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APPENDICES

Appendix A Physical Data for a Hot-oil Heat Exchanger (Model A)

$$M_o(kg/h) = F_o(m^3/h) \times Density\ (kg/m^3)$$
$$= F_o(m^3/h) \times (-0.6048T_{o,in} + 875.12)$$
$$M_{et}(kg/h) = F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times MW(g/mol) \times \frac{1\ kg}{1000\ g}$$
$$= F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times 29.9(g/mol) \times \frac{1\ kg}{1000\ g}$$
$$C_{p,o}(kJ/kg\ ^\circ C) = 0.0036T_{o,in} + 1.8089$$
$$C_{p,et}(kJ/kg\ ^\circ C) = -0.0068T_{et,in} + 2.58$$
$$A(m^2) = 46.1$$
$$U(W/m^{2\circ}C) = 310.6$$

Appendix B Data Reconciliation Source Code of GAMS for Model A (Random Error Only)

```
$call GDXXRW.EXE 3519E02z.xlsx set=R1 rng=A4:A4 Rdim=1 set=A
rng=B3:B3 Cdim=1 Par=Foil rng=A3:B4 Rdim=1 Cdim=1 set=B rng=D3:D3
Cdim=1 Par=Fethprod rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3 Cdim=1
Par=Toin rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1 Par=Toout
rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Tethprodin
rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=Tethprodout
rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=U rng=M3:N4
Rdim=1 Cdim=1

$GDXin 3519E02z.gdx

Set R1(*),A(*),B(*),C(*),D(*),E(*),F(*),G(*);
$load R1 A B C D E F G

Parameter Foil(R1,A), Fethprod(R1,B), Toin(R1,C), Toout(R1,D),
Tethprodin(R1,E), Tethprodout(R1,F), U(R1,G);
$load Foil Fethprod Toin Toout Tethprodin Tethprodout U

Scalars
    vfoil          variance of oil flowrate                  /101.896044559869/
    vfethprod      variance of ethane product flowrate       /637.510161/
    vtoin          variance of oil inlet temp                /622.020220081312/
    vtoout         variance of oil outlet temp               /596.7130598/
    vtethprodin    variance of ethane product inlet temp     /96.0122560103276/
    vtethprodout   variance of ethane product outlet temp    /104.8419276/
    vU             variance of heat overall coefficient      /649.4030321/
    area           heat transfer area of heat exchanger      /46.1/
;
```

```
Variable
        min             objective function
        froil           reconciled oil volume flowrate
        mroil           reconciled oil mass flowrate
        frethprod       reconciled ethane product volume flowrate
        mrethprod       reconciled ethane product mass flowrate
        troin           reconciled oil inlet temp
        trout           reconciled oil outlet temp
        trethprodin     reconciled ethane product inlet temp
        trethprodout    reconciled ethane product outlet temp
        q               heat duty
        Ur              reconciled overall heat transfer coefficient
;
Equation
        mint            define objective function
        mo              oil mass flowrate
        methprod        ethane product mass flowrate
        qo              heat duty of oil
        qethprod        heat duty of ethane product
        qhx             heat duty of heat exchanger
        con1            constraint1
        con2            constraint2
        con3            constraint3
        con4            constraint4
;
mint    .. min                  =e=     (sum((R1,A),(Foil(R1,A)-
froil)/sqrt(vfoil)))**2+(sum((R1,B),(Fethprod(R1,B)-
frethprod)/sqrt(vfethprod)))**2+(sum((R1,C),(Toin(R1,C)-troin)/sqrt(vtoin)))**2
+(sum((R1,D),(Toout(R1,D)-
troout)/sqrt(vtoout)))**2+(sum((R1,E),(Tethprodin(R1,E)-
trethprodin)/sqrt(vtethprodin)))**2+(sum((R1,F),(Tethprodout(R1,F)-
trethprodout)/sqrt(vtethprodout)))**2+(sum((R1,G),(U(R1,G)-Ur)/sqrt(vU)))**2;
```

```
mo      .. mroil              =e=    froil*((-0.6048*troin)+875.12);
methprod .. mrethprod         =e=    frethprod*(29.9/22.414);
qo      .. q                  =e=    mroil*((1.8089*(troin-
troout))+(0.0018*(troin**2-troout**2)))*1000/3600;
qethprod .. q                 =e=    mrethprod*((2.58*(trethprodout-
trethprodin))+(-0.00340*(trethprodout**2-trethprodin**2)))*1000/3600;
qhx     .. q                  =e=    Ur*area*((troin-trethprodout)*(troout-
trethprodin)*((troin-trethprodout)+(troout-trethprodin))/2)**(1/3);
con1    .. troin              =g= trethprodout;
con2    .. troout             =g= trethprodin;
con3    .. troin              =g= troout;
con4    .. trethprodout       =g= trethprodin;

froil.lo          = 27.5688;      froil.up          = 51.1992;
frethprod.lo      = 24877.1439;   frethprod.up      = 46200.4101;
troin.lo          = 118.601;      troin.up          = 220.259;
troout.lo         = 70.7784;      troout.up         = 131.4456;
trethprodin.lo    = 11.0061;      trethprodin.up    = 20.4399;
trethprodout.lo   = 41.0284;      trethprodout.up   = 76.1956;
Ur.lo             = 217.42;       Ur.up             = 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, froil.l, frethprod.l, troin.l, troout.l, trethprodin.l, trethprodout.l, q.l,
Ur.l;
```

Appendix C Data Reconciliation Source Code of GAMS for Model A (Random Error with 1 Position of Gross Error)

```
$call GDXXRW.EXE 3519E02z.xlsx set=R1 rng=A4:A4 Rdim=1 set=A
rng=B3:B3 Cdim=1 Par=Foil rng=A3:B4 Rdim=1 Cdim=1 set=B rng=D3:D3
Cdim=1 Par=Fethprod rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3 Cdim=1
Par=Toin rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1 Par=Toout
rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Tethprodin
rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=Tethprodout
rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=U rng=M3:N4
Rdim=1 Cdim=1

$GDXin 3519E02z.gdx

Set R1(*),A(*),B(*),C(*),D(*),E(*),F(*),G(*);
$load R1 A B C D E F G

Parameter Foil(R1,A), Fethprod(R1,B), Toin(R1,C), Toout(R1,D),
Tethprodin(R1,E), Tethprodout(R1,F), U(R1,G);
$load Foil Fethprod Toin Toout Tethprodin Tethprodout U

Scalars
    vfoil          variance of oil flowrate                  /1312.397937/
    vfethprod      variance of ethane product flowrate       /637.510161/
    vtoin          variance of oil inlet temp                /622.020220081312/
    vtoout         variance of oil outlet temp               /596.7130598/
    vtethprodin    variance of ethane product inlet temp     /96.0122560103276/
    vtethprodout   variance of ethane product outlet temp    /104.8419276/
    vU             variance of heat overall coefficient      /649.4030321/
    area           heat transfer area of heat exchanger      /46.1/
;
```

Variable

min	objective function
froil	reconciled oil volume flowrate
mroil	reconciled oil mass flowrate
frethprod	reconciled ethane product volume flowrate
mrethprod	reconciled ethane product mass flowrate
troin	reconciled oil inlet temp
trout	reconciled oil outlet temp
trethprodin	reconciled ethane product inlet temp
trethprodout	reconciled ethane product outlet temp
q	heat duty
Ur	reconciled overall heat transfer coefficient

;

Equation

mint	define objective function
mo	oil mass flowrate
methprod	ethane product mass flowrate
qo	heat duty of oil
qethprod	heat duty of ethane product
qhx	heat duty of heat exchanger
con1	constraint1
con2	constraint2
con3	constraint3
con4	constraint4

;

```
mint    .. min                  =e=     (sum((R1,A),(Foil(R1,A)-
froil)/sqrt(vfoil)))**2+(sum((R1,B),(Fethprod(R1,B)-
frethprod)/sqrt(vfethprod)))**2+(sum((R1,C),(Toin(R1,C)-troin)/sqrt(vtoin)))**2
+(sum((R1,D),(Toout(R1,D)-
troout)/sqrt(vtoout)))**2+(sum((R1,E),(Tethprodin(R1,E)-
trethprodin)/sqrt(vtethprodin)))**2+(sum((R1,F),(Tethprodout(R1,F)-
trethprodout)/sqrt(vtethprodout)))**2+(sum((R1,G),(U(R1,G)-Ur)/sqrt(vU)))**2;
```

```
mo      .. mroil              =e=    froil*((-0.6048*troin)+875.12);
methprod .. mrethprod         =e=    frethprod*(29.9/22.414);
qo      .. q                  =e=    mroil*((1.8089*(troin-
troout))+(0.0018*(troin**2-troout**2)))*1000/3600;
qethprod .. q                 =e=    mrethprod*((2.58*(trethprodout-
trethprodin))+(-0.00340*(trethprodout**2-trethprodin**2)))*1000/3600;
qhx     .. q                  =e=    Ur*area*((troin-trethprodout)*(troout-
trethprodin)*((troin-trethprodout)+(troout-trethprodin))/2)**(1/3);
con1    .. troin              =g= trethprodout;
con2    .. troout             =g= trethprodin;
con3    .. troin              =g= troout;
con4    .. trethprodout       =g= trethprodin;

froil.lo          = 27.5688;      froil.up          = 51.1992;
frethprod.lo      = 24877.1439;   frethprod.up      = 46200.4101;
troin.lo          = 118.601;      troin.up          = 220.259;
troout.lo         = 70.7784;      troout.up         = 131.4456;
trethprodin.lo    = 11.0061;      trethprodin.up    = 20.4399;
trethprodout.lo   = 41.0284;      trethprodout.up   = 76.1956;
Ur.lo             = 217.42;       Ur.up             = 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, froil.l, frethprod.l, troin.l, troout.l, trethprodin.l, trethprodout.l, q.l,
Ur.l;
```

Appendix D Data Reconciliation Source Code of GAMS for Model A (Random Error with 2 Positions of Gross Error)

```
$call GDXXRW.EXE 3519E02z.xlsx set=R1 rng=A4:A4 Rdim=1 set=A rng=B3:B3 Cdim=1 Par=Foil rng=A3:B4 Rdim=1 Cdim=1 set=B rng=D3:D3 Cdim=1 Par=Fethprod rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3 Cdim=1 Par=Toin rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1 Par=Toout rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Tethprodin rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=Tethprodout rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=U rng=M3:N4 Rdim=1 Cdim=1

$GDXin 3519E02z.gdx

Set R1(*),A(*),B(*),C(*),D(*),E(*),F(*),G(*);
$load R1 A B C D E F G

Parameter Foil(R1,A), Fethprod(R1,B), Toin(R1,C), Toout(R1,D), Tethprodin(R1,E), Tethprodout(R1,F), U(R1,G);
$load Foil Fethprod Toin Toout Tethprodin Tethprodout U

Scalars
    vfoil          variance of oil flowrate                  /1312.397937/
    vfethprod      variance of ethane product flowrate       /637.510161/
    vtoin          variance of oil inlet temp                /622.020220081312/
    vtoout         variance of oil outlet temp               /596.7130598/
    vtethprodin    variance of ethane product inlet temp     /287.3308561/
    vtethprodout   variance of ethane product outlet temp    /104.8419276/
    vU             variance of heat overall coefficient      /649.4030321/
    area           heat transfer area of heat exchanger      /46.1/
;
```

```
Variable
        min             objective function
        froil           reconciled oil volume flowrate
        mroil           reconciled oil mass flowrate
        frethprod       reconciled ethane product volume flowrate
        mrethprod       reconciled ethane product mass flowrate
        troin           reconciled oil inlet temp
        trout           reconciled oil outlet temp
        trethprodin     reconciled ethane product inlet temp
        trethprodout    reconciled ethane product outlet temp
        q               heat duty
        Ur              reconciled overall heat transfer coefficient
;
Equation
        mint            define objective function
        mo              oil mass flowrate
        methprod        ethane product mass flowrate
        qo              heat duty of oil
        qethprod        heat duty of ethane product
        qhx             heat duty of heat exchanger
        con1            constraint1
        con2            constraint2
        con3            constraint3
        con4            constraint4
;
mint    .. min                  =e=     (sum((R1,A),(Foil(R1,A)-
froil)/sqrt(vfoil)))**2+(sum((R1,B),(Fethprod(R1,B)-
frethprod)/sqrt(vfethprod)))**2+(sum((R1,C),(Toin(R1,C)-troin)/sqrt(vtoin)))**2
+(sum((R1,D),(Toout(R1,D)-
troout)/sqrt(vtoout)))**2+(sum((R1,E),(Tethprodin(R1,E)-
trethprodin)/sqrt(vtethprodin)))**2+(sum((R1,F),(Tethprodout(R1,F)-
trethprodout)/sqrt(vtethprodout)))**2+(sum((R1,G),(U(R1,G)-Ur)/sqrt(vU)))**2;
```

```
mo      .. mroil                =e=     froil*((-0.6048*troin)+875.12);
methprod .. mrethprod           =e=     frethprod*(29.9/22.414);
qo      .. q                    =e=     mroil*((1.8089*(troin-
troout))+(0.0018*(troin**2-troout**2)))*1000/3600;
qethprod .. q                   =e=     mrethprod*((2.58*(trethprodout-
trethprodin))+(-0.00340*(trethprodout**2-trethprodin**2)))*1000/3600;
qhx     .. q                    =e=     Ur*area*((troin-trethprodout)*(troout-
trethprodin)*((troin-trethprodout)+(troout-trethprodin))/2)**(1/3);
con1    .. troin                =g= trethprodout;
con2    .. troout               =g= trethprodin;
con3    .. troin                =g= troout;
con4    .. trethprodout         =g= trethprodin;

froil.lo            = 27.5688;      froil.up            = 51.1992;
frethprod.lo        = 24877.1439;   frethprod.up        = 46200.4101;
troin.lo            = 118.601;      troin.up            = 220.259;
troout.lo           = 70.7784;      troout.up           = 131.4456;
trethprodin.lo      = 11.0061;      trethprodin.up      = 20.4399;
trethprodout.lo     = 41.0284;      trethprodout.up     = 76.1956;
Ur.lo               = 217.42;       Ur.up               = 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, froil.l, frethprod.l, troin.l, troout.l, trethprodin.l, trethprodout.l, q.l,
Ur.l;
```

Appendix E Data Reconciliation Source Code of GAMS for Model A (After Discarding 1 Position of Gross Error for 1-position Case)

```
$call GDXXRW.EXE 3519E02z.xlsx set=R1 rng=A4:A4 Rdim=1 set=B
rng=D3:D3 Cdim=1 Par=Fethprod rng=C3:D4 Rdim=1 Cdim=1 set=C
rng=F3:F3 Cdim=1 Par=Toin rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3
Cdim=1 Par=Toout rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1
Par=Tethprodin rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1
Par=Tethprodout rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1
Par=U rng=M3:N4 Rdim=1 Cdim=1

$GDXin 3519E02z.gdx

Set R1(*),B(*),C(*),D(*),E(*),F(*),G(*);
$load R1 B C D E F G

Parameter Fethprod(R1,B), Toin(R1,C), Toout(R1,D), Tethprodin(R1,E),
Tethprodout(R1,F), U(R1,G);
$load Fethprod Toin Toout Tethprodin Tethprodout U

Scalars
    vfethprod     variance of ethane product flowrate   /637.510161/
    vtoin         variance of oil inlet temp            /622.020220081312/
    vtoout        variance of oil outlet temp           /596.7130598/
    vtethprodin   variance of ethane product inlet temp /96.0122560103276/
    vtethprodout  variance of ethane product outlet temp /104.8419276/
    vU            variance of heat overall coefficient  /649.4030321/
    area          heat transfer area of heat exchanger  /46.1/
;
Variable
    min           objective function
    froil         reconciled oil volume flowrate
```

mroil	reconciled oil mass flowrate
frethprod	reconciled ethane product volume flowrate
mrethprod	reconciled ethane product mass flowrate
troin	reconciled oil inlet temp
trout	reconciled oil outlet temp
trethprodin	reconciled ethane product inlet temp
trethprodout	reconciled ethane product outlet temp
q	heat duty
Ur	reconciled overall heat transfer coefficient

;

Equation

mint	define objective function
mo	oil mass flowrate
methprod	ethane product mass flowrate
qo	heat duty of oil
qethprod	heat duty of ethane product
qhx	heat duty of heat exchanger
con1	constraint1
con2	constraint2
con3	constraint3
con4	constraint4

;

```
mint    .. min                  =e=     (sum((R1,B),(Fethprod(R1,B)-
frethprod)/sqrt(vfethprod)))**2+(sum((R1,C),(Toin(R1,C)-troin)/sqrt(vtoin)))**2
+(sum((R1,D),(Toout(R1,D)-
troout)/sqrt(vtoout)))**2+(sum((R1,E),(Tethprodin(R1,E)-
trethprodin)/sqrt(vtethprodin)))**2+(sum((R1,F),(Tethprodout(R1,F)-
trethprodout)/sqrt(vtethprodout)))**2+(sum((R1,G),(U(R1,G)-Ur)/sqrt(vU)))**2;
mo      .. mroil                =e=     foil*((-0.6048*troin)+875.12);
methprod .. mrethprod           =e=     frethprod*(29.9/22.414);
qo      .. q                    =e=     mroil*((1.8089*(troin-
troout))+(0.0018*(troin**2-troout**2)))*1000/3600;
```

```
qethprod .. q                =e=     mrethprod*((2.58*(trethprodout-
trethprodin))+(-0.00340*(trethprodout**2-trethprodin**2)))*1000/3600;
qhx      .. q                =e=     Ur*area*((troin-trethprodout)*(troout-
trethprodin)*((troin-trethprodout)+(troout-trethprodin))/2)**(1/3);
con1     .. troin            =g= trethprodout;
con2     .. troout           =g= trethprodin;
con3     .. troin            =g= troout;
con4     .. trethprodout     =g= trethprodin;

foil.lo          = 27.5688;      foil.up          = 51.1992;
frethprod.lo     = 24877.1439;   frethprod.up     = 46200.4101;
troin.lo         = 118.601;      troin.up         = 220.259;
troout.lo        = 70.7784;      troout.up        = 131.4456;
trethprodin.lo   = 11.0061;      trethprodin.up   = 20.4399;
trethprodout.lo  = 41.0284;      trethprodout.up  = 76.1956;
Ur.lo            = 217.42;       Ur.up            = 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, foil.l, frethprod.l, troin.l, troout.l, trethprodin.l, trethprodout.l, q.l, Ur.l;
```

Appendix F Data Reconciliation Source Code of GAMS for Model A (After Eliminating 1 Position of Gross Error for 2-position Case)

```
$call GDXXRW.EXE 3519E02z.xlsx set=R1 rng=A4:A4 Rdim=1 set=B
rng=D3:D3 Cdim=1 Par=Fethprod rng=C3:D4 Rdim=1 Cdim=1 set=C
rng=F3:F3 Cdim=1 Par=Toin rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3
Cdim=1 Par=Toout rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1
Par=Tethprodin rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1
Par=Tethprodout rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1
Par=U rng=M3:N4 Rdim=1 Cdim=1

$GDXin 3519E02z.gdx

Set R1(*),B(*),C(*),D(*),E(*),F(*),G(*);
$load R1 B C D E F G

Parameter Fethprod(R1,B), Toin(R1,C), Toout(R1,D), Tethprodin(R1,E),
Tethprodout(R1,F), U(R1,G);
$load Fethprod Toin Toout Tethprodin Tethprodout U

Scalars
    vfethprod     variance of ethane product flowrate   /637.510161/
    vtoin         variance of oil inlet temp            /622.020220081312/
    vtoout        variance of oil outlet temp           /596.7130598/
    vtethprodin   variance of ethane product inlet temp /287.3308561/
    vtethprodout  variance of ethane product outlet temp /104.8419276/
    vU            variance of heat overall coefficient  /649.4030321/
    area          heat transfer area of heat exchanger  /46.1/
;
Variable
    min           objective function
    froil         reconciled oil volume flowrate
```

mroil	reconciled oil mass flowrate
frethprod	reconciled ethane product volume flowrate
mrethprod	reconciled ethane product mass flowrate
troin	reconciled oil inlet temp
trout	reconciled oil outlet temp
trethprodin	reconciled ethane product inlet temp
trethprodout	reconciled ethane product outlet temp
q	heat duty
Ur	reconciled overall heat transfer coefficient

;

Equation

mint	define objective function
mo	oil mass flowrate
methprod	ethane product mass flowrate
qo	heat duty of oil
qethprod	heat duty of ethane product
qhx	heat duty of heat exchanger
con1	constraint1
con2	constraint2
con3	constraint3
con4	constraint4

;

```
mint    .. min                  =e=     (sum((R1,B),(Fethprod(R1,B)-
frethprod)/sqrt(vfethprod)))**2+(sum((R1,C),(Toin(R1,C)-troin)/sqrt(vtoin)))**2
+(sum((R1,D),(Toout(R1,D)-
troout)/sqrt(vtoout)))**2+(sum((R1,E),(Tethprodin(R1,E)-
trethprodin)/sqrt(vtethprodin)))**2+(sum((R1,F),(Tethprodout(R1,F)-
trethprodout)/sqrt(vtethprodout)))**2+(sum((R1,G),(U(R1,G)-Ur)/sqrt(vU)))**2;
mo      .. mroil                =e=     foil*((-0.6048*troin)+875.12);
methprod .. mrethprod           =e=     frethprod*(29.9/22.414);
qo      .. q                    =e=     mroil*((1.8089*(troin-
troout))+(0.0018*(troin**2-troout**2)))*1000/3600;
```

```
qethprod .. q          =e=   mrethprod*((2.58*(trethprodout-
trethprodin))+(-0.00340*(trethprodout**2-trethprodin**2)))*1000/3600;
qhx    .. q            =e=   Ur*area*((troin-trethprodout)*(troout-
trethprodin)*((troin-trethprodout)+(troout-trethprodin))/2)**(1/3);
con1   .. troin        =g= trethprodout;
con2   .. troout       =g= trethprodin;
con3   .. troin        =g= troout;
con4   .. trethprodout =g= trethprodin;

foil.lo          = 27.5688;     foil.up          = 51.1992;
frethprod.lo     = 24877.1439;  frethprod.up     = 46200.4101;
troin.lo         = 118.601;     troin.up         = 220.259;
troout.lo        = 70.7784;     troout.up        = 131.4456;
trethprodin.lo   = 11.0061;     trethprodin.up   = 20.4399;
trethprodout.lo  = 41.0284;     trethprodout.up  = 76.1956;
Ur.lo            = 217.42;      Ur.up            = 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, foil.l, frethprod.l, troin.l, troout.l, trethprodin.l, trethprodout.l, q.l, Ur.l;
```

Appendix G Physical Data for Utility Heat Exchanger Network (Model B)

1st heat exchanger in network

$$M_o(kg/h) = F_o(m^3/h) \times Density\ (kg/m^3)$$
$$= F_o(m^3/h) \times (-0.6048T_{o,in} + 875.12)$$

$$M_{et}(kg/h) = F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times MW(g/mol) \times \frac{1\ kg}{1000\ g}$$
$$= F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times 29.9(g/mol) \times \frac{1\ kg}{1000\ g}$$

$C_{p,o}(kJ/kg\ °C) = 0.0036T_{o,in} + 1.8089$

$C_{p,et}(kJ/kg\ °C) = -0.0068T_{et,in} + 2.58$

$A_1(m^2) = 46.1$

$U_1(W/m^2°C) = 310.6$

2nd heat exchanger in network

$$M_o(kg/h) = F_o(m^3/h) \times Density\ (kg/m^3)$$
$$= F_o(m^3/h) \times (-0.6048T_{o,in} + 875.12)$$

$$M_{et}(kg/h) = F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times MW(g/mol) \times \frac{1\ kg}{1000\ g}$$
$$= F_{et}(Nm^3/h) \times \frac{1\ mol}{22.414\ L} \times \frac{1000\ L}{1\ m^3} \times 29.9(g/mol) \times \frac{1\ kg}{1000\ g}$$

$C_{p,o}(kJ/kg\ °C) = 0.0036T_{o,in} + 1.8089$

$C_{p,et}(kJ/kg\ °C) = 0.0615T_{et,in} + 0.40315$

$A_2(m^2) = 16.7$

$U_2(W/m^2°C) = 863.8$

Appendix H Data Reconciliation Source Code of GAMS for Model B (Random Error Only)

```
$call GDXXRW.EXE 3519E02zzzz.xlsx set=R1 rng=A4:A4 Rdim=1 set=A
rng=B3:B3 Cdim=1 Par=Fo rng=A3:B4 Rdim=1 Cdim=1 set=B rng=D3:D3
Cdim=1 Par=Fo1 rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3 Cdim=1
Par=Fo2 rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1 Par=Fet1
rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Fet2 rng=I3:J4
Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=To1in rng=K3:L4 Rdim=1
Cdim=1 set=G rng=N3:N3 Cdim=1 Par=To1out rng=M3:N4 Rdim=1 Cdim=1
set=H rng=P3:P3 Cdim=1 Par=To2out rng=O3:P4 Rdim=1 Cdim=1 set=I
rng=R3:R3 Cdim=1 Par=Tet1in rng=Q3:R4 Rdim=1 Cdim=1 set=J rng=T3:T3
Cdim=1 Par=Tet1out rng=S3:T4 Rdim=1 Cdim=1 set=K rng=V3:V3 Cdim=1
Par=Tet2in rng=U3:V4 Rdim=1 Cdim=1 set=L rng=X3:X3 Cdim=1
Par=Tet2out rng=W3:X4 Rdim=1 Cdim=1 set=M rng=Z3:Z3 Cdim=1 Par=U1
rng=Y3:Z4 Rdim=1 Cdim=1

$GDXin 3519E02zzzz.gdx

Set R1(*),A(*),B(*),C(*),D(*),E(*),F(*),G(*),H(*),I(*),J(*),K(*),L(*),M(*);
$load R1 A B C D E F G H I J K L M

Parameter Fo(R1,A), Fo1(R1,B), Fo2(R1,C), Fet1(R1,D), Fet2(R1,E), To1in(R1,F),
To1out(R1,G), To2out(R1,H), Tet1in(R1,I), Tet1out(R1,J), Tet2in(R1,K),
Tet2out(R1,L), U1(R1,M);
$load Fo Fo1 Fo2 Fet1 Fet2 To1in To1out To2out Tet1in Tet1out Tet2in Tet2out U1

Scalars
    vfo     variance of oil flowrate     /101.896/
    vfo1    variance of oil flowrate1    /92.676/
    vfo2    variance of oil flowrate2    /94.744/
    vfet1   variance of ethane1          /637.510161/
```

vfet2	variance of ethane2	/672.7382207/
vto1in	variance of oil1 inlet temp	/622.0202201/
vto1out	variance of oil1 outlet temp	/596.713/
vto2out	variance of oil2 outlet temp	/597.558/
vtet1in	variance of ethane1 inlet temp	/96.012/
vtet1out	variance of ethane1 outlet temp	/104.842/
vtet2in	variance of ethane2 inlet temp	/101.148/
vtet2out	variance of ethane2 outlet temp	/91.803/
vU1	variance of heat overall coefficient1	/649.4030321/
area1	heat transfer area of heat exchanger1	/46.1/
area2	heat transfer area of heat exchanger2	/16.7/

;

Variable

min	objective function
fro	reconciled oil volume flowrate
mro	reconciled oil mass flowrate
fro1	reconciled oil1 volume flowrate
fro2	reconciled oil2 volume flowrate
mro2	reconciled oil2 mass flowrate
fret1	reconciled ethane1 volume flowrate
mret1	reconciled ethane1 mass flowrate
fret2	reconciled ethane2 volume flowrate
mret2	reconciled ethane2 mass flowrate
tro1in	reconciled oil1 inlet temp
tro1out	reconciled oil1 outlet temp
tro2out	reconciled oil2 outlet temp
tret1in	reconciled ethane1 inlet temp
tret1out	reconciled ethane1 outlet temp
tret2in	reconciled ethane2 inlet temp
tret2out	reconciled ethane2 outlet temp
q1	heat duty of heat exchanger1
q2	heat duty of heat exchanger2

```
        Ur1             reconciled overall heat transfer coefficient of heat exchanger1
        U2              overall heat transfer coefficient of heat exchanger2
;
Equation
        mint            define objective function
        mo              oil mass flowrate
        mo2             oil mass flowrate2
        met1            ethane product mass flowrate1
        met2            ethane product mass flowrate2
        Fb              oil volumetric flowrate balance
        qo1             heat duty of oil1
        qet1            heat duty of ethane product1
        qhx1            heat duty of heat exchanger1
        qo2             heat duty of oil2
        qet2            heat duty of ethane product2
        qhx2            heat duty of heat exchanger2
        con1            constraint1
        con2            constraint2
        con3            constraint3
        con4            constraint4
        con5            constraint5
        con6            constraint6
        con7            constraint7
        con8            constraint8
;
mint    .. min          =e=     (sum((R1.A),abs(Fo(R1.A)-
fro) sqrt(vfo)))**2+(sum((R1.B),abs(Fo1(R1.B)-
fro1) sqrt(vfo1)))**2+(sum((R1.C),abs(Fo2(R1.C)-
fro2) sqrt(vfo2)))**2+(sum((R1.D),abs(Fet1(R1.D)-
fret1) sqrt(vfet1)))**2+(sum((R1.E),abs(Fet2(R1.E)-
fret2) sqrt(vfet2)))**2+(sum((R1.F),abs(To1in(R1.F)-tro1in)/sqrt(vto1in)))**2
```

```
+(sum((R1.G),abs(To1out(R1.G)-
tro1out)/sqrt(vto1out)))**2+(sum((R1.H),abs(To2out(R1.H)-
tro2out)/sqrt(vto2out)))**2+(sum((R1.I),abs(Tet1in(R1.I)-
tret1in)/sqrt(vtet1in)))**2+(sum((R1.J),abs(Tet1out(R1.J)-
tret1out)/sqrt(vtet1out)))**2+(sum((R1.K),abs(Tet2in(R1.K)-
tret2in)/sqrt(vtet2in)))**2+(sum((R1.L),abs(Tet2out(R1.L)-
tret2out)/sqrt(vtet2out)))**2+(sum((R1.M),abs(U1(R1.M)-Ur1)/sqrt(vU1)))**2;
mo      .. mro          =e= fro*((-0.6048*tro1in)+875.12);
mo2     .. mro2         =e= fro2*((-0.6048*tro1out)+875.12);
met1    .. mret1        =e= fret1*(29.9/22.414);
met2    .. mret2        =e= fret2*(29.9/22.414);
Fb      .. fro2         =e= 0.762*fro;
qo1     .. q1           =e=     mro*((1.8089*(tro1in-tro1out))+(0.0018*(tro1in**2-
tro1out**2)))*1000/3600;
qet1    .. q1           =e=     mret1*((2.58*(tret1out-tret1in))+(-
0.00340*(tret1out**2-tret1in**2)))*1000/3600;
qhx1    .. q1           =e=     Ur1*area1*((tro1in-tret1out)*(tro1out-
tret1in)*((tro1in-tret1out)+(tro1out-tret1in))/2)**(1/3);
qo2     .. q2           =e=     mro2*((1.8089*(tro1out-
tro2out))+(0.0018*(tro1out**2-tro2out**2)))*1000/3600;
qet2    .. q2           =e=     mret2*((0.40315*(tret2out-
tret2in))+(0.0615*(tret2out**2-tret2in**2)))*1000/3600;
qhx2    .. q2           =e=     U2*area2*((tro1out-tret2out)*(tro2out-
tret2in)*((tro1out-tret2out)+(tro2out-tret2in))/2)**(1/3);
con1    .. tro1in       =g= tret1out;
con2    .. tro1out      =g= tret1in;
con3    .. tro1in       =g= tro1out;
con4    .. tret1out     =g= tret1in;
con5    .. tro1out      =g= tret2out;
con6    .. tro2out      =g= tret2in;
con7    .. tro1out      =g= tro2out;
con8    .. tret2out     =g= tret2in;
```

fro.lo	= 27.5688;	fro.up	= 51.1992;
fro1.lo	= 6.5688;	fro1.up	= 12.1992;
fro2.lo	= 21.0000;	fro2.up	= 39.0000;
fret1.lo	= 24877.1439;	fret1.up	= 46200.4101;
fret2.lo	= 24524.3521;	fret2.up	= 45545.2253;
tro1in.lo	= 118.601;	tro1in.up	= 220.259;
tro1out.lo	= 70.7784;	tro1out.up	= 131.4456;
tro2out.lo	= 63.0070;	tro2out.up	= 117.0130;
tret1in.lo	= 11.0061;	tret1in.up	= 20.4399;
tret1out.lo	= 41.0284;	tret1out.up	= 76.1956;
tret2in.lo	= 20.4428;	tret2in.up	= 37.9652;
tret2out.lo	= 34.8894;	tret2out.up	= 64.7946;
Ur1.lo	= 217.42;	Ur1.up	= 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, fro.l, fro1.l, fro2.l, fret1.l, fret2.l, tro1in.l, tro1out.l, tro2out.l, tret1in.l, tret1out.l, tret2in.l, tret2out.l, q1.l, q2.l, Ur1.l, U2.l;

Appendix I Data Reconciliation Source Code of GAMS for Model B (Random Error with 2 Positions of Gross Error)

```
$call GDXXRW.EXE 3519E02zzzz.xlsx set=R1 rng=A4:A4 Rdim=1 set=A rng=B3:B3 Cdim=1 Par=Fo rng=A3:B4 Rdim=1 Cdim=1 set=B rng=D3:D3 Cdim=1 Par=Fo1 rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3 Cdim=1 Par=Fo2 rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1 Par=Fet1 rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Fet2 rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=To1in rng=K3:L4 Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=To1out rng=M3:N4 Rdim=1 Cdim=1 set=H rng=P3:P3 Cdim=1 Par=To2out rng=O3:P4 Rdim=1 Cdim=1 set=I rng=R3:R3 Cdim=1 Par=Tet1in rng=Q3:R4 Rdim=1 Cdim=1 set=J rng=T3:T3 Cdim=1 Par=Tet1out rng=S3:T4 Rdim=1 Cdim=1 set=K rng=V3:V3 Cdim=1 Par=Tet2in rng=U3:V4 Rdim=1 Cdim=1 set=L rng=X3:X3 Cdim=1 Par=Tet2out rng=W3:X4 Rdim=1 Cdim=1 set=M rng=Z3:Z3 Cdim=1 Par=U1 rng=Y3:Z4 Rdim=1 Cdim=1

$GDXin 3519E02zzzz.gdx

Set R1(*),A(*),B(*),C(*),D(*),E(*),F(*),G(*),H(*),I(*),J(*),K(*),L(*),M(*);
$load R1 A B C D E F G H I J K L M

Parameter Fo(R1,A), Fo1(R1,B), Fo2(R1,C), Fet1(R1,D), Fet2(R1,E), To1in(R1,F), To1out(R1,G), To2out(R1,H), Tet1in(R1,I), Tet1out(R1,J), Tet2in(R1,K), Tet2out(R1,L), U1(R1,M);
$load Fo Fo1 Fo2 Fet1 Fet2 To1in To1out To2out Tet1in Tet1out Tet2in Tet2out U1

Scalars
    vfo     variance of oil flowrate    /1312.395529/
    vfo1    variance of oil flowrate1   /92.676/
    vfo2    variance of oil flowrate2   /94.744/
    vfet1   variance of ethane1         /637.510161/
```

vfet2	variance of ethane2	/672.7382207/
vto1in	variance of oil1 inlet temp	/622.0202201/
vto1out	variance of oil1 outlet temp	/596.713/
vto2out	variance of oil2 outlet temp	/597.558/
vtet1in	variance of ethane1 inlet temp	/287.336401/
vtet1out	variance of ethane1 outlet temp	/104.842/
vtet2in	variance of ethane2 inlet temp	/101.148/
vtet2out	variance of ethane2 outlet temp	/91.803/
vU1	variance of heat overall coefficient1	/649.4030321/
area1	heat transfer area of heat exchanger1	/46.1/
area2	heat transfer area of heat exchanger2	/16.7/

;

Variable

min	objective function
fro	reconciled oil volume flowrate
mro	reconciled oil mass flowrate
fro1	reconciled oil1 volume flowrate
fro2	reconciled oil2 volume flowrate
mro2	reconciled oil2 mass flowrate
fret1	reconciled ethane1 volume flowrate
mret1	reconciled ethane1 mass flowrate
fret2	reconciled ethane2 volume flowrate
mret2	reconciled ethane2 mass flowrate
tro1in	reconciled oil1 inlet temp
tro1out	reconciled oil1 outlet temp
tro2out	reconciled oil2 outlet temp
tret1in	reconciled ethane1 inlet temp
tret1out	reconciled ethane1 outlet temp
tret2in	reconciled ethane2 inlet temp
tret2out	reconciled ethane2 outlet temp
q1	heat duty of heat exchanger1
q2	heat duty of heat exchanger2

```
        Ur1             reconciled overall heat transfer coefficient of heat exchanger1
        U2              overall heat transfer coefficient of heat exchanger2
;
Equation
        mint            define objective function
        mo              oil mass flowrate
        mo2             oil mass flowrate2
        met1            ethane product mass flowrate1
        met2            ethane product mass flowrate2
        Fb              oil volumetric flowrate balance
        qo1             heat duty of oil1
        qet1            heat duty of ethane product1
        qhx1            heat duty of heat exchanger1
        qo2             heat duty of oil2
        qet2            heat duty of ethane product2
        qhx2            heat duty of heat exchanger2
        con1            constraint1
        con2            constraint2
        con3            constraint3
        con4            constraint4
        con5            constraint5
        con6            constraint6
        con7            constraint7
        con8            constraint8
;
mint    .. min          =e=     (sum((R1,A),abs(Fo(R1,A)-
fro)/sqrt(vfo)))**2+(sum((R1,B),abs(Fo1(R1,B)-
fro1)/sqrt(vfo1)))**2+(sum((R1,C),abs(Fo2(R1,C)-
fro2)/sqrt(vfo2)))**2+(sum((R1,D),abs(Fet1(R1,D)-
fret1)/sqrt(vfet1)))**2+(sum((R1,E),abs(Fet2(R1,E)-
fret2)/sqrt(vfet2)))**2+(sum((R1,F),abs(To1in(R1,F)-tro1in)/sqrt(vto1in)))**2
```

```
+(sum((R1,G),abs(To1out(R1,G)-
tro1out)/sqrt(vto1out)))**2+(sum((R1,H),abs(To2out(R1,H)-
tro2out)/sqrt(vto2out)))**2+(sum((R1,I),abs(Tet1in(R1,I)-
tret1in)/sqrt(vtet1in)))**2+(sum((R1,J),abs(Tet1out(R1,J)-
tret1out)/sqrt(vtet1out)))**2+(sum((R1,K),abs(Tet2in(R1,K)-
tret2in)/sqrt(vtet2in)))**2+(sum((R1,L),abs(Tet2out(R1,L)-
tret2out)/sqrt(vtet2out)))**2+(sum((R1,M),abs(U1(R1,M)-Ur1)/sqrt(vU1)))**2;
mo      .. mro          =e= fro*((-0.6048*tro1in)+875.12);
mo2     .. mro2         =e= fro2*((-0.6048*tro1out)+875.12);
met1    .. mret1        =e= fret1*(29.9/22.414);
met2    .. mret2        =e= fret2*(29.9/22.414);
Fb      .. fro2         =e= 0.762*fro;
qo1     .. q1           =e=     mro*((1.8089*(tro1in-tro1out))+(0.0018*(tro1in**2-
tro1out**2)))*1000/3600;
qet1    .. q1           =e=     mret1*((2.58*(tret1out-tret1in))+(-
0.00340*(tret1out**2-tret1in**2)))*1000/3600;
qhx1    .. q1           =e=     Ur1*area1*((tro1in-tret1out)*(tro1out-
tret1in)*((tro1in-tret1out)+(tro1out-tret1in))/2)**(1/3);
qo2     .. q2           =e=     mro2*((1.8089*(tro1out-
tro2out))+(0.0018*(tro1out**2-tro2out**2)))*1000/3600;
qet2    .. q2           =e=     mret2*((0.40315*(tret2out-
tret2in))+(0.0615*(tret2out**2-tret2in**2)))*1000/3600;
qhx2    .. q2           =e=     U2*area2*((tro1out-tret2out)*(tro2out-
tret2in)*((tro1out-tret2out)+(tro2out-tret2in))/2)**(1/3);
con1    .. tro1in       =g= tret1out;
con2    .. tro1out      =g= tret1in;
con3    .. tro1in       =g= tro1out;
con4    .. tret1out     =g= tret1in;
con5    .. tro1out      =g= tret2out;
con6    .. tro2out      =g= tret2in;
con7    .. tro1out      =g= tro2out;
con8    .. tret2out     =g= tret2in;
```

fro.lo	= 27.5688;	fro.up	= 51.1992;
fro1.lo	= 6.5688;	fro1.up	= 12.1992;
fro2.lo	= 21.0000;	fro2.up	= 39.0000;
fret1.lo	= 24877.1439;	fret1.up	= 46200.4101;
fret2.lo	= 24524.3521;	fret2.up	= 45545.2253;
tro1in.lo	= 118.601;	tro1in.up	= 220.259;
tro1out.lo	= 70.7784;	tro1out.up	= 131.4456;
tro2out.lo	= 63.0070;	tro2out.up	= 117.0130;
tret1in.lo	= 11.0061;	tret1in.up	= 20.4399;
tret1out.lo	= 41.0284;	tret1out.up	= 76.1956;
tret2in.lo	= 20.4428;	tret2in.up	= 37.9652;
tret2out.lo	= 34.8894;	tret2out.up	= 64.7946;
Ur1.lo	= 217.42;	Ur1.up	= 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, fro.l, fro1.l, fro2.l, fret1.l, fret2.l, tro1in.l, tro1out.l, tro2out.l, tret1in.l, tret1out.l, tret2in.l, tret2out.l, q1.l, q2.l, Ur1.l, U2.l;

Appendix J Data Reconciliation Source Code of GAMS for Model B (After Discarding 1 Position of Gross Error)

```
$call GDXXRW.EXE 3519E02zzzz.xlsx set=R1 rng=A4:A4 Rdim=1 set=B
rng=D3:D3 Cdim=1 Par=Fo1 rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3
Cdim=1 Par=Fo2 rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1
Par=Fet1 rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Fet2
rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=To1in rng=K3:L4
Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=To1out rng=M3:N4 Rdim=1
Cdim=1 set=H rng=P3:P3 Cdim=1 Par=To2out rng=O3:P4 Rdim=1 Cdim=1
set=I rng=R3:R3 Cdim=1 Par=Tet1in rng=Q3:R4 Rdim=1 Cdim=1 set=J
rng=T3:T3 Cdim=1 Par=Tet1out rng=S3:T4 Rdim=1 Cdim=1 set=K
rng=V3:V3 Cdim=1 Par=Tet2in rng=U3:V4 Rdim=1 Cdim=1 set=L
rng=X3:X3 Cdim=1 Par=Tet2out rng=W3:X4 Rdim=1 Cdim=1 set=M
rng=Z3:Z3 Cdim=1 Par=U1 rng=Y3:Z4 Rdim=1 Cdim=1

$GDXin 3519E02zzzz.gdx

Set R1(*),B(*),C(*),D(*),E(*),F(*),G(*),H(*),I(*),J(*),K(*),L(*),M(*);
$load R1 B C D E F G H I J K L M

Parameter Fo1(R1,B), Fo2(R1,C), Fet1(R1,D), Fet2(R1,E), To1in(R1,F),
To1out(R1,G), To2out(R1,H), Tet1in(R1,I), Tet1out(R1,J), Tet2in(R1,K),
Tet2out(R1,L), U1(R1,M);
$load Fo1 Fo2 Fet1 Fet2 To1in To1out To2out Tet1in Tet1out Tet2in Tet2out U1

Scalars
    vfo1        variance of oil flowrate1        /92.676/
    vfo2        variance of oil flowrate2        /94.744/
    vfet1       variance of ethane1              /637.510161/
    vfet2       variance of ethane2              /672.7382207/
    vto1in      variance of oil1 inlet  temp     /622.0202201/
```

vto1out	variance of oil1 outlet temp	/596.713/
vto2out	variance of oil2 outlet temp	/597.558/
vtet1in	variance of ethane1 inlet temp	/287.336401/
vtet1out	variance of ethane1 outlet temp	/104.842/
vtet2in	variance of ethane2 inlet temp	/101.148/
vtet2out	variance of ethane2 outlet temp	/91.803/
vU1	variance of heat overall coefficient1	/649.4030321/
area1	heat transfer area of heat exchanger1	/46.1/
area2	heat transfer area of heat exchanger2	/16.7/

;

Variable

min	objective function
fo	oil volume flowrate
mro	reconciled oil mass flowrate
fro1	reconciled oil1 volume flowrate
fro2	reconciled oil2 volume flowrate
mro2	reconciled oil2 mass flowrate
fret1	reconciled ethane1 volume flowrate
mret1	reconciled ethane1 mass flowrate
fret2	reconciled ethane2 volume flowrate
mret2	reconciled ethane2 mass flowrate
tro1in	reconciled oil1 inlet temp
tro1out	reconciled oil1 outlet temp
tro2out	reconciled oil2 outlet temp
tret1in	reconciled ethane1 inlet temp
tret1out	reconciled ethane1 outlet temp
tret2in	reconciled ethane2 inlet temp
tret2out	reconciled ethane2 outlet temp
q1	heat duty of heat exchanger1
q2	heat duty of heat exchanger2
Ur1	reconciled overall heat transfer coefficient of heat exchanger1
U2	overall heat transfer coefficient of heat exchanger2

;

Equation

mint	define objective function
mo	oil mass flowrate
mo2	oil mass flowrate2
met1	ethane product mass flowrate1
met2	ethane product mass flowrate2
Fb	oil volumetric flowrate balance
qo1	heat duty of oil1
qet1	heat duty of ethane product1
qhx1	heat duty of heat exchanger1
qo2	heat duty of oil2
qet2	heat duty of ethane product2
qhx2	heat duty of heat exchanger2
con1	constraint1
con2	constraint2
con3	constraint3
con4	constraint4
con5	constraint5
con6	constraint6
con7	constraint7
con8	constraint8

;

```
mint    .. min          =e=     (sum((R1,B),abs(Fo1(R1,B)-
fro1)/sqrt(vfo1)))**2+(sum((R1,C),abs(Fo2(R1,C)-
fro2)/sqrt(vfo2)))**2+(sum((R1,D),abs(Fet1(R1,D)-
fret1)/sqrt(vfet1)))**2+(sum((R1,E),abs(Fet2(R1,E)-
fret2)/sqrt(vfet2)))**2+(sum((R1,F),abs(To1in(R1,F)-tro1in)/sqrt(vto1in)))**2
+(sum((R1,G),abs(To1out(R1,G)-
tro1out)/sqrt(vto1out)))**2+(sum((R1,H),abs(To2out(R1,H)-
tro2out)/sqrt(vto2out)))**2+(sum((R1,I),abs(Tet1in(R1,I)-
tret1in)/sqrt(vtet1in)))**2+(sum((R1,J),abs(Tet1out(R1,J)-
```

```
tret1out)/sqrt(vtet1out)))**2+(sum((R1,K),abs(Tet2in(R1,K)-
tret2in)/sqrt(vtet2in)))**2+(sum((R1,L),abs(Tet2out(R1,L)-
tret2out)/sqrt(vtet2out)))**2+(sum((R1,M),abs(U1(R1,M)-Ur1)/sqrt(vU1)))**2;
mo      .. mro          =e= fo*((-0.6048*tro1in)+875.12);
mo2     .. mro2         =e= fro2*((-0.6048*tro1out)+875.12);
met1    .. mret1        =e= fret1*(29.9/22.414);
met2    .. mret2        =e= fret2*(29.9/22.414);
Fb      .. fro2         =e= 0.762*fro;
qo1     .. q1           =e=     mro*((1.8089*(tro1in-tro1out))+(0.0018*(tro1in**2-
tro1out**2)))*1000/3600;
qet1    .. q1           =e=     mret1*((2.58*(tret1out-tret1in))+(-
0.00340*(tret1out**2-tret1in**2)))*1000/3600;
qhx1    .. q1           =e=     Ur1*area1*((tro1in-tret1out)*(tro1out-
tret1in)*((tro1in-tret1out)+(tro1out-tret1in))/2)**(1/3);
qo2     .. q2           =e=     mro2*((1.8089*(tro1out-
tro2out))+(0.0018*(tro1out**2-tro2out**2)))*1000/3600;
qet2    .. q2           =e=     mret2*((0.40315*(tret2out-
tret2in))+(0.0615*(tret2out**2-tret2in**2)))*1000/3600;
qhx2    .. q2           =e=     U2*area2*((tro1out-tret2out)*(tro2out-
tret2in)*((tro1out-tret2out)+(tro2out-tret2in))/2)**(1/3);
con1    .. tro1in       =g= tret1out;
con2    .. tro1out      =g= tret1in;
con3    .. tro1in       =g= tro1out;
con4    .. tret1out     =g= tret1in;
con5    .. tro1out      =g= tret2out;
con6    .. tro2out      =g= tret2in;
con7    .. tro1out      =g= tro2out;
con8    .. tret2out     =g= tret2in;

fo.lo           = 27.5688;          fo.up           = 51.1992;
fro1.lo         = 6.5688;           fro1.up         = 12.1992;
fro2.lo         = 21.0000;          fro2.up         = 39.0000;
```

fret1.lo	= 24877.1439;	fret1.up	= 46200.4101;
fret2.lo	= 24524.3521;	fret2.up	= 45545.2253;
tro1in.lo	= 118.601;	tro1in.up	= 220.259;
tro1out.lo	= 70.7784;	tro1out.up	= 131.4456;
tro2out.lo	= 63.0070;	tro2out.up	= 117.0130;
tret1in.lo	= 11.0061;	tret1in.up	= 20.4399;
tret1out.lo	= 41.0284;	tret1out.up	= 76.1956;
tret2in.lo	= 20.4428;	tret2in.up	= 37.9652;
tret2out.lo	= 34.8894;	tret2out.up	= 64.7946;
Ur1.lo	= 217.42;	Ur1.up	= 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, fo.l, fro1.l, fro2.l, fret1.l, fret2.l, tro1in.l, tro1out.l, tro2out.l, tret1in.l, tret1out.l, tret2in.l, tret2out.l, q1.l, q2.l, Ur1.l, U2.l;

Appendix K Data Reconciliation Source Code of GAMS for Model B (After Discarding 2 Positions of Gross Error)

```
$call GDXXRW.EXE 3519E02zzzz.xlsx set=R1 rng=A4:A4 Rdim=1 set=B
rng=D3:D3 Cdim=1 Par=Fo1 rng=C3:D4 Rdim=1 Cdim=1 set=C rng=F3:F3
Cdim=1 Par=Fo2 rng=E3:F4 Rdim=1 Cdim=1 set=D rng=H3:H3 Cdim=1
Par=Fet1 rng=G3:H4 Rdim=1 Cdim=1 set=E rng=J3:J3 Cdim=1 Par=Fet2
rng=I3:J4 Rdim=1 Cdim=1 set=F rng=L3:L3 Cdim=1 Par=To1in rng=K3:L4
Rdim=1 Cdim=1 set=G rng=N3:N3 Cdim=1 Par=To1out rng=M3:N4 Rdim=1
Cdim=1 set=H rng=P3:P3 Cdim=1 Par=To2out rng=O3:P4 Rdim=1 Cdim=1
set=J rng=T3:T3 Cdim=1 Par=Tet1out rng=S3:T4 Rdim=1 Cdim=1 set=K
rng=V3:V3 Cdim=1 Par=Tet2in rng=U3:V4 Rdim=1 Cdim=1 set=L
rng=X3:X3 Cdim=1 Par=Tet2out rng=W3:X4 Rdim=1 Cdim=1 set=M
rng=Z3:Z3 Cdim=1 Par=U1 rng=Y3:Z4 Rdim=1 Cdim=1

$GDXin 3519E02zzzz.gdx

Set R1(*),B(*),C(*),D(*),E(*),F(*),G(*),H(*),J(*),K(*),L(*),M(*);
$load R1 B C D E F G H J K L M

Parameter Fo1(R1,B), Fo2(R1,C), Fet1(R1,D), Fet2(R1,E), To1in(R1,F),
To1out(R1,G), To2out(R1,H), Tet1out(R1,J), Tet2in(R1,K), Tet2out(R1,L),
U1(R1,M);
$load Fo1 Fo2 Fet1 Fet2 To1in To1out To2out Tet1out Tet2in Tet2out U1

Scalars
        vfo1        variance of oil flowrate1        /92.676/
        vfo2        variance of oil flowrate2        /94.744/
        vfet1       variance of ethane1              /637.510161/
        vfet2       variance of ethane2              /672.7382207/
        vto1in      variance of oil1 inlet  temp     /622.0202201/
        vto1out     variance of oil1 outlet temp     /596.713/
```

vto2out	variance of oil2 outlet temp	/597.558/
vtet1out	variance of ethane1 outlet temp	/104.842/
vtet2in	variance of ethane2 inlet temp	/101.148/
vtet2out	variance of ethane2 outlet temp	/91.803/
vU1	variance of heat overall coefficient1	/649.4030321/
area1	heat transfer area of heat exchanger1	/46.1/
area2	heat transfer area of heat exchanger2	/16.7/

:

Variable

min	objective function
mro	reconciled oil mass flowrate
fro1	reconciled oil1 volume flowrate
fro2	reconciled oil2 volume flowrate
mro2	reconciled oil2 mass flowrate
fret1	reconciled ethane1 volume flowrate
mret1	reconciled ethane1 mass flowrate
fret2	reconciled ethane2 volume flowrate
mret2	reconciled ethane2 mass flowrate
tro1in	reconciled oil1 inlet temp
tro1out	reconciled oil1 outlet temp
tro2out	reconciled oil2 outlet temp
tret1in	reconciled ethane1 inlet temp
tret1out	reconciled ethane1 outlet temp
tret2in	reconciled ethane2 inlet temp
tret2out	reconciled ethane2 outlet temp
q1	heat duty of heat exchanger1
q2	heat duty of heat exchanger2
Ur1	reconciled overall heat transfer coefficient of heat exchanger1
U2	overall heat transfer coefficient of heat exchanger2

:

Equation

mint	define objective function

```
mo          oil mass flowrate
mo2         oil mass flowrate2
met1        ethane product mass flowrate1
met2        ethane product mass flowrate2
Fb          oil volumetric flowrate balance
qo1         heat duty of oil1
qet1        heat duty of ethane product1
qhx1        heat duty of heat exchanger1
qo2         heat duty of oil2
qet2        heat duty of ethane product2
qhx2        heat duty of heat exchanger2
con1        constraint1
con2        constraint2
con3        constraint3
con4        constraint4
con5        constraint5
con6        constraint6
con7        constraint7
con8        constraint8
;
mint    .. min          =e=     (sum((R1,B),abs(Fo1(R1,B)-
fro1)/sqrt(vfo1)))**2+(sum((R1,C),abs(Fo2(R1,C)-
fro2)/sqrt(vfo2)))**2+(sum((R1,D),abs(Fet1(R1,D)-
fret1)/sqrt(vfet1)))**2+(sum((R1,E),abs(Fet2(R1,E)-
fret2)/sqrt(vfet2)))**2+(sum((R1,F),abs(To1in(R1,F)-tro1in)/sqrt(vto1in)))**2
+(sum((R1,G),abs(To1out(R1,G)-
tro1out)/sqrt(vto1out)))**2+(sum((R1,H),abs(To2out(R1,H)-
tro2out)/sqrt(vto2out)))**2+(sum((R1,J),abs(Tet1out(R1,J)-
tret1out)/sqrt(vtet1out)))**2+(sum((R1,K),abs(Tet2in(R1,K)-
tret2in)/sqrt(vtet2in)))**2+(sum((R1,L),abs(Tet2out(R1,L)-
tret2out)/sqrt(vtet2out)))**2+(sum((R1,M),abs(U1(R1,M)-Ur1)/sqrt(vU1)))**2;
mo      .. mro          =e=     fo*((-0.6048*tro1in)+875.12);
```

```
mo2     .. mro2         =e= fro2*((-0.6048*tro1out)+875.12);
met1    .. mret1        =e= fret1*(29.9/22.414);
met2    .. mret2        =e= fret2*(29.9/22.414);
Fb      .. fro2         =e= 0.762*fo;
qo1     .. q1           =e=     mro*((1.8089*(tro1in-tro1out))+(0.0018*(tro1in**2-
tro1out**2)))*1000/3600;
qet1    .. q1           =e=     mret1*((2.58*(tret1out-tet1in))+(-
0.00340*(tret1out**2-tet1in**2)))*1000/3600;
qhx1    .. q1           =e=     Ur1*area1*((tro1in-tret1out)*(tro1out-tet1in)*((tro1in-
tret1out)+(tro1out-tet1in))/2)**(1/3);
qo2     .. q2           =e=     mro2*((1.8089*(tro1out-
tro2out))+(0.0018*(tro1out**2-tro2out**2)))*1000/3600;
qet2    .. q2           =e=     mret2*((0.40315*(tret2out-
tret2in))+(0.0615*(tret2out**2-tret2in**2)))*1000/3600;
qhx2    .. q2           =e=     U2*area2*((tro1out-tret2out)*(tro2out-
tret2in)*((tro1out-tret2out)+(tro2out-tret2in))/2)**(1/3);
con1    .. tro1in       =g=     tret1out;
con2    .. tro1out      =g=     tet1in;
con3    .. tro1in       =g=     tro1out;
con4    .. tret1out     =g=     tet1in;
con5    .. tro1out      =g=     tret2out;
con6    .. tro2out      =g=     tret2in;
con7    .. tro1out      =g=     tro2out;
con8    .. tret2out     =g=     tret2in;

fro1.lo         = 6.5688;           fro1.up         = 12.1992;
fro2.lo         = 21.0000;          fro2.up         = 39.0000;
fret1.lo        = 24877.1439;       fret1.up        = 46200.4101;
fret2.lo        = 24524.3521;       fret2.up        = 45545.2253;
tro1in.lo       = 118.601;          tro1in.up       = 220.259;
tro1out.lo      = 70.7784;          tro1out.up      = 131.4456;
tro2out.lo      = 63.0070;          tro2out.up      = 117.0130;
```

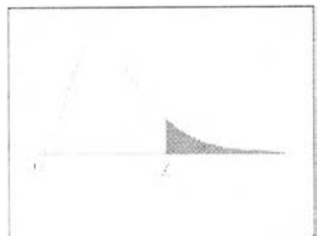
tret1in.lo	= 11.0061;	tret1in.up	= 20.4399;
tret1out.lo	= 41.0284;	tret1out.up	= 76.1956;
tret2in.lo	= 20.4428;	tret2in.up	= 37.9652;
tret2out.lo	= 34.8894;	tret2out.up	= 64.7946;
Ur1.lo	= 217.42;	Ur1.up	= 403.78;

Model reconciledall /all/;

Solve reconciledall using nlp minimizing min;

display min.l, fro1.l, fro2.l, fret1.l, fret2.l, tro1in.l, tro1out.l, tro2out.l, tet1in.l, tret1out.l, tret2in.l, tret2out.l, q1.l, q2.l, Ur1.l, U2.l;

Appendix L Chi-squared Distribution Table



[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	0.004	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.211	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.838
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.779	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.237	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.812	[illegible]
[illegible]	[illegible]	1.239	1.690	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.362	[illegible]	[illegible]	[illegible]	[illegible]
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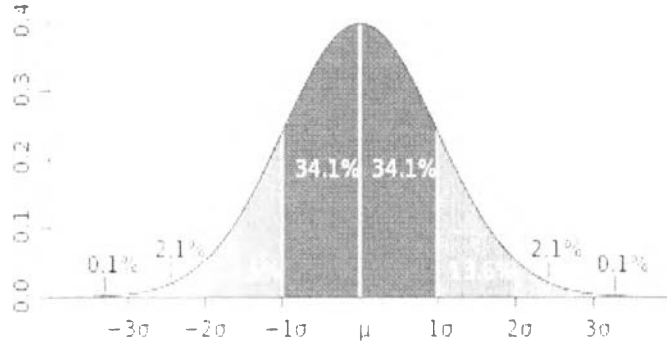
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.675	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.549	[illegible]	[illegible]	[illegible]	28.300
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.812	22.362	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	5.629	[illegible]	[illegible]	21.064	[illegible]	26.119	[illegible]	[illegible]
[illegible]	[illegible]	5.229	6.262	[illegible]	[illegible]	22.307	24.996	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.296	28.845	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.085	24.769	27.587	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.865	25.989	28.869	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.651	27.204	30.144	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.443	28.412	31.410	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	11.591	[illegible]	[illegible]	32.671	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33.924	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32.007	35.172	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15.659	[illegible]	36.415	[illegible]	[illegible]	45.559
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.652	[illegible]	44.314	46.928

Appendix M Normal Distribution Table



Standard normal distribution: Table Values Represent AREA to the LEFT of the Z scores.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592

-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
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1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361

2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
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3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
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3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

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Proceedings:

1. Pathompong, K.; and Kitipat, S. (2014, April 23) Data Reconciliation with Gross Error Detection using NLP for a Hot-oil Heat Exchanger. Proceedings of the 5th Research Symposium on Petrochemical and Materials Technology and the 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.
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Presentations:

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