i=1}^{n} (P_i + V_i)}{\%Eff} = \frac{\sum_{i=1}^{n} (P_i + V_i)}{1 - E_0}$$

$$(\%Eff)B = \sum_{i=1}^{n} (P_i + V_i)$$

$$\%Eff = \frac{\sum_{i=1}^{n} (P_i + V_i)}{B} = 1 - E_0$$

$$\sum_{i=1}^{n} (P_i + V_i) = \%Eff(B) = (1 - E_0)B$$

**% Pigment in Total Charge $x_p$**
**Formula #11**

**Given Total Charge,** $\sum_{i=1}^{n} (P_i + V_i) = \sum_{i=1}^{n} P_i + \sum_{i=1}^{n} V_i$

$$x_p = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} (P_i + V_i)} = \frac{\sum_{i=1}^{n} P_i}{\%Eff(B)}$$

**<u>% Vehicle in Total Charge $x_v$</u>**
**Formula #13**

**Given Total Charge,** $\sum_{i=1}^{n}(P_i + V_i) = \sum_{i=1}^{n} P_i + \sum_{i=1}^{n} V_i$

$$x_v = \frac{\sum_{i=1}^{n} V_i}{\sum_{i=1}^{n}(P_i + V_i)} = \frac{\sum_{i=1}^{n} V_i}{\%Eff(B)}$$

**<u>% Pigment ($x_p$) & % Vehicle (xv)</u>**
**Formula #12**

**Given the total charge,** $\sum_{i=1}^{n}(P_i + V_i)$

$$\frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n}(P_i + V_i)} + \frac{\sum_{i=1}^{n} V_i}{\sum_{i=1}^{n}(P_i + V_i)} = \frac{\sum_{i=1}^{n} P +_i \sum_{i=1}^{n} V_i}{\sum_{i=1}^{n}(P_i + V_i)} = 1$$

$$x_p + x_v = 1$$

$$x_p = 1 - x_v$$

$$x_v = 1 - x_p$$

**<u>Pigment Charge Distribution P(i)</u>**
**Formula #19**

**Given capacity B:** $B = \sum_{i=1}^{n-1}(P_i + V_i) + \frac{P_n}{r} + V_n$

$$B = \sum_{i=1}^{i-1}(P_i + V_i) + \frac{P_i}{r} + V_i$$

$$B - \sum_{i=1}^{i-1}(P_i + V_i) = \frac{P_i}{r} + V_i$$

$$V_i = B - \sum_{i=1}^{i-1}(P_i + V_i) - \frac{P_i}{r}$$

**Pigment Charge Distribution P(i) (Continued)**

$$xv_{j_v} = \frac{\sum_{i=1}^{j-1} V_i + V_j}{\sum_{i=1}^{n} (P_i + V_i)}$$

$$xv_j \left[ \sum_{i=1}^{j} (P_i + V_i) \right] = \sum_{i=1}^{j-1} V_i + V_j$$

$$xv_j \left[ \sum_{i=1}^{j} (P_i + V_i) \right] - \sum_{i=1}^{j-1} V_i = V_j$$

Equation Set:

$$V_i = B - \sum_{i=1}^{i-1} (P_i + V_i) - \frac{P_i}{r}$$

$$V_j = xv_j \left[ \sum_{i=1}^{j} (P_i + V_i) \right] - \sum_{1=1}^{j-1} V_i$$

$$V_j = V_j$$

$$B - \sum_{i=1}^{j-1} (P_i + V_i) - \frac{P_j}{r} = xv_j \left[ \sum_{i=1}^{j-1} (P_i + V_i) + P_j + B - \sum_{i=1}^{j-1} (P_i + V_i) - \frac{P_j}{r} \right] - \sum_{i=1}^{j-1} V_i$$

$$B - \sum_{i=1}^{j-1} (P_i + V_i) - \frac{P_j}{r} = xv_j \left[ P_j - \frac{P_j}{r} + B \right] - \sum_{i=1}^{j-1} V_i$$

$$B - \sum_{i=1}^{j-1} P_i - \sum_{i=1}^{j-1} V_i - \frac{P_j}{r} = xv_j \left[ P_j - \frac{P_j}{r} + B \right] - \sum_{i=1}^{j-1} V_i$$

$$B - \sum_{i=1}^{j-1} P_i - \sum_{i=1}^{j-1} V_i - \frac{P_j}{r} + \sum_{i=1}^{j-1} V_i = xv_j \left[ P_j (1 - \frac{1}{r}) + B \right]$$

$$B - \sum_{i=1}^{j-1} P_i - \frac{P_j}{r} = xv_j P_j (1 - \frac{1}{r}) + xv_j B$$

$$B - xv_j B - \sum_{i=1}^{j-1} P_i = \frac{P_j}{r} + xv_j P_j (1 - \frac{1}{r})$$

$$B(1 - xv_j) - \sum_{i=1}^{j-1} P_i = P_j \left[ \frac{1}{r} + xv_j (1 - \frac{1}{r}) \right]$$

**Pigment Charge Distribution P(i) (Continued)**

$$\frac{(B)xv_j - \sum_{i=1}^{j-1} P_i}{\left[\frac{1}{r} + xv_j(1 - \frac{1}{r})\right]} = P_j$$

**Vehicle Charge Distribution V(i)**

**Given**: $xp_j = 1 - xv_j$

**Then:** $V_j = B - \sum_{i=1}^{j-1}(P_i + V_i) - \frac{P_j}{r}$

**Water Displacement & Distribution with respect to Time $W_D(t)$**

**Formula #30 & #31**

**Given Water Displacement for a given stage (i) : $W_D$**

$W_D$ Water Displaced in stage (i): $W_i = \frac{P_i}{r} - P_i$

$w_i(t) = W_D(1 - e^{-kt^2})$ Water Displacement Function: t (hours)

Given: $\left[W_i = \frac{P_i}{r} - P_i\right]$ and $\left[y = \frac{1}{e^{kx^2}}\right]$ ; $1 - \frac{w_i(t)}{W_D} = \frac{1}{e^{kt^2}}$

$$W_i(t) = \frac{P_i(t)}{r} - P_i(t) \qquad 1 - \frac{w_i(t)}{W_D} = \frac{1}{e^{kt^2}}$$

$$W_i(t) = \frac{P_i(t)}{r} - \frac{rP_i(t)}{r} \qquad 1 - \frac{1}{e^{kt^2}} = \frac{w_i(t)}{W_D}$$

$$W_i(t) = \frac{P_i(t)}{r}(1 - r) \qquad 1 - e^{-kt^2} = \frac{w_i(t)}{W_D}$$

$$w_i(t) = \frac{P_i(t)}{r}(1 - r) \mid w_i = W_i \qquad W_D(1 - e^{-kt^2}) = w_i(t)$$

$$\frac{P_i(t)}{r}(1 - r) = W_D(1 - e^{-kt^2})$$

$$P_i(t) = \frac{rW_D(1 - e^{-kt^2})}{(1 - r)}$$

Pigment Wetting Function: t (hours) #31

# APPENDIX – B

**Time Required to Displace the Water (hours)**
**Formula #32**
**Given Water Displacement for a given stage (i) : $W_D$**

Use the Water Distribution [$W_i$] from Formula #30 above and Substitute [$W_i$] for $w_i(t)$ in Water Displacement Function and solve for [t].

$$\boxed{w_i(t) = W_D\left(1 - e^{-kt^2}\right)}$$

$$\frac{w_i(t)}{W_D} = 1 - e^{-kt^2}$$

$$e^{-kt^2} = 1 - \frac{w_i(t)}{W_D}$$

$$-kt^2 = \ln\left(1 - \frac{w_i(t)}{W_D}\right)$$

$$t^2 = \left(\frac{1}{-k}\right)\ln\left(1 - \frac{w_i(t)}{W_D}\right)$$

$$\boxed{t = \sqrt{\left(\frac{1}{-k}\right)\ln\left(1 - \frac{w_i(t)}{W_D}\right)}}$$

**Water Displacement Rate (1lbs/hours)**
**Formula #34**

Rate Analysis is all about the slopes of the functions developed in the previous sections. The fist derivative of the (Water Remaining) model generates the function which describe how the dependent variable is changing with respect to the independent variable. On a 2-dimensional [x, y] graph, the 1st derivative is expressed as $\frac{dy}{dx}$. If the 2-dimensions are [t, w(t)], the 1st derivative is $\frac{dw(t)}{dt} = \frac{w'(t)}{dt}$.

Compare the graphs of the Water Functions and 1st derivatives below.

The Y-Axis represents the proportion of water and the X-Axis is the time axis

# APPENDIX – B

Water **Displacement** Function: k=1

$$\boxed{\begin{aligned} w(t) &= W_D(1 - e^{-kt^2}) \\ w(t) &= W_D - W_D e^{-kt^2} \\ y &= 1 - e^{-kx^2} \end{aligned}}$$

Displacement Rate:

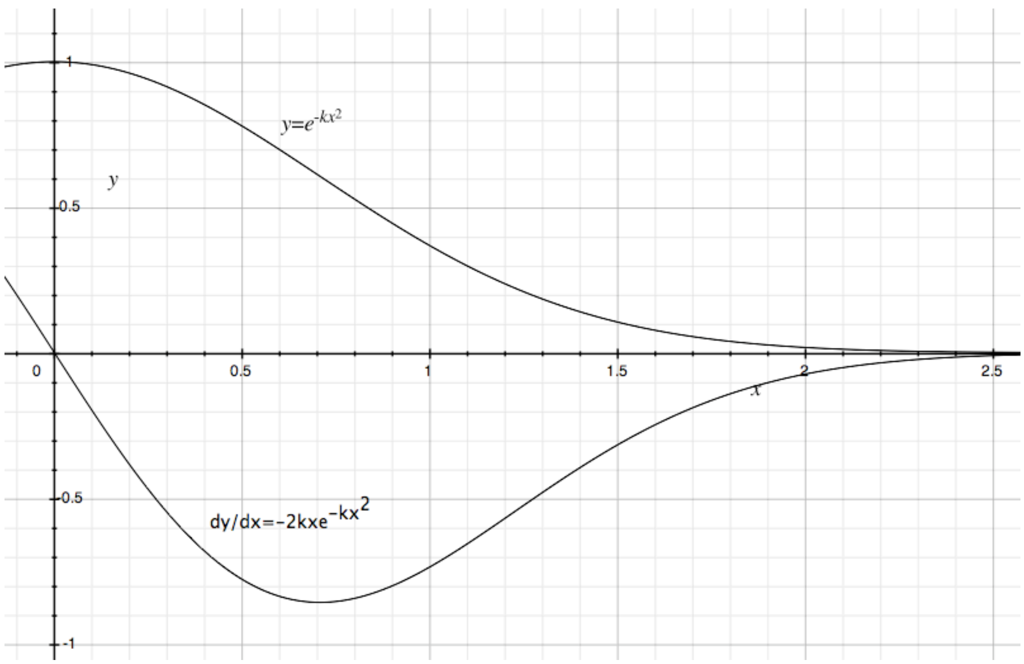
$$\boxed{\begin{aligned} \frac{w(t)}{dt} &= 2W_D k t e^{-kt^2} \\ y &= 2kxe^{-kx^2} \end{aligned}}$$

Water **Remaining** Function: k=1

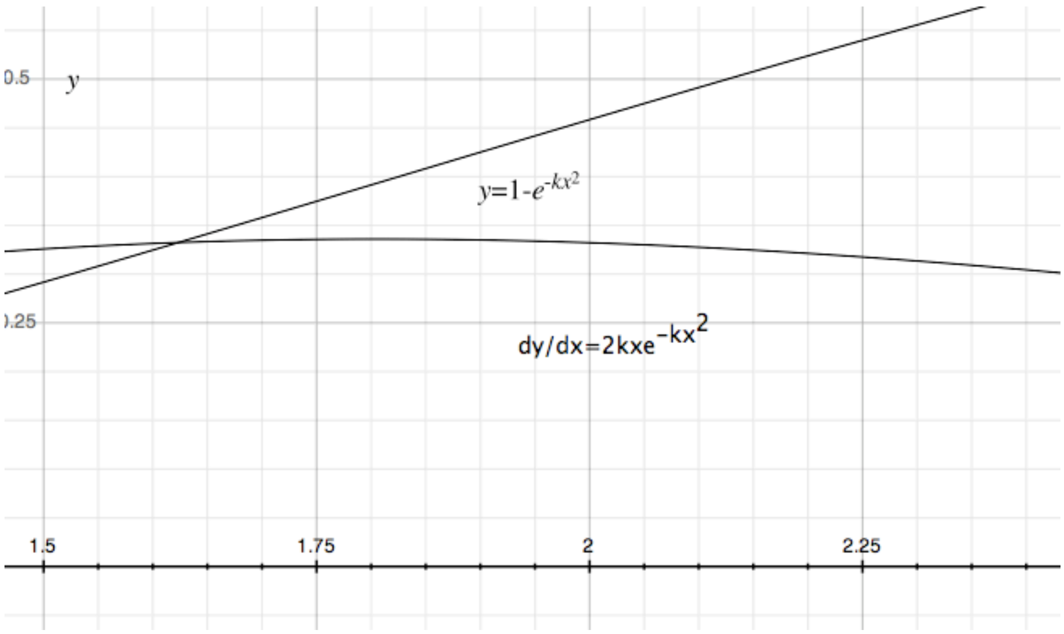
$$\boxed{\begin{aligned} w(t) &= W_D e^{-kt^2} \\ y &= e^{-kx^2} \end{aligned}}$$

Water Remaining Rate:

$$\boxed{\begin{aligned} \frac{w(t)}{dt} &= -2W_D k t e^{-kt^2} \\ y &= -2kxe^{-kx^2} \end{aligned}}$$



# APPENDIX – B




The maximum rate of displacement is can be calculated by setting the 2nd derivative of the rate function equal to zero and solving for [t]. In other words, finding where the rate function has a slope equal to zero.

Given the rate function: $\frac{w(t)}{dt} = 2W_D kte^{-kt^2}$

2nd Derivative:

$$\boxed{\begin{aligned}\frac{w''(t)}{dt^2} &= \frac{d}{dt}\left(2W_D kte^{-kt^2}\right)\\ \frac{d}{dt}uv &= u\frac{dv}{dt} + v\frac{du}{dt}\end{aligned}}$$

$$\boxed{\begin{aligned}u &= 2W_D kt\\ \frac{du}{dt} &= 2W_D k\end{aligned}}$$

$$\boxed{\begin{aligned}v &= e^{-kt^2}\\ \frac{dv}{dt} &= -2kte^{-kt^2}\end{aligned}}$$

$$\frac{w''(t)}{dt^2} = u\frac{dv}{dt} + v\frac{du}{dt}$$

$$\frac{w''(t)}{dt^2} = 2W_D kt\frac{dv}{dt} + e^{-kt^2}\frac{du}{dt}$$
$$\frac{w''(t)}{dt^2} = 2W_D kt\left(-2kte^{-kt^2}\right) + e^{-kt^2}\left(2W_D k\right)$$
$$\frac{w''(t)}{dt^2} = -4W_D k^2 t^2 e^{-kt^2} + 2W_D ke^{-kt^2}$$
$$\frac{w''(t)}{dt^2} = 2W_D ke^{-kt^2}\left(-2kt^2 + 1\right)$$
$$\frac{w''(t)}{dt^2} = 2W_D ke^{-kt^2}\left(1 - 2kt^2\right)$$

Maximum Rate: $\frac{w''(t)}{dt^2} = 0$ $\quad 0 = 2W_D ke^{-kt^2}\left(1 - 2kt^2\right)$

Root #1:
$$\boxed{\begin{aligned} 0 &= 2W_D ke^{-kt^2} \\ 0 &= \frac{1}{e^{kt^2}} \\ t &\to \infty \end{aligned}}$$

Root #2:
$$\boxed{\begin{aligned} 0 &= 1 - 2kt^2 \\ 2kt^2 &= 1 \\ t^2 &= \frac{1}{2k} \\ t &= \pm\sqrt{\frac{1}{2k}} \\ t &= \pm\frac{1}{\sqrt{2k}} \end{aligned}}$$

**<u>Paste Formation Rate (1lbs/hours)</u>**
**Formula #35**

Paste Formation Function is: $P(t) = \frac{r}{1-r}w(t)$

Paste Formation Rate is:
$$\boxed{\begin{aligned} \frac{dP(t)}{dt} &= \frac{r}{1-r}\left[\frac{dw(t)}{dt}\right] \\ \frac{dP(t)}{dt} &= \frac{r}{1-r}\left[2W_D kte^{-kt^2}\right] \end{aligned}}$$

**% Pigment Relationship [$x_p(t)$] and % Vehicle [$x_V(t)$]**

$$x_{P_i} = \frac{\sum_{j=1}^{i} P_j}{\sum_{j=1}^{i}\left(P_j + V_j\right)} = \frac{\sum_{j=1}^{i-1} P_j + P_i}{\sum_{j=1}^{i}\left(P_j + V_j\right)}$$

Given $P_i$ is the pigment charge at stage (i).
Since $P_i$ can be expressed as a function of time; $P_i(t)$ informula #31:

$$P_i(t) = \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1-r)}$$

Given: $T_{95_{i-1}} < t_i < T_{95_i}$

$$\boxed{T_{95_i} = \sqrt{\left(\frac{1}{-k}\right)\ln\left(1 - \frac{W_i}{W_D}\right)}}$$

**#36**

$$\boxed{x_{P_i}(t) = \frac{\sum_{j=1}^{i-1} P_j + P_i(t)}{\sum_{j=1}^{i}\left(P_j + V_j\right)} = \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1-r)}}{\sum_{j=1}^{i}\left(P_j + V_j\right)}}$$

**% Vehicle with respect to mix time**

**#37**

$$\boxed{\begin{aligned} x_{V_i}(t) &= 1 - x_{P_i}(t) \\ x_{V_i}(t) &= 1 - \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D\left(1 - e^{-kt^2}\right)}{(1-r)}}{\sum_{j=1}^{i}\left(P_j + V_j\right)} \end{aligned}}$$

## Time and Relative Viscosity [η(t)]

The Relative Viscosity is changing with respect to time (Mix Hours) as the pigment charge [$P_i$] is wetted by the vehicle charge [$V_i$] in stage (i). In the previous section, the % pigment and time relationship [$x_p(t)$] was developed. This section will develop the relationship between the relative viscosity and time using much of the same logic.

Refer to Appendix Formula #16 for Relative Viscosity:

$$\eta_i = \eta_p e^{k_v x_v}$$

$$\eta_i(t) = \eta_p e^{k_v x_v(t)}$$

$$\eta_i(t) = \eta_p e^{k_v[1 - x_p(t)]}$$

$$\eta_i(t) = \eta_p e^{k_v\left[1 - \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D(1-e^{-kt^2})}{(1-r)}}{\sum_{j=1}^{i}(P_j + V_j)}\right]}$$

Given

$$\boxed{\begin{aligned} x_{V_i}(t) &= 1 - x_{P_i}(t) \\ x_{V_i}(t) &= 1 - \frac{\sum_{j=1}^{i-1} P_j + \frac{rW_D(1-e^{-kt^2})}{(1-r)}}{\sum_{j=1}^{i}(P_j + V_j)} \end{aligned}}$$

# MATHCAD-6 MODEL-A TREATMENT #1
## WRITTEN BY HERBERT NORMAN SR.
## Original: 07/28/2005
## 1st Revision: 05/28/2009 (Relative Viscosity Distribution)

### INDEPENDENT VARIABLES

| | |
|---|---|
| $B := 3000$ | **Mixer Capacity** |
| $E := .15$ | **Allowance (0.10 to 0.20)** |
| $P := 1350$ | **Initial Pigment Charge** |
| $V := 1200$ | **Initial Vehicle Charge** |
| $\eta p := 240000$ | **Viscosity of Pigment** |
| $\eta v := 100$ | **Viscosity of Vehicle** |
| $r := .2$ | **% Solids of Presscake** |

### DEPENDENT VARIABLES

| | | |
|---|---|---|
| $Xp := \dfrac{P}{P + V}$ | **Pigment Content (Mix)** | $Xp = 0.5294$ |
| $Xv := 1 - Xp$ | **Vehicle Content (Mix)** | $Xv = 0.4706$ |
| $Kv := \ln\left(\dfrac{\eta v}{\eta p}\right)$ | **Viscosity Constant (Mix)** | $Kv = -7.7832$ |
| $\eta\_mix := \eta p \cdot e^{Kv \cdot Xv}$ | **Viscosity of Mix** | $\eta\_mix = 6159.19$ |
| $N := \left[\dfrac{(1 - E)\cdot\dfrac{Xp}{r} + Xv}{Xv}\right]$ | **Exact number of mix stages** | $N = 5.7813$ |

# MATHCAD-6 MODEL-A TREATMENT #1

## WRITTEN BY HERBERT NORMAN SR.

## Original: 07/28/2005

## 1st Revision: 05/28/2009 (Relative Viscosity Distribution)

$n := \mathrm{ceil}(N)$ **Optimized number of stages** $n = 6$

$kvn := \ln\left(\dfrac{\eta v}{\eta\_mix}\right)$ **Relative Viscosity Constant** $kvn = -4.120$

$i := 1..n$ **Stage Counter (1 to n)**

$\eta_i := \eta\_mix \cdot \left(1 - e^{kvn \cdot \frac{i}{n}}\right) + \eta v$ **Viscosity Distribution**

$xv_i := \dfrac{\ln\left(\dfrac{\eta_i}{\eta p}\right)}{Kv}$ **% Vehicle Distribution**

$xp_i := 1 - xv_i$ **% Pigment Distribution**

$P_0 := 0 \qquad V_0 := 0$ **Initialize Pigment & Vehicle Distribution**

$$P_i := \frac{B \cdot xp_i - \displaystyle\sum_{i=1}^{i-1} P_i}{\left[\dfrac{1}{r} + xv_i \cdot \left(1 - \dfrac{1}{r}\right)\right]}$$

**Pigment Distribution**

# MATHCAD-6 MODEL-A TREATMENT #1
## WRITTEN BY HERBERT NORMAN SR.
## Original: 07/28/2005
## 1st Revision: 05/28/2009 (Relative Viscosity Distribution)

$Wd_i := \frac{P_i}{r} - P_i$ **Water Displacement Distribution**

$V1 := B - \left(P_1 + Wd_1\right)$

$V2 := B - V1 - P_1 - \frac{P_2}{r}$

$V_i := B - \frac{P_i}{r} - \left[\sum_{i=1}^{i-1} \left(P_i + V_i\right)\right]$ **Vehicle Distribution** $V_1 := V1$ $V_2 := V2$

| $i$ | $P_i$ | $V_i$ | $xp_i$ | $xv_i$ | $Wd_i$ | $\eta_i$ |
|---|---|---|---|---|---|---|
| **1** | 479.69 | **601.55** | 0.4436 | 0.5564 | 1918.76 | 3160 |
| **2** | 337.16 | **232.97** | 0.4946 | 0.5054 | 1348.63 | 4699 |
| **3** | 237.46 | **161.33** | 0.5143 | 0.4857 | 949.84 | 5474 |
| **4** | 166.53 | **117.18** | 0.5231 | 0.4769 | 666.13 | 5864 |
| **5** | 116.15 | **85.40** | 0.5273 | 0.4727 | 464.58 | 6060 |
| **6** | 80.58 | **61.69** | 0.5294 | 0.4706 | 322.32 | 6159 |

**Total Optimized Charge** $\sum_{i=1}^{n} P_i = 1417.$ $\sum_{i=1}^{n} V_i = 1260.$

# MATHCAD-6 MODEL-B TREATMENT #1

# WRITTEN BY HERBERT NORMAN SR.

# Original: 07/23/2005

# 1st Revision: 06/01/2009 (Relative Viscosity Distribution)

## INDEPENDENT VARIABLES

| | |
|---|---|
| $B := 3000$ | **Mixer Capacity** |
| $E := .15$ | **Allowance (0.10 to 0.20)** |
| $Xp := 0.5294$ | **Pigment Content (Mix)** |
| $\eta p := 240000$ | **Viscosity of Pigment** |
| $\eta v := 100$ | **Viscosity of Vehicle** |
| $r := .2$ | **% Solids of Presscake** |

## DEPENDENT VARIABLES

| | | |
|---|---|---|
| $P := (1 - E)\cdot B\cdot Xp$ | **Pigment Charge** | $P = 1349.97$ |
| $Xv := 1 - Xp$ | **Vehicle Content (Mix)** | $Xv = 0.4706$ |
| $V := (1 - E)\cdot B\cdot Xv$ | **Vehicle Charge** | $V = 1200.03$ |
| $Kv := \ln\left(\frac{\eta v}{\eta p}\right)$ | **Viscosity Constant (Mix)** | $Kv = -7.7832$ |
| $\eta\_mix := \eta p\cdot e^{Kv\cdot Xv}$ | **Viscosity of Mix** | $\eta\_mix = 6158.626$ |
| $N := \left[\frac{(1 - E)\cdot\frac{Xp}{r} + Xv}{Xv}\right]$ | **Exact number of mix stages** | $N = 5.781$ |

$n := \mathrm{ceil}(N)$ **Optimized number of stages** $n = 6$

$kvn := \ln\left(\frac{\eta v}{\eta\_mix}\right)$ **Relative Viscosity Constant** $kvn = -4.1204$

$i := 1..n$ **Stage Counter (1 to n)**

$\eta_i := \eta\_mix \cdot \left(1 - e^{kvn \cdot \frac{i}{n}}\right) + \eta v$ **Viscosity Distribution**

$xv_i := \frac{\ln\left(\frac{\eta_i}{\eta p}\right)}{Kv}$ **% Vehicle Distribution**

$xp_i := 1 - xv_i$ **% Pigment Distribution**

$P_0 := 0$ $V_0 := 0$ **Initialize Pigment & Vehicle Distribution**

$$P_i := \frac{B \cdot xp_i - \sum_{i=1}^{i-1} P_i}{\left[\frac{1}{r} + xv_i \cdot \left(1 - \frac{1}{r}\right)\right]}$$

**Pigment Distribution**

$Wd_i := \frac{P_i}{r} - P_i$ **Water Displacement Distribution**

$$V1 := B - \left(P_1 + Wd_1\right)$$

$$V2 := B - V1 - P_1 - \frac{P_2}{r}$$

$$V_i := B - \frac{P_i}{r} - \left[\sum_{i=1}^{i-1} \left(P_i + V_i\right)\right]$$

**Vehicle Distribution** $V_1 := V1$ $V_2 := V2$

| $i$ | $P_i$ | $V_i$ | $xp_i$ | $xv_i$ | $Wd_i$ | $\eta_i$ |
|---|---|---|---|---|---|---|
| 1 | 479.6896 | 601.5518 | 0.4436 | 0.5564 | 1918.7586 | 3159.5193 |
| 2 | 337.1576 | 232.9707 | 0.4946 | 0.5054 | 1348.6303 | 4699.1122 |
| 3 | 237.4599 | 161.3311 | 0.5143 | 0.4857 | 949.8394 | 5473.8569 |
| 4 | 166.5316 | 117.1814 | 0.5231 | 0.4769 | 666.1264 | 5863.7192 |
| 5 | 116.1461 | 85.3957 | 0.5273 | 0.4727 | 464.5845 | 6059.9034 |
| 6 | 80.5797 | 61.6862 | 0.5294 | 0.4706 | 322.3187 | 6158.626 |

**Total Optimized Charge** $\sum_{i=1}^{n} P_i = 1417.5645$ $\sum_{i=1}^{n} V_i = 1260.1168$

# MATHCAD-6 MODEL-C1 (Geometric Series Non-Optimized)
## WRITTEN BY HERBERT NORMAN SR.
### Original: 07/24/2005: 1st Revision: 06/03/2009 (Reproduced from notes)

**INDEPENDENT VARIABLES**

| | |
|---|---|
| $B := 3000$ | **Mixer Capacity** |
| $P := 1350$ | **Pigment Charge** |
| $V := 1200$ | **Vehicle Charge** |
| $\eta p := 240000$ | **Viscosity of Pigment** |
| $\eta v := 100$ | **Viscosity of Vehicle** |
| $r := .2$ | **% Solids of Presscake** |

**DEPENDENT VARIABLES**

| | | |
|---|---|---|
| $Xp := 0.5294$ | **Pigment Content (Mix)** | $Xp = 0.5294$ |
| $Xv := 1 - Xp$ | **Vehicle Content (Mix)** | $Xv = 0.4706$ |
| $Kv := \ln\left(\frac{\eta v}{\eta p}\right)$ | **Viscosity Constant (Mix)** | $Kv = -7.7832$ |
| $\eta\_mix := \eta p \cdot e^{Kv \cdot Xv}$ | **Viscosity of Mix** | $\eta\_mix = 6158.626$ |
| $N := \left[\frac{\left(\frac{P}{r}\right) + V}{Xp \cdot B}\right]$ | **Exact number of mix stages** | $N = 5.0057$ |
| $n := \mathrm{ceil}(N)$ | **Optimized number of stages** | $n = 6$ |
| $Pn := r \cdot \frac{B - (P + V)}{1 - r}$ | **Last Stage Pigment Charge** | $Pn = 112.5$ |

# MATHCAD-6 MODEL-C1 (Geometric Series Non-Optimized)
# WRITTEN BY HERBERT NORMAN SR.
## Original: 07/24/2005: 1st Revision: 06/03/2009 (Reproduced from notes)

$Rg := 1$ $\quad f(Rg) := \left[\frac{Pn\cdot\left(Rg^{n}-1\right)}{Rg-1} - P\right]$ $\quad solution := root(f(Rg), Rg)$ $\quad solution = 1.2755$ $\quad R := solution$

$Pt := P$ $\quad Vt := V$ $\quad$ **Stage Counter (j):** $j := n-1, n-2..0$ $\quad i := 1..n$

$Q_j := Pn\cdot R^{j}$ $\quad P_i := Q_{(n-i)}$ $\quad V_0 := 0$

$V1 := B - \frac{P_1}{r}$ $\quad V2 := B - V1 - P_1 - \frac{P_2}{r}$ $\quad V_i := B - \frac{P_i}{r} - \left[\sum_{i=1}^{i-1}\left(P_i + V_i\right)\right]$ $\quad V_1 := V1$ $\quad V_2 := V2$

$Sum\_P_i := \sum_{i=1}^{i} P_i$ $\quad Sum\_V_i := \sum_{i=1}^{i} V_i$ $\quad xp_i := \frac{Sum\_P_i}{Sum\_P_i + Sum\_V_i}$ $\quad xv_i := 1 - xp_i$

$\eta_i := \eta p\cdot e^{Kv\cdot xv_i}$ **Viscosity Distribution** $\quad Wd_i := \frac{P_i}{r} - P_i$ **Water Displacement Distribution**

| $i$ | $P_i$ | $V_i$ | $xp_i$ | $xv_i$ | $Wd_i$ | $\eta_i$ |
|---|---|---|---|---|---|---|
| 1 | 379.7842 | 1101.0788 | 0.2565 | 0.7435 | 1519.137 | 736.0271 |
| 2 | 297.7557 | 30.3586 | 0.3745 | 0.6255 | 1191.0227 | 1845.163 |
| 3 | 233.4442 | 23.8015 | 0.4409 | 0.5591 | 933.777 | 3092.5231 |
| 4 | 183.0233 | 18.6607 | 0.4824 | 0.5176 | 732.093 | 4271.3767 |
| 5 | 143.4926 | 14.6302 | 0.5101 | 0.4899 | 573.9703 | 5299.3304 |
| 6 | 112.5 | 11.4703 | 0.5294 | 0.4706 | 450 | 6159.1899 |

$\sum_{i=1}^{n} P_i = 1350$ $\quad \sum_{i=1}^{n} V_i = 1200$

$\sum_{i=1}^{n} Wd_i = 5400$

# MATHCAD-6 MODEL-C2 (Geometric Series Optimized)

# WRITTEN BY HERBERT NORMAN SR.

**Original: 07/24/2005: 1st Revision: 06/03/2009 (Reproduced from notes)**

## INDEPENDENT VARIABLES

| | |
|---|---|
| $B := 3000$ | ***Mixer Capacity*** |
| $P := 1393$ | ***Pigment Charge*** |
| $V := 1239$ | ***Vehicle Charge*** |
| $\eta p := 240000$ | ***Viscosity of Pigment*** |
| $\eta v := 100$ | ***Viscosity of Vehicle*** |
| $r := .2$ | ***% Solids of Presscake*** |

## DEPENDENT VARIABLES

| | | |
|---|---|---|
| $Xp := 0.5294$ | ***Pigment Content (Mix)*** | $Xp = 0.5294$ |
| $Xv := 1 - Xp$ | ***Vehicle Content (Mix)*** | $Xv = 0.4706$ |
| $Kv := \ln\left(\frac{\eta v}{\eta p}\right)$ | ***Viscosity Constant (Mix)*** | $Kv = -7.7832$ |
| $\eta\_mix := \eta p \cdot e^{Kv \cdot Xv}$ | ***Viscosity of Mix*** | $\eta\_mix = 6158.626$ |
| $N := \left[\frac{\left(\frac{P}{r}\right) + V}{Xp \cdot B}\right]$ | ***Exact number of mix stages*** | $N = 5.1656$ |
| $n := \mathrm{ceil}(N)$ | ***Optimized number of stages*** | $n = 6$ |
| $Pn := r \cdot \frac{B - (P + V)}{1 - r}$ | ***Last Stage Pigment Charge*** | $Pn = 92$ |

# MATHCAD-6 MODEL-C2 (Geometric Series Optimized)
## WRITTEN BY HERBERT NORMAN SR.
### Original: 07/24/2005: 1st Revision: 06/03/2009 (Reproduced from notes)

$Rg := 1$ $\quad f(Rg) := \left[\frac{Pn\cdot\left(Rg^{n}-1\right)}{Rg-1} - P\right]$ $\quad solution := root(f(Rg), Rg)$ $\quad solution = 1.3693$ $\quad R := solution$

$Pt := P$ $\quad Vt := V$ $\quad$ **Stage Counter (j):** $\quad j := n-1, n-2..0$ $\quad i := 1..n$

$Q_j := Pn\cdot R^{j}$ $\quad P_i := Q_{(n-i)}$ $\quad V_0 := 0$

$V1 := B - \frac{P_1}{r}$ $\quad V2 := B - V1 - P_1 - \frac{P_2}{r}$ $\quad V_i := B - \frac{P_i}{r} - \left[\sum_{i=1}^{i-1}\left(P_i + V_i\right)\right]$ $\quad V_1 := V1$ $\quad V_2 := V2$

$Sum\_P_i := \sum_{i=1}^{i} P_i$ $\quad Sum\_V_i := \sum_{i=1}^{i} V_i$ $\quad xp_i := \frac{Sum\_P_i}{Sum\_P_i + Sum\_V_i}$ $\quad xv_i := 1 - xp_i$

$\eta_i := \eta p\cdot e^{Kv\cdot xv_i}$ **Viscosity Distribution** $\quad Wd_i := \frac{P_i}{r} - P_i$ **Water Displacement**

| $i$ | $P_i$ | $V_i$ | $xp_i$ | $xv_i$ | $Wd_i$ | $\eta_i$ |
|---|---|---|---|---|---|---|
| 1 | 442.8826 | 785.5868 | 0.3605 | 0.6395 | 1771.5306 | 1654.3201 |
| 2 | 323.4361 | 154.3501 | 0.4491 | 0.5509 | 1293.7444 | 3297.0902 |
| 3 | 236.2046 | 112.7215 | 0.4878 | 0.5122 | 944.8183 | 4455.2948 |
| 4 | 172.4996 | 82.3202 | 0.5087 | 0.4913 | 689.9985 | 5240.8773 |
| 5 | 125.9761 | 60.1182 | 0.5212 | 0.4788 | 503.9042 | 5778.4582 |
| 6 | 92 | 43.9042 | 0.5293 | 0.4707 | 368 | 6151.6767 |

$\sum_{i=1}^{n} P_i = 1392.999$ $\quad \sum_{i=1}^{n} V_i = 1239.001$

$\sum_{i=1}^{n} Wd_i = 5571.996$

# MIXER PROGRAMMING MODELS
## VBA Programs Created by Herb Norman Sr. 07/02/2010

**EXCEL MACROS: MDL-A0**

```
Sub Mixer_PGM_A0()
   Worksheets("PGM_A0").Activate

Rem CLEAR CONTENTS
   Worksheets("PGM_A0").Range("C13:C18").ClearContents
   Worksheets("PGM_A0").Range("C21:S35").ClearContents
   Worksheets("PGM_A0").Range("A28:A35").ClearContents

Rem Start Procedure

Rem Input Parameters
Rem ==============================================================================
nb$ = Cells(1, "C"): Rem INPUT "Batch Nbr (NB$) .............. NB$ ="; nb$
P = Cells(4, "C"): Rem   INPUT "Total Pigment Charge (P) ........ P ="; P
V = Cells(5, "C"): Rem   INPUT "Total Vehicle Charge (V) ........ V ="; V
np = Cells(6, "C"): Rem  INPUT "Pigment Viscosity (np) ......... np ="; np
nv = Cells(7, "C"): Rem  INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
r = Cells(8, "C"): Rem   INPUT "% Solids of Pigment (r) ......... r ="; r
B = Cells(9, "C"): Rem   INPUT "Mixer Capacity (B) ............. B ="; B
Allowance_pct = Cells(10, "C")
tp = Cells(23, "A"): Rem INPUT "Process Time ......... tp
Cells(29, "A") = 1: b2 = 1: Rem INPUT "2nd Water Distribution Constant .. b2=1
wp = Cells(24, "A"): Rem INPUT "Water Content % ........ wp
Mix_pct = Cells(27, "A"): Rem INPUT "Mix to % Completion .... Mix_pct
```

```
Rem Calculate Constants
Rem ===================
kv = Log(nv / np): Cells(17, "C") = kv
xv = V / (P + V): xp = (1 - xv): Cells(15, "C") = xv: Cells(16, "C") = xp
nmix = np * Exp(kv * xv): Cells(18, "C") = nmix
n = Int((P / r + V) / (xv * B) + 0.5): Cells(14, "C") = n
n0 = (P / r + V) / (xv * B): Cells(13, "C") = n0
a = Log(nv / nmix)


Rem Calculate Viscosity Distribution n(j)
Rem =====================================

For j = 1 To n
Rem    n(j) = nmix * (1 - Exp(a * j / n)) + nv
   Cells(20 + j, "C") = j: Rem Stage (j)
   Cells(20 + j, "D") = nmix * (1 - Exp(a * j / n)) + nv: Rem Viscosity=n(j)

   Rem  xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
   Cells(20 + j, "F") = Int(((Log(Cells(20 + j, "D") / np)) / kv) * 10000 + 0.5) / 10000: Rem %Veh=xv(j)
   Cells(20 + j, "E") = 1 - Cells(20 + j, "F"): Rem %Pgmt=1-xv(j)
```

```
    If j = 1 Then
        Cells(20 + j, "G") = Int(B * Cells(20 + j, "E") / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5)
        Cells(20 + j, "H") = B - Cells(20 + j, "G") / r
    End If

    If j > 1 Then
        K1 = K1 + Cells(20 + j - 1, "G"): K2 = K2 + Cells(20 + j - 1, "H")
        Cells(20 + j, "G") = Int((B * Cells(20 + j, "E") - K1) / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5): Rem Pigment
        Cells(20 + j, "H") = Int(B - (K1 + K2) - Cells(20 + j, "G") / r + 0.5): Rem Vehicle
    End If

    Cells(20 + j, "I") = Cells(20 + j, "G") * (1 / r - 1): Rem Water Displacement wd(j)
    SumP = SumP + Cells(20 + j, "G"): SumV = SumV + Cells(20 + j, "H"): SumW = SumW + Cells(20 + j, "I")
    Cells(20 + j, "J") = SumP:
    Cells(20 + j, "K") = SumV:
    Cells(20 + j, "L") = Cells(20 + j, "G") + Cells(20 + j, "H")
    Cells(20 + j, "M") = SumP + SumV
    Cells(20 + j, "N") = SumV / SumP
Next j

Cells(4, "D") = SumP: Cells(5, "D") = SumV
```

```
Rem Calculate Mix Time Prameters
Rem ==============================
   kw = Log(B * wp / Cells(21, "I")) / -tp ^ 2: Cells(28, "A") = kw
   tx = tp / Sqr(-Log(wp)): Cells(30, "A") = tx
   x_val = Sqr(-Log(1 - Mix_pct)): Cells(31, "A") = x_val
   Wtr_1 = Cells(21, "I"): Wtr_Residual = 0: WR = 0: Wtr_pct = 0
   T_est = x_val * tx: T_Init = T_est: Sum_T_est = 0
   TA_est = Sqr((1 / -kw) * Log(1 - Mix_pct)): Sum_TA_est = 0
   TB_est = 0: Sum_TB_est = 0

For j = 1 To n
   Wtr_Residual = (1 - Mix_pct) * (Wtr_Residual + Cells(20 + j, "I")): Cells(20 + j, "O") = Wtr_Residual
   Wtr_pct = (WR + Cells(20 + j, "I")) / (WR + Cells(20 + j, "I") + Cells(20 + j, "M")): Cells(20 + j, "P") = Wtr_pct
   TB_est = Sqr((1 / (-kw * j)) * Log(1 - Cells(27, "A"))): Cells(20 + j, "S") = TB_est
   If j = 1 Then
      Cells(20 + j, "Q") = T_est
      Cells(20 + j, "R") = TA_est
   End If
   If j > 1 Then
      T_est = T_Init - Sqr(tx ^ 2 * Log(Wtr_pct) * (-1)): Cells(20 + j, "Q") = T_est
      TA_est = Sqr((1 / -kw) * Log(1 - (Cells(20 + j, "I") + Cells(19 + j, "O")) / Wtr_1)): Cells(20 + j, "R") = TA_est
   End If
   Sum_T_est = Sum_T_est + T_est
   Sum_TA_est = Sum_TA_est + TA_est
   Sum_TB_est = Sum_TB_est + TB_est
   WR = Wtr_Residual
Next j

Cells(33, "A") = Sum_T_est
```

```
Cells(34, "A") = Sum_TA_est
Cells(35, "A") = Sum_TB_est

End Sub
```

**EXCEL MACROS: MDL-AN**

```
Sub Mixer_PGM_AN()
   Worksheets("PGM_AN").Activate

Rem CLEAR CONTENTS
   Worksheets("PGM_AN").Range("C13:C13").ClearContents
   Worksheets("PGM_AN").Range("C15:C18").ClearContents
   Worksheets("PGM_AN").Range("C21:S35").ClearContents
   Worksheets("PGM_AN").Range("A28:A35").ClearContents

Rem Start Procedure

Rem Input Parameters
Rem ======================================================================
nb$ = Cells(1, "C"): Rem INPUT "Batch Nbr (NB$) .............. NB$ ="; nb$
P = Cells(4, "C"): Rem   INPUT "Total Pigment Charge (P) ........ P ="; P
V = Cells(5, "C"): Rem   INPUT "Total Vehicle Charge (V) ........ V ="; V
np = Cells(6, "C"): Rem  INPUT "Pigment Viscosity (np) ......... np ="; np
nv = Cells(7, "C"): Rem  INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
r = Cells(8, "C"): Rem   INPUT "% Solids of Pigment (r) ......... r ="; r
B = Cells(9, "C"): Rem   INPUT "Mixer Capacity (B) ............. B ="; B
Allowance_pct = Cells(10, "C")
n = Cells(14, "C"): Rem  INPUT "Nbr of Mix Stages (n) ........... n ="; n
tp = Cells(23, "A"): Rem INPUT "Process Time ......... tp
Cells(29, "A") = 1: b2 = 1: Rem INPUT "2nd Water Distribution Constant .. b2=1

wp = Cells(24, "A"): Rem INPUT "Water Content % ........ wp
```

```
Mix_pct = Cells(27, "A"): Rem INPUT "Mix to % Completion .... Mix_pct

Rem Calculate Constants
Rem ===================
Rem P(0) = W * (1 - xv(0))
Rem V(0) = W * xv(0)
kv = Log(nv / np): Cells(17, "C") = kv
xv = V / (P + V): xp = (1 - xv): Cells(15, "C") = xv: Cells(16, "C") = xp
nmix = np * Exp(kv * xv): Cells(18, "C") = nmix
Rem n = Int((P / r + V) / (xv * B) + 0.5): Cells(14, "C") = n
n0 = (P / r + V) / (xv * B): Cells(13, "C") = n0
a = Log(nv / nmix)

Rem Calculate Viscosity Distribution n(j)
Rem ======================================

For j = 1 To n
Rem    n(j) = nmix * (1 - Exp(a * j / n)) + nv
    Cells(20 + j, "C") = j: Rem Stage (j)
    Cells(20 + j, "D") = nmix * (1 - Exp(a * j / n)) + nv: Rem Viscosity=n(j)

    Rem  xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    Cells(20 + j, "F") = Int(((Log(Cells(20 + j, "D") / np)) / kv) * 10000 + 0.5) / 10000: Rem %Veh=xv(j)
    Cells(20 + j, "E") = 1 - Cells(20 + j, "F"): Rem %Pgmt=1-xv(j)

    If j = 1 Then
        Cells(20 + j, "G") = Int(B * Cells(20 + j, "E") / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5)
        Cells(20 + j, "H") = B - Cells(20 + j, "G") / r
    End If
```

```
    If j > 1 Then
        K1 = K1 + Cells(20 + j - 1, "G"): K2 = K2 + Cells(20 + j - 1, "H")
        Cells(20 + j, "G") = Int((B * Cells(20 + j, "E") - K1) / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5): Rem Pigment
        Cells(20 + j, "H") = Int(B - (K1 + K2) - Cells(20 + j, "G") / r + 0.5): Rem Vehicle
    End If

    Cells(20 + j, "I") = Cells(20 + j, "G") * (1 / r - 1): Rem Water Displacement wd(j)
    SumP = SumP + Cells(20 + j, "G"): SumV = SumV + Cells(20 + j, "H"): SumW = SumW + Cells(20 + j, "I")
    Cells(20 + j, "J") = SumP:
    Cells(20 + j, "K") = SumV:
    Cells(20 + j, "L") = Cells(20 + j, "G") + Cells(20 + j, "H")
    Cells(20 + j, "M") = SumP + SumV
    Cells(20 + j, "N") = SumV / SumP
Next j
Cells(4, "D") = SumP: Cells(5, "D") = SumV

Rem Calculate Mix Time Prameters
Rem ==============================
kw = Log(B * wp / Cells(21, "I")) / -tp ^ 2: Cells(28, "A") = kw
tx = tp / Sqr(-Log(wp)): Cells(30, "A") = tx
x_val = Sqr(-Log(1 - Mix_pct)): Cells(31, "A") = x_val
Wtr_1 = Cells(21, "I") : Wtr_pct = 0
    T_est = x_val * tx: T_Init = T_est: Sum_T_est = 0
    TA_est = Sqr((1 / -kw) * Log(1 - Mix_pct)): Sum_TA_est = 0
    TB_est = 0: Sum_TB_est = 0

For j = 1 To n
    Wtr_Residual = (1 - Mix_pct) * (Wtr_Residual + Cells(20 + j, "I")): Cells(20 + j, "O") = Wtr_Residual
```

```
   Wtr_pct = (WR + Cells(20 + j, "I")) / (WR + Cells(20 + j, "I") + Cells(20 + j, "M")): Cells(20 + j, "P") = Wtr_pct
   TB_est = Sqr((1 / (-kw * j)) * Log(1 - Cells(27, "A"))): Cells(20 + j, "S") = TB_est
   If j = 1 Then
      Cells(20 + j, "Q") = T_est
      Cells(20 + j, "R") = TA_est
   End If
   If j > 1 Then
      T_est = T_Init - Sqr(tx ^ 2 * Log(Wtr_pct) * (-1)): Cells(20 + j, "Q") = T_est
      TA_est = Sqr((1 / -kw) * Log(1 - (Cells(20 + j, "I") + Cells(19 + j, "O")) / Wtr_1)): Cells(20 + j, "R") = TA_est

   End If
      Sum_T_est = Sum_T_est + T_est
   Sum_TA_est = Sum_TA_est + TA_est
   Sum_TB_est = Sum_TB_est + TB_est
   WR = Wtr_Residual
Next j
Cells(33, "A") = Sum_T_est
Cells(34, "A") = Sum_TA_est
Cells(35, "A") = Sum_TB_est

End Sub
```

**EXCEL MACROS: MDL-B0**

```
Sub Mixer_PGM_B0()
   Worksheets("PGM_B0").Activate

Rem CLEAR CONTENTS
   Worksheets("PGM_B0").Range("C13:C18").ClearContents
```

```
    Worksheets("PGM_B0").Range("C21:S35").ClearContents
    Worksheets("PGM_B0").Range("A28:A35").ClearContents

Rem Start Procedure
Rem Input Parameters
Rem =========================================================================
nb$ = Cells(1, "C"): Rem INPUT "Batch Nbr (NB$) .............. NB$ ="; nb$
Rem P = Cells(4, "C"): Rem   INPUT "Total Pigment Charge (P) ........ P ="; P
Rem V = Cells(5, "C"): Rem   INPUT "Total Vehicle Charge (V) ........ V ="; V
np = Cells(6, "C"): Rem  INPUT "Pigment Viscosity (np) ......... np ="; np
nv = Cells(7, "C"): Rem  INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
r = Cells(8, "C"): Rem   INPUT "% Solids of Pigment (r) ......... r ="; r
B = Cells(9, "C"): Rem   INPUT "Mixer Capacity (B) ............. B ="; B
xp = Cells(10, "C"): Rem  INPUT "% Pigment in Mix (xp) ......... xp ="; xp
tp = Cells(23, "A"): Rem INPUT "Process Time ......... tp
Cells(29, "A") = 1: b2 = 1: Rem INPUT "2nd Water Distribution Constant .. b2=1
wp = Cells(24, "A"): Rem INPUT "Water Content % ........ wp
Mix_pct = Cells(27, "A"): Rem INPUT "Mix to % Completion .... Mix_pct
xv = (1 - xp)


Rem Calculate Constants
Rem ===================
P = 0.85 * B * xp: Cells(4, "C") = P
V = 0.85 * B * xv: Cells(5, "C") = V
kv = Log(nv / np): Cells(17, "C") = kv
Rem xv = V / (P + V)
Cells(15, "C") = xv: Cells(16, "C") = xp
nmix = np * Exp(kv * xv): Cells(18, "C") = nmix
```

```
n = Int((P / r + V) / (xv * B) + 0.5): Cells(14, "C") = n
n0 = (P / r + V) / (xv * B): Cells(13, "C") = n0
a = Log(nv / nmix)

Rem Calculate Viscosity Distribution n(j)
Rem ======================================

For j = 1 To n
Rem    n(j) = nmix * (1 - Exp(a * j / n)) + nv
    Cells(20 + j, "C") = j: Rem Stage (j)
    Cells(20 + j, "D") = nmix * (1 - Exp(a * j / n)) + nv: Rem Viscosity=n(j)

    Rem  xv(j) = INT(((LOG(n(j) / np)) / kv) * 10000 + .5) / 10000
    Cells(20 + j, "F") = Int(((Log(Cells(20 + j, "D") / np)) / kv) * 10000 + 0.5) / 10000: Rem %Veh=xv(j)
    Cells(20 + j, "E") = 1 - Cells(20 + j, "F"): Rem %Pgmt=1-xv(j)
```

```
    If j = 1 Then
        Cells(20 + j, "G") = Int(B * Cells(20 + j, "E") / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5)
        Cells(20 + j, "H") = B - Cells(20 + j, "G") / r
    End If

    If j > 1 Then
        K1 = K1 + Cells(20 + j - 1, "G"): K2 = K2 + Cells(20 + j - 1, "H")
        Cells(20 + j, "G") = Int((B * Cells(20 + j, "E") - K1) / ((1 / r) + Cells(20 + j, "F") * (1 - 1 / r)) + 0.5): Rem Pigment
        Cells(20 + j, "H") = Int(B - (K1 + K2) - Cells(20 + j, "G") / r + 0.5): Rem Vehicle
    End If

    Cells(20 + j, "I") = Cells(20 + j, "G") * (1 / r - 1): Rem Water Displacement wd(j)
    SumP = SumP + Cells(20 + j, "G"): SumV = SumV + Cells(20 + j, "H"): SumW = SumW + Cells(20 + j, "I")
    Cells(20 + j, "J") = SumP:
    Cells(20 + j, "K") = SumV:
    Cells(20 + j, "L") = Cells(20 + j, "G") + Cells(20 + j, "H")
    Cells(20 + j, "M") = SumP + SumV
    Cells(20 + j, "N") = SumV / SumP
Next j

Cells(4, "D") = SumP: Cells(5, "D") = SumV
```

```
Rem Calculate Mix Time Prameters
Rem ============================
   kw = Log(B * wp / Cells(21, "I")) / -tp ^ 2: Cells(28, "A") = kw
   tx = tp / Sqr(-Log(wp)): Cells(30, "A") = tx
   x_val = Sqr(-Log(1 - Mix_pct)): Cells(31, "A") = x_val
   Wtr_1 = Cells(21, "I")
   Wtr_Residual = 0: WR = 0 : Wtr_pct = 0
   T_est = x_val * tx: T_Init = T_est: Sum_T_est = 0
   TA_est = Sqr((1 / -kw) * Log(1 - Mix_pct)): Sum_TA_est = 0
   TB_est = 0: Sum_TB_est = 0

For j = 1 To n
   Wtr_Residual = (1 - Mix_pct) * (Wtr_Residual + Cells(20 + j, "I")): Cells(20 + j, "O") = Wtr_Residual
   Wtr_pct = (WR + Cells(20 + j, "I")) / (WR + Cells(20 + j, "I") + Cells(20 + j, "M")): Cells(20 + j, "P") = Wtr_pct
   TB_est = Sqr((1 / (-kw * j)) * Log(1 - Cells(27, "A"))): Cells(20 + j, "S") = TB_est

   If j = 1 Then
      Cells(20 + j, "Q") = T_est
      Cells(20 + j, "R") = TA_est
   End If

   If j > 1 Then
      T_est = T_Init - Sqr(tx ^ 2 * Log(Wtr_pct) * (-1)): Cells(20 + j, "Q") = T_est
      TA_est = Sqr((1 / -kw) * Log(1 - (Cells(20 + j, "I") + Cells(19 + j, "O")) / Wtr_1)): Cells(20 + j, "R") = TA_est
   End If
```

```
    Sum_T_est = Sum_T_est + T_est
    Sum_TA_est = Sum_TA_est + TA_est
    Sum_TB_est = Sum_TB_est + TB_est
    WR = Wtr_Residual
Next j

Cells(33, "A") = Sum_T_est
Cells(34, "A") = Sum_TA_est
Cells(35, "A") = Sum_TB_est

End Sub
```

**EXCEL MACROS: MDL-C0**

```
Sub Mixer_PGM_C0()
   Worksheets("PGM_C0").Activate

Rem CLEAR CONTENTS
   Worksheets("PGM_C0").Range("C10:C10").ClearContents
   Worksheets("PGM_C0").Range("C13:C18").ClearContents
   Worksheets("PGM_C0").Range("C21:S35").ClearContents
   Worksheets("PGM_C0").Range("A28:A35").ClearContents

Rem Start Procedure
Rem Input Parameters
Rem =======================================================================
nb$ = Cells(1, "C"): Rem INPUT "Batch Nbr (NB$) .............. NB$ ="; nb$
P = Cells(4, "C"): Rem   INPUT "Total Pigment Charge (P) ........ P ="; P
V = Cells(5, "C"): Rem   INPUT "Total Vehicle Charge (V) ........ V ="; V
np = Cells(6, "C"): Rem  INPUT "Pigment Viscosity (np) ......... np ="; np
nv = Cells(7, "C"): Rem  INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
r = Cells(8, "C"): Rem   INPUT "% Solids of Pigment (r) ......... r ="; r
B = Cells(9, "C"): Rem   INPUT "Mixer Capacity (B) ............. B ="; B

tp = Cells(23, "A"): Rem INPUT "Process Time ......... tp
Cells(29, "A") = 1: b2 = 1: Rem INPUT "2nd Water Distribution Constant .. b2=1
wp = Cells(24, "A"): Rem INPUT "Water Content % ........ wp
Mix_pct = Cells(27, "A"): Rem INPUT "Mix to % Completion .... Mix_pct
e = 2.7183
ex = 0.5
```

```
Rem Calculate Constants
Rem ===================
kv = Log(nv / np): Cells(17, "C") = kv
xv = V / (P + V): xp = (1 - xv): Cells(15, "C") = xv: Cells(16, "C") = xp
nmix = np * Exp(kv * xv): Cells(18, "C") = nmix
n = Int((((P / r) + V) / (xp * B)) + 0.5): Cells(14, "C") = n
n0 = (P / r + V) / (xv * B): Cells(13, "C") = n0
pn = (r / (1 - r)) * (B - (P + V))
Cells(20 + n, "E") = xp: Cells(20 + n, "F") = xv
y = -10
x = 0

Do While y < 0
  x = x + 1
  Ri = 1 + (x / 10000)
  y = Ri ^ n - (P / pn) * (Ri - 1) - 1
Loop

Rx = Ri
If y > 0 Then
  Rx = 1 + (x - 1) / 10000
End If
```

```
Cells(10, "C") = Rx
SumP = 0: SumV = 0: Total_Chrg = 0
px = pn

For j = 1 To n
   Cells(20 + j, "C") = j
   Cells(20 + j, "G") = pn * Rx ^ (n - j)
   SumP = SumP + Cells(20 + j, "G"): Cells(20 + j, "J") = SumP
   Cells(20 + j, "H") = B - Total_Chrg - Cells(20 + j, "G") / r
   SumV = SumV + Cells(20 + j, "H"): Cells(20 + j, "K") = SumV
   Cells(20 + j, "L") = Cells(20 + j, "G") + Cells(20 + j, "H")
   Total_Chrg = SumP + SumV: Cells(20 + j, "M") = Total_Chrg
   Cells(20 + j, "N") = SumV / SumP
   Cells(20 + j, "E") = (SumP / Total_Chrg)
   Cells(20 + j, "F") = 1 - Cells(20 + j, "E")
   Cells(20 + j, "D") = np * Exp(kv * Cells(20 + j, "F"))
   Cells(20 + j, "I") = Cells(20 + j, "G") * (1 - r) / r
Next j
Cells(4, "D") = SumP: Cells(5, "D") = SumV

Rem Calculate Mix Time Prameters
Rem ============================
   kw = Log(B * wp / Cells(21, "I")) / -tp ^ 2: Cells(28, "A") = kw
   tx = tp / Sqr(-Log(wp)): Cells(30, "A") = tx
   x_val = Sqr(-Log(1 - Mix_pct)): Cells(31, "A") = x_val
   Wtr_1 = Cells(21, "I")
   Wtr_Residual = 0: WR = 0
   Wtr_pct = 0
```

```
   T_est = x_val * tx: T_Init = T_est: Sum_T_est = 0
   TA_est = Sqr((1 / -kw) * Log(1 - Mix_pct)): Sum_TA_est = 0
   TB_est = 0: Sum_TB_est = 0

For j = 1 To n
   Wtr_Residual = (1 - Mix_pct) * (Wtr_Residual + Cells(20 + j, "I")): Cells(20 + j, "O") = Wtr_Residual
   Wtr_pct = (WR + Cells(20 + j, "I")) / (WR + Cells(20 + j, "I") + Cells(20 + j, "M")): Cells(20 + j, "P") = Wtr_pct
   TB_est = Sqr((1 / (-kw * j)) * Log(1 - Cells(27, "A"))): Cells(20 + j, "S") = TB_est

   If j = 1 Then
      Cells(20 + j, "Q") = T_est
      Cells(20 + j, "R") = TA_est
   End If

   If j > 1 Then
      T_est = T_Init - Sqr(tx ^ 2 * Log(Wtr_pct) * (-1)): Cells(20 + j, "Q") = T_est
      TA_est = Sqr((1 / -kw) * Log(1 - (Cells(20 + j, "I") + Cells(19 + j, "O")) / Wtr_1)): Cells(20 + j, "R") = TA_est
   End If

   Sum_T_est = Sum_T_est + T_est
   Sum_TA_est = Sum_TA_est + TA_est
   Sum_TB_est = Sum_TB_est + TB_est
   WR = Wtr_Residual
Next j
Cells(33, "A") = Sum_T_est
Cells(34, "A") = Sum_TA_est
Cells(35, "A") = Sum_TB_est

End Sub
```

**EXCEL MACROS: MDL-D0**

```
Sub Mixer_PGM_D0()
   Worksheets("PGM_D0").Activate

Rem CLEAR CONTENTS
   Worksheets("PGM_D0").Range("C10:C10").ClearContents
   Worksheets("PGM_D0").Range("C13:C13").ClearContents
   Worksheets("PGM_D0").Range("C15:C18").ClearContents
   Worksheets("PGM_D0").Range("C21:S35").ClearContents
   Worksheets("PGM_D0").Range("A28:A35").ClearContents

Rem Start Procedure
Rem Input Parameters
Rem ====================================================================
nb$ = Cells(1, "C"): Rem INPUT "Batch Nbr (NB$) .............. NB$ ="; nb$
P = Cells(4, "C"): Rem   INPUT "Total Pigment Charge (P) ........ P ="; P
V = Cells(5, "C"): Rem   INPUT "Total Vehicle Charge (V) ........ V ="; V
np = Cells(6, "C"): Rem  INPUT "Pigment Viscosity (np) ......... np ="; np
nv = Cells(7, "C"): Rem  INPUT "Vehicle Viscosity (nv) ......... nv ="; nv
r = Cells(8, "C"): Rem   INPUT "% Solids of Pigment (r) ......... r ="; r
B = Cells(9, "C"): Rem   INPUT "Mixer Capacity (B) ............. B ="; B
n = Int(Cells(14, "C")): Rem INPUT "Number of Stages (n) ......... n ="; n
tp = Cells(23, "A"): Rem INPUT "Process Time ......... tp
Cells(29, "A") = 1: b2 = 1: Rem INPUT "2nd Water Distribution Constant .. b2=1
wp = Cells(24, "A"): Rem INPUT "Water Content % ........ wp

Mix_pct = Cells(27, "A"): Rem INPUT "Mix to % Completion .... Mix_pct
```

```
e = 2.7183
ex = 0.5

Rem Calculate Constants
Rem ===================
kv = Log(nv / np): Cells(17, "C") = kv
xv = V / (P + V): xp = (1 - xv): Cells(15, "C") = xv: Cells(16, "C") = xp
nmix = np * Exp(kv * xv): Cells(18, "C") = nmix
Rem n = Int((((P / r) + V) / (xp * B)) + 0.5): Cells(14, "C") = n
n0 = (P / r + V) / (xv * B): Cells(13, "C") = n0
Rem a = Log(nv / nmix)
pn = (r / (1 - r)) * (B - (P + V))
Cells(20 + n, "E") = xp: Cells(20 + n, "F") = xv
Rem 06/03/2009 Modify Iteration to DO WHILE (4 Place Accuracy)
y = -10
x = 0
Do While y < 0
  x = x + 1
  Ri = 1 + (x / 10000)
  y = Ri ^ n - (P / pn) * (Ri - 1) - 1
Loop
Rx = Ri
If y > 0 Then
  Rx = 1 + (x - 1) / 10000
End If

Cells(10, "C") = Rx
SumP = 0: SumV = 0: Total_Chrg = 0 : px = pn
```

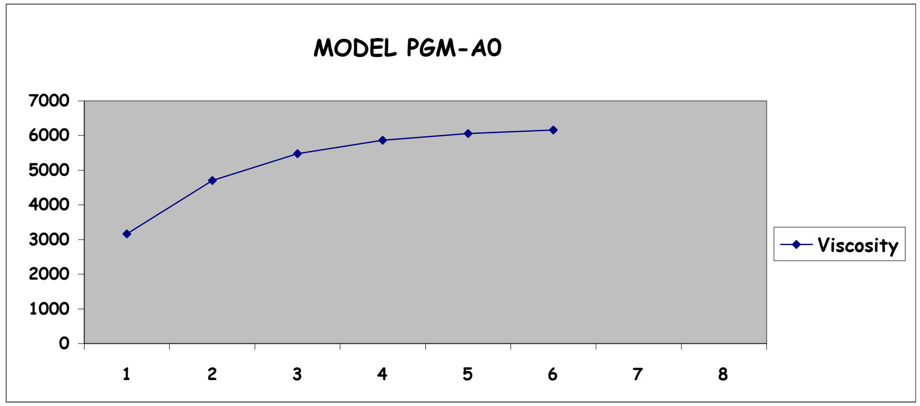
```
For j = 1 To n
   Cells(20 + j, "C") = j
   Cells(20 + j, "G") = pn * Rx ^ (n - j)
   SumP = SumP + Cells(20 + j, "G"): Cells(20 + j, "J") = SumP
   Cells(20 + j, "H") = B - Total_Chrg - Cells(20 + j, "G") / r
   SumV = SumV + Cells(20 + j, "H"): Cells(20 + j, "K") = SumV
   Cells(20 + j, "L") = Cells(20 + j, "G") + Cells(20 + j, "H")
   Total_Chrg = SumP + SumV: Cells(20 + j, "M") = Total_Chrg
   Cells(20 + j, "N") = SumV / SumP
   Cells(20 + j, "E") = (SumP / Total_Chrg)
   Cells(20 + j, "F") = 1 - Cells(20 + j, "E")
   Cells(20 + j, "D") = np * Exp(kv * Cells(20 + j, "F"))
   Cells(20 + j, "I") = Cells(20 + j, "G") * (1 - r) / r
Next j
Cells(4, "D") = SumP: Cells(5, "D") = SumV

Rem Calculate Mix Time Prameters
Rem ==============================
   kw = Log(B * wp / Cells(21, "I")) / -tp ^ 2: Cells(28, "A") = kw
   tx = tp / Sqr(-Log(wp)): Cells(30, "A") = tx
   x_val = Sqr(-Log(1 - Mix_pct)): Cells(31, "A") = x_val : Wtr_1 = Cells(21, "I")
   Wtr_Residual = 0: WR = 0 : Wtr_pct = 0
   T_est = x_val * tx: T_Init = T_est: Sum_T_est = 0

   TA_est = Sqr((1 / -kw) * Log(1 - Mix_pct)): Sum_TA_est = 0
   TB_est = 0: Sum_TB_est = 0
```

```
For j = 1 To n
    Wtr_Residual = (1 - Mix_pct) * (Wtr_Residual + Cells(20 + j, "I")): Cells(20 + j, "O") = Wtr_Residual

    Wtr_pct = (WR + Cells(20 + j, "I")) / (WR + Cells(20 + j, "I") + Cells(20 + j, "M")): Cells(20 + j, "P") = Wtr_pct
    TB_est = Sqr((1 / (-kw * j)) * Log(1 - Cells(27, "A"))): Cells(20 + j, "S") = TB_est
    If j = 1 Then
        Cells(20 + j, "Q") = T_est
        Cells(20 + j, "R") = TA_est
    End If

    If j > 1 Then
        T_est = T_Init - Sqr(tx ^ 2 * Log(Wtr_pct) * (-1)): Cells(20 + j, "Q") = T_est
        TA_est = Sqr((1 / -kw) * Log(1 - (Cells(20 + j, "I") + Cells(19 + j, "O")) / Wtr_1)): Cells(20 + j, "R") = TA_est
    End If

    Sum_T_est = Sum_T_est + T_est
    Sum_TA_est = Sum_TA_est + TA_est
    Sum_TB_est = Sum_TB_est + TB_est
    WR = Wtr_Residual

Next j

Cells(33,"A") = Sum_T_est
Cells(34,"A") = Sum_TA_est
Cells(35,"A") = Sum_TB_est

End Sub
```

| PGM_A0 BATCH NBR = | PGM-A0 |
|---|---|

| INPUT | INPUT | Optimized |
|---|---|---|
| Total Pigment Charge -------> | 1350 | 1418 |
| Total Vehicle Charge -------> | 1200 | 1258 |
| Pigment Viscosity ----------> | 240000 | |
| Vehicle Viscosity ----------> | 100 | |
| % Solids (Presscake) -------> | 0.20 | |
| Bulk Capacity -------------> | 3000 | |
| Allowance % | 15% | |

Update PGM - A0



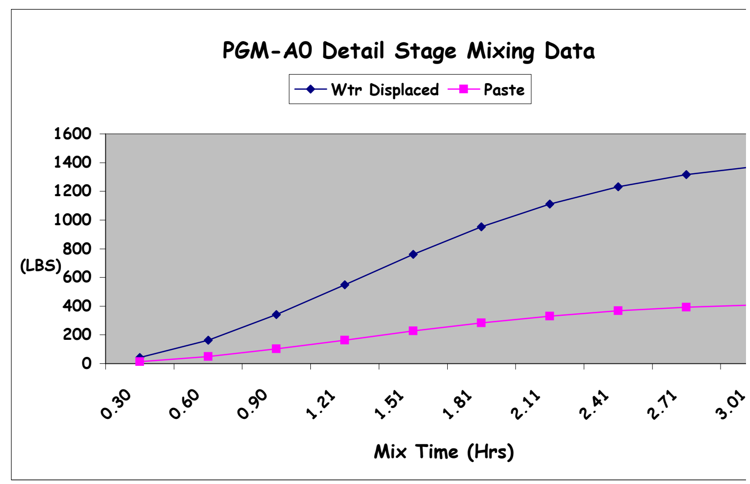

| OUTPUT | OUTPUT |
|---|---|
| Stages (Calculated) | 5.6313 |
| Stages (Optimized) | 6 |
| % Vehicle Charge | 0.4706 |
| % Pigment Charge | 0.5294 |
| System Visc Constabt (k) | -7.7832 |
| Mix Viscosity | 6159.19 |

| Flush Distribution | Stage (j) | Viscosity | % Pgmt | % Veh | Pigment | Vehicle | Wtr Disp | Cum Pgmt | Cum Veh | P(j)+V(j) | Cum Chrg | V/P Ratio | Water Rsidual | % Water Displaced | Mix Time Est | Mix Time Method-A | Mix Time Method-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPUT DATA (Mix Rate) | 1 | 3159.85 | 0.4437 | 0.5563 | 480 | 600 | 1920 | 480 | 600 | 1080 | 1080 | 1.25 | 96.00 | 64.00% | 3.16 | 4.42 | 4.42 |
| | 2 | 4699.58 | 0.4947 | 0.5053 | 337 | 235 | 1348 | 817 | 835 | 572 | 1652 | 1.02 | 72.20 | 46.64% | 1.57 | 3.01 | 3.12 |
| | 3 | 5474.38 | 0.5143 | 0.4857 | 237 | 163 | 948 | 1054 | 998 | 400 | 2052 | 0.95 | 51.01 | 33.21% | 1.24 | 2.22 | 2.55 |
| | 4 | 5864.27 | 0.5231 | 0.4769 | 167 | 113 | 668 | 1221 | 1111 | 280 | 2332 | 0.91 | 35.95 | 23.57% | 0.97 | 1.75 | 2.21 |
| | 5 | 6060.46 | 0.5273 | 0.4727 | 116 | 88 | 464 | 1337 | 1199 | 204 | 2536 | 0.90 | 25.00 | 16.47% | 0.71 | 1.40 | 1.98 |
| | 6 | 6159.19 | 0.5294 | 0.4706 | 81 | 59 | 324 | 1418 | 1258 | 140 | 2676 | 0.89 | 17.45 | 11.54% | 0.48 | 1.14 | 1.80 |

| | |
|---|---|
| 1 | = Process Stage # |
| 1.75 | = Process Time hrs (tp) |
| 40.00% | = Water Content % (wp) |
| 25.0 | = Temp deg (C) |
| 77.0 | = Temp deg (F) |
| 95.0% | = Mix to % Completion |
| 0.1535 | = Water Dist Const (kw) |
| 1 | = 2nd Water Dist Const (b) |
| 1.83 | = Mix Time Const (tx) |
| 1.73 | = X-Val Const for % Complete |
| | Mix Time Totals (Hours) |
| 8.13 | = Mix Time Estimate |
| 13.95 | = Mix Time Method (A) |
| 16.08 | = Mix Time Method (B) |

| | ITEM | Viscosity | Charge | Pct % |
|---|---|---|---|---|
| Input the Item Codes -------> | X-K1387 | 66300.00 | 125.82 | 53.54% |
| Vehicle Substitution ----> | S-535 | 0.0560 | 109.18 | 46.46% |
| for Stage # --------> | 2 | 100.00 | 235.00 | 100.00% |

| | Detailed Mixing Process Data Mass Units = # (lbs, kg, etc) | Est Mix Time | Wtr Displaced | Rate Wtr Displaced | Pigment Wetting | Rate-Pgmt Wetting | Paste Formation | Rate-Paste Formation | Paste Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 2 | <-- Select Stage (INPUT) | t (hrs) | w(t) # | w'(t) #/hr | P(t) # | P'(t) #/hr | PV(t) # | PV'(t) #/hr | Visc(t) |
| 3.01 | <-- Stage Mix Time (hrs) | 0.30 | 42.62 | 278.53 | 10.65 | 69.63 | 18.08 | 118.19 | 2.57 |
| 1444 | <-- Stage Water Displacement | 0.60 | 163.07 | 509.17 | 40.77 | 127.29 | 69.20 | 216.06 | 4.04 |
| 0.3297 | <-- Stage Constant (Method A) | 0.90 | 341.26 | 657.52 | 85.31 | 164.38 | 144.81 | 279.01 | 8.26 |
| -17.0366 | <-- System Constant (Water Kw) | 1.21 | 549.87 | 710.84 | 137.47 | 177.71 | 233.33 | 301.63 | 20.78 |
| 600 | <-- Cum Vehicle ( j - 1 ) | 1.51 | 761.17 | 678.56 | 190.29 | 169.64 | 322.99 | 287.94 | 58.98 |
| 480 | <-- Cum Pigment ( j - 1 ) | 1.81 | 952.87 | 585.68 | 238.22 | 146.42 | 404.33 | 248.52 | 169.76 |
| 4699.58 | <-- Est End Viscosiy @ 0% Water | 2.11 | 1111.29 | 462.88 | 277.82 | 115.72 | 471.56 | 196.42 | 446.57 |
| | | 2.41 | 1231.72 | 337.53 | 307.93 | 84.38 | 522.66 | 143.22 | 994.12 |
| | | 2.71 | 1316.43 | 228.18 | 329.11 | 57.05 | 558.61 | 96.83 | 1812.45 |
| | | 3.01 | 1371.80 | 143.50 | 342.95 | 35.87 | 582.10 | 60.89 | 2733.12 |

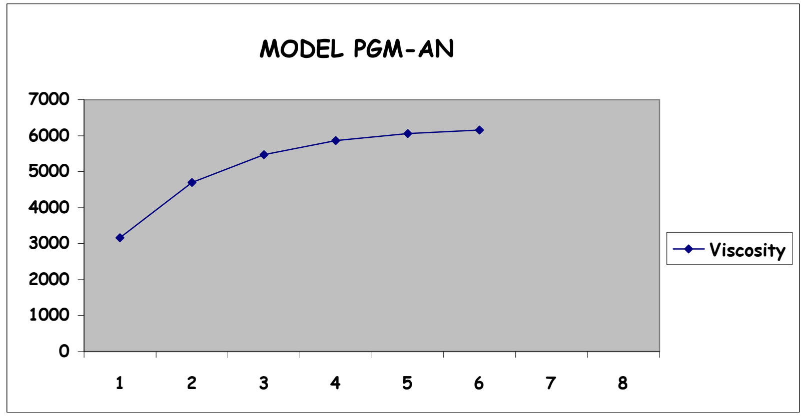


| PGM_AN BATCH NBR = | PGM-AN |
|---|---|

| INPUT | INPUT | Optimized |
|---|---|---|
| Total Pigment Charge -------> | 1350 | 1418 |
| Total Vehicle Charge -------> | 1200 | 1258 |
| Pigment Viscosity ----------> | 240000 | |
| Vehicle Viscosity ----------> | 100 | |
| % Solids (Presscake) -------> | 0.20 | |
| Bulk Capacity -------------> | 3000 | |
| Allowance % | 15% | |

Update PGM - AN

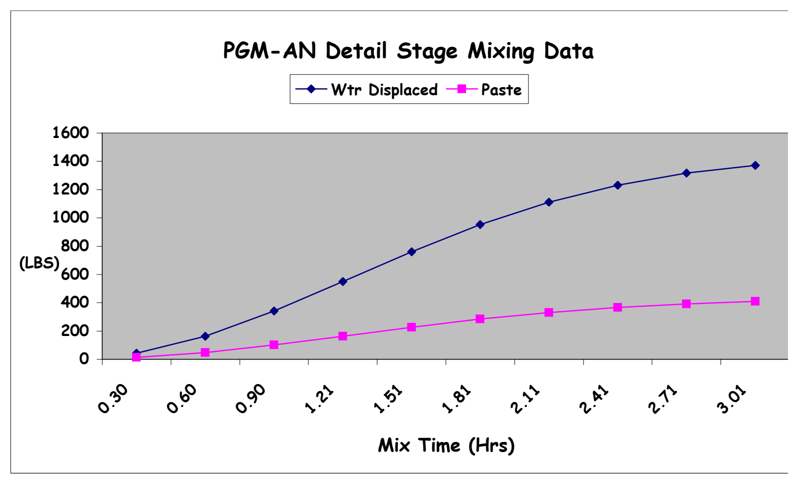
| OUTPUT | OUTPUT |
|---|---|
| Stages (Calculated) | 5.6313 |
| Stages (INPUT) -----------> | 6.0000 |
| % Vehicle Charge | 0.4706 |
| % Pigment Charge | 0.5294 |
| System Visc Constabt (k) | -7.7832 |
| Mix Viscosity | 6159.19 |




| | Flush Distribution | Stage (j) | Viscosity | % Pgmt | % Veh | Pigment | Vehicle | Wtr Disp | Cum Pgmt | Cum Veh | P(j)+V(j) | Cum Chrg | V/P Ratio | Water Rsidual | % Water Displaced | Mix Time Est | Mix Time Method-A | Mix Time Method-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | INPUT DATA (Mix Rate) | 1 | 3159.85 | 0.4437 | 0.5563 | 480 | 600 | 1920 | 480 | 600 | 1080 | 1080 | 1.25 | 96.00 | 64.00% | 3.16 | 4.42 | 4.42 |
| 1 | = Process Stage # | 2 | 4699.58 | 0.4947 | 0.5053 | 337 | 235 | 1348 | 817 | 835 | 572 | 1652 | 1.02 | 72.20 | 46.64% | 1.57 | 3.01 | 3.12 |
| 1.75 | = Process Time hrs (tp) | 3 | 5474.38 | 0.5143 | 0.4857 | 237 | 163 | 948 | 1054 | 998 | 400 | 2052 | 0.95 | 51.01 | 33.21% | 1.24 | 2.22 | 2.55 |
| 40.00% | = Water Content % (wp) | 4 | 5864.27 | 0.5231 | 0.4769 | 167 | 113 | 668 | 1221 | 1111 | 280 | 2332 | 0.91 | 35.95 | 23.57% | 0.97 | 1.75 | 2.21 |
| 25.0 | = Temp deg (C) | 5 | 6060.46 | 0.5273 | 0.4727 | 116 | 88 | 464 | 1337 | 1199 | 204 | 2536 | 0.90 | 25.00 | 16.47% | 0.71 | 1.40 | 1.98 |
| 77.0 | = Temp deg (F) | 6 | 6159.19 | 0.5294 | 0.4706 | 81 | 59 | 324 | 1418 | 1258 | 140 | 2676 | 0.89 | 17.45 | 11.54% | 0.48 | 1.14 | 1.80 |
| 95.0% | = Mix to % Completion | | | | | | | | | | | | | | | | | |
| 0.1535 | = Water Dist Const (kw) | | | | | | | | | | | | | | | | | |
| 1 | = 2nd Water Dist Const (b) | | | | | | | | | | | | | | | | | |
| 1.83 | = Mix Time Const (tx) | | | | | | | | | | | | | | | | | |
| 1.73 | = X-Val Const for % Complete | | | | | | | | | | | | | | | | | |
| | Mix Time Totals | | | | | | | | | | | | | | | | | |
| 8.13 | = Mix Time Estimate | | | | | | | | | | | | | | | | | |
| 13.95 | = Mix Time Method (A) | | | | | | | | | | | | | | | | | |
| 16.08 | = Mix Time Method (B) | | | | | | | | | | | | | | | | | |

| | ITEM | Viscosity | Charge | Pct % |
|---|---|---|---|---|
| Input the Item Codes -------> | X-K444 | 670000000.00 | 75.83 | 32.27% |
| Vehicle Substitution ----> | S-535 | 0.0560 | 159.17 | 67.73% |
| for Stage # --------> | 2 | 100.00 | 235.00 | 100.00% |

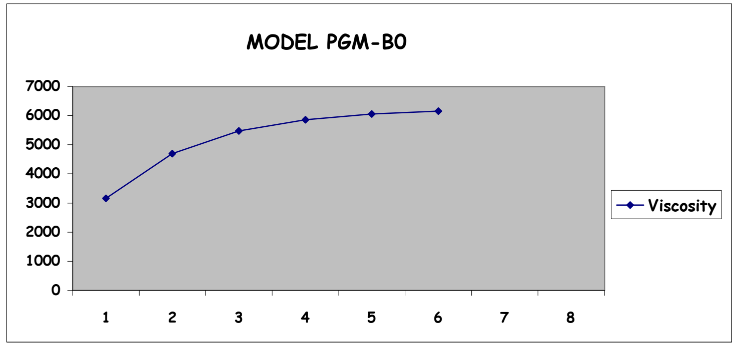
| | Detailed Mixing Process Data<br>Mass Units = # (lbs, kg, etc) | Est Mix Time | Wtr Displaced | Rate Wtr Displaced | Pigment Wetting | Rate-Pgmt Wetting | Paste Formation | Rate-Paste Formation | Paste Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 2 | <-- Select Stage (INPUT) | t (hrs) | w(t) # | w'(t) #/hr | P(t) # | P'(t) #/hr | PV(t) # | PV'(t) #/hr | Visc(t) |
| 3.01 | <-- Stage Mix Time (hrs) | 0.30 | 42.62 | 278.53 | 10.65 | 69.63 | 18.08 | 118.19 | 2.57 |
| 1444 | <-- Stage Water Displacement | 0.60 | 163.07 | 509.17 | 40.77 | 127.29 | 69.20 | 216.06 | 4.04 |
| 0.3297 | <-- Stage Constant (Method A) | 0.90 | 341.26 | 657.52 | 85.31 | 164.38 | 144.81 | 279.01 | 8.26 |
| -17.0366 | <-- System Constant (Water Kw) | 1.21 | 549.87 | 710.84 | 137.47 | 177.71 | 233.33 | 301.63 | 20.78 |
| 600 | <-- Cum Vehicle ( j - 1 ) | 1.51 | 761.17 | 678.56 | 190.29 | 169.64 | 322.99 | 287.94 | 58.98 |
| 480 | <-- Cum Pigment ( j - 1 ) | 1.81 | 952.87 | 585.68 | 238.22 | 146.42 | 404.33 | 248.52 | 169.76 |
| 4699.58 | <-- Est End Viscosiy @ 0% Water | 2.11 | 1111.29 | 462.88 | 277.82 | 115.72 | 471.56 | 196.42 | 446.57 |
| | | 2.41 | 1231.72 | 337.53 | 307.93 | 84.38 | 522.66 | 143.22 | 994.12 |
| | | 2.71 | 1316.43 | 228.18 | 329.11 | 57.05 | 558.61 | 96.83 | 1812.45 |
| | | 3.01 | 1371.80 | 143.50 | 342.95 | 35.87 | 582.10 | 60.89 | 2733.12 |



| PGM_B0 BATCH NBR = | PGM-B0 |
|---|---|

| INPUT | INPUT | Optimized |
|---|---|---|
| Total Pigment Charge (OUTPUT) | 1349.97 | 1418 |
| Total Vehicle Charge (OUTPUT) | 1200.03 | 1258 |
| Pigment Viscosity ------------> | 240000 | |
| Vehicle Viscosity ------------> | 100 | |
| % Solids (Presscake) ---------> | 0.20 | |
| Bulk Capacity ----------------> | 3000 | |
| % Pigment in Mix (xp) --------> | 52.94% | |

Update PGM - B0



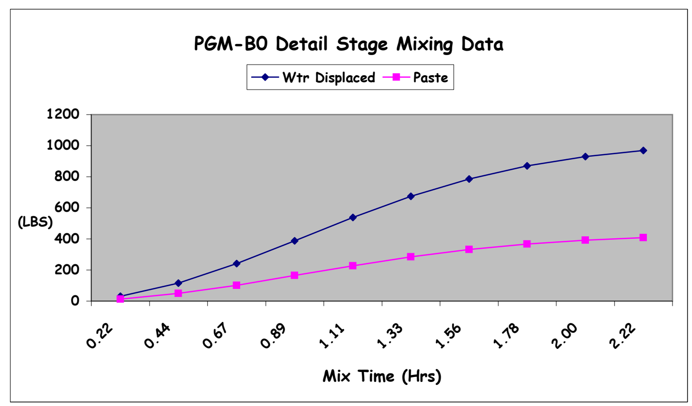

| OUTPUT | OUTPUT |
|---|---|
| Stages (Calculated) | 5.6310 |
| Stages (Optimized) | 6 |
| % Vehicle Charge | 0.4706 |
| % Pigment Charge | 0.5294 |
| System Visc Constabt (k) | -7.7832 |
| Mix Viscosity | 6158.63 |

| Flush Distribution | Stage (j) | Viscosity | % Pgmt | % Veh | Pigment | Vehicle | Wtr Disp | Cum Pgmt | Cum Veh | P(j)+V(j) | Cum Chrg | V/P Ratio | Water Rsidual | % Water Displaced | Mix Time Est | Mix Time Method-A | Mix Time Method-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPUT DATA (Mix Rate) | 1 | 3159.52 | 0.4436 | 0.5564 | 480 | 600 | 1920 | 480 | 600 | 1080 | 1080 | 1.25 | 96.00 | 64.00% | 3.16 | 4.42 | 4.42 |
| | 2 | 4699.11 | 0.4946 | 0.5054 | 337 | 235 | 1348 | 817 | 835 | 572 | 1652 | 1.02 | 72.20 | 46.64% | 1.57 | 3.01 | 3.12 |
| | 3 | 5473.86 | 0.5143 | 0.4857 | 237 | 163 | 948 | 1054 | 998 | 400 | 2052 | 0.95 | 51.01 | 33.21% | 1.24 | 2.22 | 2.55 |
| | 4 | 5863.72 | 0.5231 | 0.4769 | 167 | 113 | 668 | 1221 | 1111 | 280 | 2332 | 0.91 | 35.95 | 23.57% | 0.97 | 1.75 | 2.21 |
| | 5 | 6059.90 | 0.5273 | 0.4727 | 116 | 88 | 464 | 1337 | 1199 | 204 | 2536 | 0.90 | 25.00 | 16.47% | 0.71 | 1.40 | 1.98 |
| | 6 | 6158.63 | 0.5294 | 0.4706 | 81 | 59 | 324 | 1418 | 1258 | 140 | 2676 | 0.89 | 17.45 | 11.54% | 0.48 | 1.14 | 1.80 |

| | |
|---|---|
| 1 | = Process Stage # |
| 1.75 | = Process Time hrs (tp) |
| 40.00% | = Water Content % (wp) |
| 25.0 | = Temp deg (C) |
| 77.0 | = Temp deg (F) |
| 95.0% | = Mix to % Completion |
| 0.1535 | = Water Dist Const (kw) |
| 1 | = 2nd Water Dist Const (b) |
| 1.83 | = Mix Time Const (tx) |
| 1.73 | = X-Val Const for % Complete |
| | Mix Time Totals (Hours) |
| 8.13 | = Mix Time Estimate |
| 13.95 | = Mix Time Method (A) |
| 16.08 | = Mix Time Method (B) |

| | ITEM | Viscosity | Charge | Pct % |
|---|---|---|---|---|
| Input the Item Codes -------> | X-K1387 | 66300.00 | 125.82 | 53.54% |
| Vehicle Substitution ----> | S-535 | 0.0560 | 109.18 | 46.46% |
| for Stage # --------> | 2 | 100.00 | 235.00 | 100.00% |

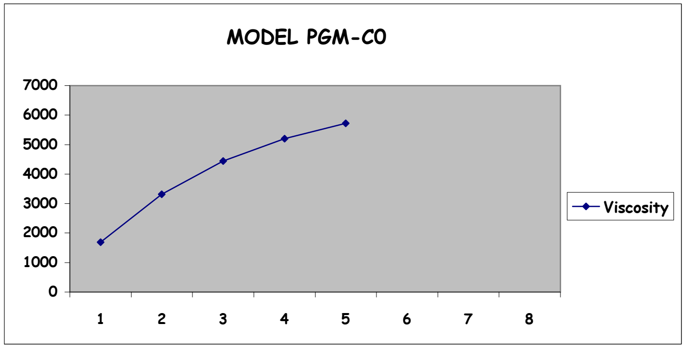
| | Detailed Mixing Process Data<br>Mass Units = # (lbs, kg, etc) | Est Mix Time | Wtr Displaced | Rate Wtr Displaced | Pigment Wetting | Rate-Pgmt Wetting | Paste Formation | Rate-Paste Formation | Paste Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 3 | <-- Select Stage (INPUT) | t (hrs) | w(t) # | w'(t) #/hr | P(t) # | P'(t) #/hr | PV(t) # | PV'(t) #/hr | Visc(t) |
| 2.22 | <-- Stage Mix Time (hrs) | 0.22 | 30.11 | 266.94 | 7.53 | 66.73 | 12.70 | 112.63 | 35.57 |
| 1020.2 | <-- Stage Water Displacement | 0.44 | 115.21 | 487.99 | 28.80 | 122.00 | 48.61 | 205.90 | 50.29 |
| 0.6066 | <-- Stage Constant (Method A) | 0.67 | 241.10 | 630.16 | 60.28 | 157.54 | 101.73 | 265.89 | 86.03 |
| -17.0366 | <-- System Constant (Water Kw) | 0.89 | 388.49 | 681.27 | 97.12 | 170.32 | 163.92 | 287.45 | 167.97 |
| 835 | <-- Cum Vehicle ( j - 1 ) | 1.11 | 537.78 | 650.33 | 134.44 | 162.58 | 226.91 | 274.40 | 347.50 |
| 817 | <-- Cum Pigment ( j - 1 ) | 1.33 | 673.21 | 561.31 | 168.30 | 140.33 | 284.06 | 236.84 | 704.75 |
| 5473.86 | <-- Est End Viscosiy @ 0% Water | 1.56 | 785.14 | 443.62 | 196.28 | 110.91 | 331.28 | 187.18 | 1312.71 |
| | | 1.78 | 870.22 | 323.48 | 217.56 | 80.87 | 367.18 | 136.49 | 2159.22 |
| | | 2.00 | 930.07 | 218.69 | 232.52 | 54.67 | 392.44 | 92.27 | 3106.70 |
| | | 2.22 | 969.19 | 137.53 | 242.30 | 34.38 | 408.94 | 58.03 | 3966.06 |



| PGM_CO BATCH NBR = | PGM-CO |
|---|---|

| INPUT | INPUT | Optimized |
|---|---|---|
| Total Pigment Charge ---------> | 1350 | 1299.768397 |
| Total Vehicle Charge ---------> | 1200 | 1200.231603 |
| Pigment Viscosity ------------> | 240000 | |
| Vehicle Viscosity ------------> | 100 | |
| % Solids (Presscake) ---------> | 0.20 | |
| Bulk Capacity ---------------> | 3000 | |
| R-Facror (Ratio) OUTPUT | 1.3729 | |

Update PGM - CO



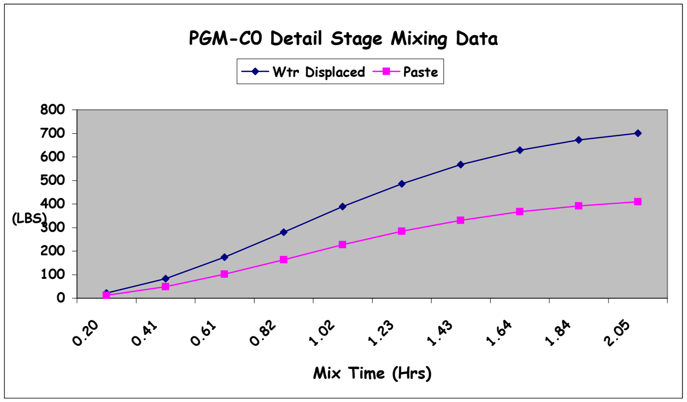

| OUTPUT | OUTPUT |
|---|---|
| Stages (Calculated) | 5.3472 |
| Stages (Optimized) | 5 |
| % Vehicle Charge | 0.4800 |
| % Pigment Charge | 0.5200 |
| System Visc Constabt (k) | -7.7832 |
| Mix Viscosity | 5724.13 |

| | Flush Distribution |
|---|---|
| | INPUT DATA (Mix Rate) |
| 1 | = Process Stage # |
| 1.75 | = Process Time hrs (tp) |
| 40.00% | = Water Content % (wp) |
| 25.0 | = Temp deg (C) |
| 77.0 | = Temp deg (F) |
| 95.0% | = Mix to % Completion |
| 0.1281 | = Water Dist Const (kw) |
| 1 | = 2nd Water Dist Const (b) |
| 1.83 | = Mix Time Const (tx) |
| 1.73 | = X-Val Const for % Complete |
| | Mix Time Totals (Hours) |
| 7.67 | = Mix Time Estimate |
| 14.55 | = Mix Time Method (A) |
| 15.63 | = Mix Time Method (B) |

| Stage (j) | Viscosity | % Pgmt | % Veh | Pigment | Vehicle | Wtr Disp | Cum Pgmt | Cum Veh | P(j)+V(j) | Cum Chrg | V/P Ratio | Water Rsidual | % Water Displaced | Mix Time Est | Mix Time Method-A | Mix Time Method-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1685.49 | 0.3629 | 0.6371 | 444.08 | 779.5774 | 1776.34 | 444.08 | 779.58 | 1223.66 | 1223.66 | 1.76 | 88.82 | 59.21% | 3.16 | 4.84 | 4.84 |
| 2 | 3316.42 | 0.4499 | 0.5501 | 323.46 | 159.0152 | 1293.86 | 767.55 | 938.59 | 482.48 | 1706.14 | 1.22 | 69.13 | 44.76% | 1.53 | 3.43 | 3.42 |
| 3 | 4446.31 | 0.4875 | 0.5125 | 235.61 | 115.8243 | 942.43 | 1003.16 | 1054.42 | 351.43 | 2057.57 | 1.05 | 50.58 | 32.96% | 1.24 | 2.57 | 2.79 |
| 4 | 5204.69 | 0.5078 | 0.4922 | 171.61 | 84.36471 | 686.45 | 1174.77 | 1138.78 | 255.98 | 2313.55 | 0.97 | 36.85 | 24.16% | 0.99 | 2.05 | 2.42 |
| 5 | 5720.01 | 0.5199 | 0.4801 | 125.00 | 61.45 | 500.00 | 1299.77 | 1200.23 | 186.45 | 2500.00 | 0.92 | 26.84 | 17.68% | 0.76 | 1.68 | 2.16 |

| | ITEM | Viscosity | Charge | Pct % |
|---|---|---|---|---|
| Input the Item Codes -------> | X-K1387 | 66300.00 | 85.14 | 53.54% |
| Vehicle Substitution ----> | S-535 | 0.0560 | 73.87 | 46.46% |
| for Stage # --------> | 2 | 100.00 | 159.02 | 100.00% |

| | Detailed Mixing Process Data Mass Units = # (lbs, kg, etc) | Est Mix Time | Wtr Displaced | Rate Wtr Displaced | Pigment Wetting | Rate-Pgmt Wetting | Paste Formation | Rate-Paste Formation | Paste Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 4 | <-- Select Stage (INPUT) | t (hrs) | w(t) # | w'(t) #/hr | P(t) # | P'(t) #/hr | PV(t) # | PV'(t) #/hr | Visc(t) |
| 2.05 | <-- Stage Mix Time (hrs) | 0.20 | 21.75 | 209.49 | 5.44 | 52.37 | 8.11 | 78.12 | 155.71 |
| 737.03 | <-- Stage Water Displacement | 0.41 | 83.23 | 382.96 | 20.81 | 95.74 | 31.04 | 142.81 | 201.39 |
| 0.7158 | <-- Stage Constant (Method A) | 0.61 | 174.18 | 494.54 | 43.54 | 123.63 | 64.95 | 184.41 | 298.69 |
| -17.0366 | <-- System Constant (Water Kw) | 0.82 | 280.66 | 534.64 | 70.16 | 133.66 | 104.66 | 199.37 | 484.30 |
| 1054.42 | <-- Cum Vehicle ( j - 1 ) | 1.02 | 388.51 | 510.37 | 97.13 | 127.59 | 144.88 | 190.32 | 810.80 |
| 1003.16 | <-- Cum Pigment ( j - 1 ) | 1.23 | 486.35 | 440.50 | 121.59 | 110.13 | 181.36 | 164.26 | 1325.74 |
| 5204.69 | <-- Est End Viscosiy @ 0% Water | 1.43 | 567.21 | 348.15 | 141.80 | 87.04 | 211.51 | 129.82 | 2027.91 |
| | | 1.64 | 628.68 | 253.86 | 157.17 | 63.47 | 234.43 | 94.67 | 2835.22 |
| | | 1.84 | 671.92 | 171.62 | 167.98 | 42.91 | 250.56 | 64.00 | 3612.41 |
| | | 2.05 | 700.18 | 107.93 | 175.04 | 26.98 | 261.10 | 40.25 | 4244.89 |

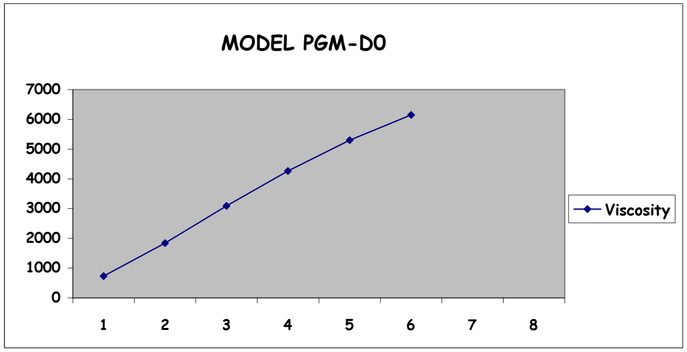


| PGM_DO BATCH NBR = | PGM-DO |
|---|---|

| INPUT | INPUT | Optimized |
|---|---|---|
| Total Pigment Charge ----------> | 1350 | 1349.70 |
| Total Vehicle Charge ----------> | 1200 | 1200.30 |
| Pigment Viscosity -------------> | 240000 | |
| Vehicle Viscosity -------------> | 100 | |
| % Solids (Presscake) ----------> | 0.20 | |
| Bulk Capacity -----------------> | 3000 | |
| R-Facror (Ratio) OUTPUT | 1.2754 | |

Update PGM-DO

| OUTPUT | OUTPUT |
|---|---|
| Stages (Calculated) | 5.6313 |
| Stages (INPUT) --------------> | 6.0000 |
| % Vehicle Charge | 0.4706 |
| % Pigment Charge | 0.5294 |
| System Visc Constabt (k) | -7.7832 |
| Mix Viscosity | 6159.19 |

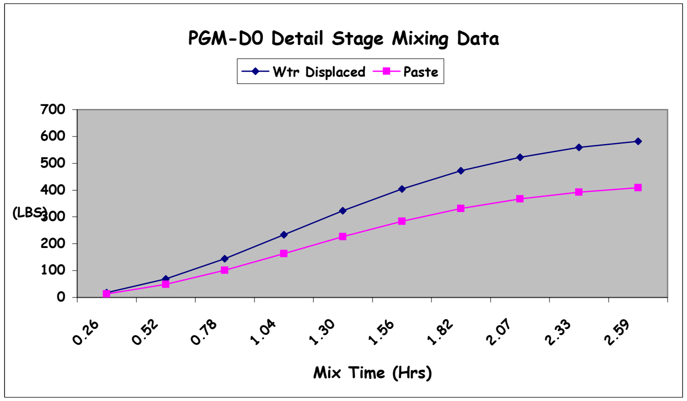



| Flush Distribution | Stage (j) | Viscosity | % Pgmt | % Veh | Pigment | Vehicle | Wtr Disp | Cum Pgmt | Cum Veh | P(j)+V(j) | Cum Chrg | V/P Ratio | Water Rsidual | % Water Displaced | Mix Time Est | Mix Time Method-A | Mix Time Method-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPUT DATA (Mix Rate) | 1 | 734.98 | 0.2563 | 0.7437 | 379.65 | 1101.7448 | 1518.60 | 379.65 | 1101.74 | 1481.40 | 1481.40 | 2.90 | 75.93 | 50.62% | 3.16 | 6.24 | 6.24 |
| | 2 | 1842.45 | 0.3744 | 0.6256 | 297.67 | 30.243488 | 1190.69 | 677.32 | 1131.99 | 327.92 | 1809.31 | 1.67 | 63.33 | 41.18% | 1.44 | 4.83 | 4.41 |
| | 3 | 3088.42 | 0.4407 | 0.5593 | 233.40 | 23.712944 | 933.58 | 910.72 | 1155.70 | 257.11 | 2066.42 | 1.27 | 49.85 | 32.54% | 1.23 | 3.73 | 3.60 |
| | 4 | 4266.38 | 0.4822 | 0.5178 | 183.00 | 18.592554 | 731.99 | 1093.72 | 1174.29 | 201.59 | 2268.01 | 1.07 | 39.09 | 25.64% | 1.03 | 3.07 | 3.12 |
| | 5 | 5293.86 | 0.5100 | 0.4900 | 143.48 | 14.577822 | 573.93 | 1237.20 | 1188.87 | 158.06 | 2426.07 | 0.96 | 30.65 | 20.17% | 0.85 | 2.59 | 2.79 |
| | 6 | 6153.52 | 0.5293 | 0.4707 | 112.50 | 11.43 | 450.00 | 1349.70 | 1200.30 | 123.93 | 2550.00 | 0.89 | 24.03 | 15.86% | 0.68 | 2.22 | 2.55 |

| | |
|---|---|
| 1 | = Process Stage # |
| 1.75 | = Process Time hrs (tp) |
| 40.00% | = Water Content % (wp) |
| 25.0 | = Temp deg (C) |
| 77.0 | = Temp deg (F) |
| 95.0% | = Mix to % Completion |
| 0.0769 | = Water Dist Const (kw) |
| 1 | = 2nd Water Dist Const (b) |
| 1.83 | = Mix Time Const (tx) |
| 1.73 | = X-Val Const for % Complete |
| | Mix Time Totals (Hours) |
| 8.40 | = Mix Time Estimate |
| 22.69 | = Mix Time Method (A) |
| 22.72 | = Mix Time Method (B) |

| | ITEM | Viscosity | Charge | Pct % |
|---|---|---|---|---|
| Input the Item Codes --------> | X-K1387 | 66300.00 | 16.19 | 53.54% |
| Vehicle Substitution -----> | S-535 | 0.0560 | 14.05 | 46.46% |
| for Stage # ---------> | 2 | 100.00 | 30.24 | 100.00% |

| | Detailed Mixing Process Data Mass Units = # (lbs, kg, etc) | Est Mix Time | Wtr Displaced | Rate Wtr Displaced | Pigment Wetting | Rate-Pgmt Wetting | Paste Formation | Rate-Paste Formation | Paste Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 5 | <-- Select Stage (INPUT) | t (hrs) | w(t) # | w'(t) #/hr | P(t) # | P'(t) #/hr | PV(t) # | PV'(t) #/hr | Visc(t) |
| 2.59 | <-- Stage Mix Time (hrs) | 0.26 | 18.09 | 137.47 | 4.52 | 34.37 | 4.98 | 37.86 | 288.91 |
| 613.0218 | <-- Stage Water Displacement | 0.52 | 69.23 | 251.30 | 17.31 | 62.83 | 19.07 | 69.21 | 358.64 |
| 0.4456 | <-- Stage Constant (Method A) | 0.78 | 144.87 | 324.52 | 36.22 | 81.13 | 39.90 | 89.37 | 499.05 |
| -17.0366 | <-- System Constant (Water Kw) | 1.04 | 233.43 | 350.83 | 58.36 | 87.71 | 64.29 | 96.62 | 747.30 |
| 1174.294 | <-- Cum Vehicle ( j - 1 ) | 1.30 | 323.14 | 334.90 | 80.79 | 83.73 | 88.99 | 92.23 | 1147.59 |
| 1093.716 | <-- Cum Pigment ( j - 1 ) | 1.56 | 404.52 | 289.06 | 101.13 | 72.26 | 111.41 | 79.61 | 1725.36 |
| 5293.86 | <-- Est End Viscosiy @ 0% Water | 1.82 | 471.78 | 228.45 | 117.94 | 57.11 | 129.93 | 62.92 | 2451.57 |
| | | 2.07 | 522.90 | 166.59 | 130.73 | 41.65 | 144.01 | 45.88 | 3231.43 |
| | | 2.33 | 558.87 | 112.62 | 139.72 | 28.15 | 153.91 | 31.02 | 3943.88 |
| | | 2.59 | 582.37 | 70.82 | 145.59 | 17.71 | 160.38 | 19.50 | 4502.62 |



| CODE | DESCRIPTION | VISCOSITY | TEMP-0 | TEMP-k |
|---|---|---|---|---|
| **P-PGMT** | General Organic Pigment | 240000 | | |
| **S-470** | #470 Oil | 0.033 | | |
| **S-500** | #500 Oil | 0.0573 | | |
| **S-5300** | #5300 Oil | 0.405 | | |
| **S-535** | #535 Oil | 0.056 | | |
| **S-GEN** | General Industrial Solvent | 0.00944 | | |
| **S-HYD47** | Hydrocarbon Solvent #47 | 0.0385 | | |
| **S-HYD52** | Hydrocarbon Solvent #52 | 0.058 | | |
| **S-TDA** | Trydecyl Alcohol Ethoxylate | 0.161 | | |
| **S-WTR** | Water | 0.009579 | 3.7 | -0.02021 |
| **V-0** | Litho #0 Regular | 115 | | |
| **V-00** | Litho #00 Regular | 70 | | |
| **V-000** | Litho #000 Regular | 20 | | |
| **V-1** | Litho #1 Regular | 204 | 5.14E+14 | -0.09577 |
| **V-2** | Litho #2 Regular | 325 | | |
| **V-3** | Litho #3 Regular | 458 | | |
| **V-4** | Litho #4 Regular | 808 | | |
| **V-5** | Litho #5 Regular | 1746 | | |
| **V-6** | Litho #6 Regular | 2263 | | |
| **V-7** | Litho #7 Regular | 48000 | | |
| **V-EXP200** | Experimental Resin Solution #200 | 200 | 1.14E+11 | -0.09163 |
| **V-EXP850** | Experimental Resin Solution #850 | 850 | 171136 | -0.01786 |
| **X-454K** | Pentaerythritol Ester of Rosin #454 | 8000000 | | |
| **X-858K** | Pentaerythritol Ester of Rosin #858 | 2450000 | | |
| **X-K1387** | Modified Phenolic Resin #1387 | 66300 | | |
| **X-K444** | Pentaerythritol Ester of Rosin #454 | 670000000 | | |
| **X-P6140** | Pico 6140 | 46500 | | |
| **X-Pent K** | Pentaerythritol Ester of Rosin | 7400000 | | |

| | Viscosiy | Degrees - F | Degrees - C | Degrees - K |
|---|---|---|---|---|
| Vehicle #1 = | 0.009579 | 72 | 22.22 | 295.37 |
| Vehicle #2 = | 0.005588 | 120 | 48.89 | 322.04 |
| Target = | 0.007 | 99.94 | 37.74 | 310.89 |

| | |
|---|---|
| TEMP-k = | -0.020211 |
| TEMP-0 = | 3.75 |