ภาคผนวก ค

ผลการคำนวณของแบบจำลองทางคณิตศาสตร์ BREEZE HAZ

ในส่วนของแบบจำลองฯ Fire แบบจำลองฯ ย่อย Unconfined Pool Fire

- กรณีการเกิดรูรั่ว 1 นิ้ว เวลาในการรั่วไหล10 นาที ความคงตัวของบรรยากาศแบบ A

UNCONFINED POOL FIRE MODEL

STORAGE TANK LEAK WITH IMMEDIATE IGNITION OF SPILLED CONTENTS

FUEL
  Name   : JET A-1
  Temperature   : 28.2 °C
  Pressure (absolute)   : 1.01 bar
  Physical state   : Liquid phase only

CONSTANT PROPERTIES
  Molecular weight   : 170.0
  Boiling point   : 149.85 °C
  Critical temperature   : 677.8 K
  Critical pressure   : 15.49 bar
  Heat of combustion   : 4.52E+07 J/kg
  Flame temperature   : 1300 K

CALCULATED PROPERTIES
  Liquid compressibility factor   : 0.015
  Liquid density   : 463.9 kg/cu m

RELEASE DATA
  Type of spill   : Continuous
  Substance release rate   : 4.99 kg/sec
  Surface type   : Dry soil
  Target distance   : 1000.0 m
  Elevation of target   : 0.5 m

LOCAL AMBIENT CONDITIONS
  Air temperature   : 28.2 °C
  Ambient pressure   : 1.01 bar
  Wind speed   : 1.59 m/s
  Relative humidity   : 75.0%

STEADY STATE RESULTS
Maximum emissive power   : 140.0 kW/m²

Time Interval (s)	Burning Rate (kg/m² s)	Flame Length (m)	Flame tilt from vertical (deg)	Flame drag ratio	Effective emissive power (kW/m²)
60.00	0.076	12.14	45.53	1.22	118.03
120.00	0.075	11.84	45.87	1.22	117.04
180.00	0.075	11.84	45.87	1.22	117.04
240.00	0.075	11.84	45.87	1.22	117.04
300.00	0.075	11.84	45.87	1.22	117.04
360.00	0.075	11.84	45.87	1.22	117.04
420.00	0.075	11.84	45.87	1.22	117.04
480.00	0.075	11.84	45.87	1.22	117.04
540.00	0.075	11.84	45.87	1.22	117.04
600.00	0.075	11.84	45.87	1.22	117.04

Time Interval (s)	Pool Radius (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
60.00	2.53	0.00	0.00	0.00
120.00	2.46	0.00	0.00	0.00
180.00	2.46	0.00	0.00	0.00
240.00	2.46	0.00	0.00	0.00
300.00	2.46	0.00	0.00	0.00
360.00	2.46	0.00	0.00	0.00
420.00	2.46	0.00	0.00	0.00
480.00	2.46	0.00	0.00	0.00
540.00	2.46	0.00	0.00	0.00
600.00	2.46	0.00	0.00	0.00

Distance to Radiation Levels at Maximum Pool Size

Maximum pool radius   : 2.46 m
Mass burning rate   : 0.075 kg/m² s
Flame length   : 11.84 m
Flame tilt from vertical   : 45.87°
Flame drag ratio   : 1.22
Maximum emissive power   : 140.0 kW/m²
Effective emissive power   : 117.04 kW/m²

Thermal flux (kW/m²)	Distance From center of Pool (m)
37.5	9.04
12.5	16.07
5.0	22.35

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UNCONFINED POOL FIRE MODEL

STORAGE TANK LEAK WITH IMMEDIATE IGNITION OF SPILLED CONTENTS

FUEL
  Name   : JET A-1
  Temperature   : 28.2 °C
  Pressure (absolute)   : 1.01 bar
  Physical state   : Liquid phase only

CONSTANT PROPERTIES
  Molecular weight   : 170.0
  Boiling point   : 149.85 °C
  Critical temperature   : 677.8 K
  Critical pressure   : 15.49 bar
  Heat of combustion   : 4.52E+07 J/kg
  Flame temperature   : 1300 K

CALCULATED PROPERTIES
  Liquid compressibility factor : 0.015
  Liquid density   : 463.9 kg/cu m

RELEASE DATA
  Type of spill   : Continuous
  Substance release rate   : 4.99 kg/sec
  Surface type   : Dry soil
  Target distance   : 1000.0 m
  Elevation of target   : 0.5 m

LOCAL AMBIENT CONDITIONS
  Air temperature   : 28.2 °C
  Ambient pressure   : 1.01 bar
  Wind speed   : 1.59 m/s
  Relative humidity   : 75.0%

STEADY STATE RESULTS
  Maximum emissive power   : 140.0 kW/m²

Time Interval (s)	Burning Rate (kg/m² s)	Flame Length (m)	Flame tilt from vertical (deg)	Flame drag ratio	Effective emissive power (kW/m²)
60.00	0.076	12.14	45.53	1.22	118.03
120.00	0.075	11.84	45.87	1.22	117.04
180.00	0.075	11.84	45.87	1.22	117.04
240.00	0.075	11.84	45.87	1.22	117.04
300.00	0.075	11.84	45.87	1.22	117.04
360.00	0.075	11.84	45.87	1.22	117.04
420.00	0.075	11.84	45.87	1.22	117.04
480.00	0.075	11.84	45.87	1.22	117.04
540.00	0.075	11.84	45.87	1.22	117.04
600.00	0.075	11.84	45.87	1.22	117.04

Time Interval (s)	Pool Radius (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
60.00	2.53	0.00	0.00	0.00
120.00	2.46	0.00	0.00	0.00
180.00	2.46	0.00	0.00	0.00
240.00	2.46	0.00	0.00	0.00
300.00	2.46	0.00	0.00	0.00
360.00	2.46	0.00	0.00	0.00
420.00	2.46	0.00	0.00	0.00
480.00	2.46	0.00	0.00	0.00
540.00	2.46	0.00	0.00	0.00
600.00	2.46	0.00	0.00	0.00

Distance to Radiation Levels at Maximum Pool Size

Maximum pool radius   : 2.46 m
Mass burning rate   : 0.075 kg/m² s
Flame length   : 11.84 m
Flame tilt from vertical   : 45.87°
Flame drag ratio   : 1.22
Maximum emissive power   : 140.0 kW/m²
Effective emissive power   : 117.04 kW/m²

Thermal flux (kW/m²)	Distance From center of Pool (m)
37.5	9.04
12.5	16.07
5.0	22.35

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BLEVE MODEL

INPUT DATA

Selected substance:	Jet A-1
Heat of combustion:	45200000.0 J/kg
Mass of fuel in the fireball:	2995.04 kg
Radiative fraction of heat of combustion:	0.4

Duration of exposure for dose calculation: 6.49 s

RESULTS

Diameter of Fireball:	83.6 m
Duration of Fireball:	6.49 s

CALCULATED RADIATION AT SPECIFIED DISTANCES

Specified Distance m	Radiation Level kW/m²	Radiation Dose 6.5 s Exposure (W/m²)**4/3 s	Radiation Dose 6.5 s Exposure (W/m²)**4/3 s
5.00	27018.48	5.2617E+10	5.2589E+10
10.00	6754.62	8.28666E+09	8.28224E+09
15.00	3002.05	2.81062E+09	2.80913E+09
20.00	1688.66	1.30507E+09	1.30437E+09
30.00	750.51	4.42646E+08	4.4241E+08
40.00	422.16	2.05535E+08	2.05426E+08
70.00	137.85	4.62152E+07	4.61906E+07
100.00	67.55	1.78531E+07	1.78436E+07
150.00	30.02	6.05531E+06	6.05208E+06
200.00	16.89	2.81168E+06	2.81018E+06

CALCULATED DISTANCE AT SPECIFIED RADIATION LEVELS

Specified Radiation Level kW/m²	Distance To Radiation Level m	Radiation Dose 6.5 s Exposure (W/m²)**4/3 s	Radiation Dose 6.5 s Exposure (W/m²)**4/3 s
5.00	367.55	5.54887E+05	5.54592E+05
12.50	232.46	1.88274E+06	1.88174E+06
37.50	134.21	8.14616E+06	8.14183E+06

CALCULATED DISTANCE AT SPECIFIED RADIATION DOSE LEVELS

Distance to radiation dose based on an exposure time = fireball duration =6.49 s

Specified Radiation Dose $(W/m^2)**4/3$ s	Distance To Radiation Dose Level m
554887.	367.48
1882744.	232.41
8146162.	134.18

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UNCONFINED VAPOR CLOUD EXPLOSION (TNT) MODEL

INPUT DATA

Selected substance: Jet A-1
Heat of combustion:45200001.24 J/kg
Mass of flammable vapor in cloud:2995.04 kg
Yield factor (percent):10.0

RESULTS

Equivalent TNT mass:2891.47 kg

CALCULATED OVERPRESSURES AT SPECIFIED DISTANCES

Specified Distance m	Explosion Overpressure atm(g)
50.000	0.852
100.000	0.256
150.000	0.142
200.000	0.098
250.000	0.066
300.000	0.056
350.000	0.044
400.000	0.036
450.000	0.031
500.000	0.028

CALCULATED DISTANCES AT SPECIFIED OVERPRESSURES

Specified Overpressure atm(g)	Explosion Distance m
0.038	378.548
0.068	242.190
0.340	84.766

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UNCONFINED POOL FIRE MODEL

STORAGE TANK LEAK WITH IMMEDIATE IGNITION OF SPILLED CONTENTS

FUEL
  Name   : JET A-1
  Temperature   : 28.2 °C
  Pressure (absolute)   : 1.01 bar
  Physical state   : Liquid phase only

CONSTANT PROPERTIES
  Molecular weight   : 170.0
  Boiling point   : 149.85 °C
  Critical temperature   : 677.8 K
  Critical pressure   : 15.49 bar
  Heat of combustion   : 4.52E+07 J/kg
  Flame temperature   : 1300 K

CALCULATED PROPERTIES
  Liquid compressibility factor : 0.015
  Liquid density   : 463.9 kg/cu m

RELEASE DATA
  Type of spill   : Continuous
  Substance release rate   : 19.97 kg/sec
  Surface type   : Dry soil
  Target distance   : 1000.0 m
  Elevation of target   : 0.5 m

LOCAL AMBIENT CONDITIONS
  Air temperature   : 28.2 °C
  Ambient pressure   : 1.01 bar
  Wind speed   : 1.59 m/s
  Relative humidity   : 75.0%

STEADY STATE RESULTS
Maximum emissive power   : 140.0 kW/m²

Time Interval (s)	Burning Rate (kg/m² s)	Flame Length (m)	Flame tilt from vertical (deg)	Flame drag ratio	Effective emissive power (kW/m²)
60.00	0.090	20.34	37.27	1.17	134.25
120.00	0.090	19.95	37.62	1.18	133.83
180.00	0.090	19.95	37.62	1.18	133.83
240.00	0.090	19.95	37.62	1.18	133.83
300.00	0.090	19.95	37.62	1.18	133.83
360.00	0.090	19.95	37.62	1.18	133.83
420.00	0.090	19.95	37.62	1.18	133.83
480.00	0.090	19.95	37.62	1.18	133.83
540.00	0.090	19.95	37.62	1.18	133.83
600.00	0.090	19.95	37.62	1.18	133.83

Time Interval (s)	Pool Radius (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
60.00	4.54	0.00	0.00	0.00
120.00	4.43	0.00	0.00	0.00
180.00	4.43	0.00	0.00	0.00
240.00	4.43	0.00	0.00	0.00
300.00	4.43	0.00	0.00	0.00
360.00	4.43	0.00	0.00	0.00
420.00	4.43	0.00	0.00	0.00
480.00	4.43	0.00	0.00	0.00
540.00	4.43	0.00	0.00	0.00
600.00	4.43	0.00	0.00	0.00

Distance to Radiation Levels at Maximum Pool Size

Maximum pool radius   : 4.43 m
Mass burning rate   : 0.09 kg/m² s
Flame length   : 19.95 m
Flame tilt from vertical   : 37.62°
Flame drag ratio   : 1.18
Maximum emissive power   : 140.0 kW/m²
Effective emissive power   : 133.83 kW/m²

Thermal flux (kW/m²)	Distance From center of Pool (m)
37.5	14.42
12.5	26.99
5.0	39.09

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UNCONFINED POOL FIRE MODEL

STORAGE TANK LEAK WITH IMMEDIATE IGNITION OF SPILLED CONTENTS

FUEL
  Name   : JET A-1
  Temperature   : 28.2 °C
  Pressure (absolute)   : 1.01 bar
  Physical state   : Liquid phase only

CONSTANT PROPERTIES
  Molecular weight   : 170.0
  Boiling point   : 149.85 °C
  Critical temperature   : 677.8 K
  Critical pressure   : 15.49 bar
  Heat of combustion   : 4.52E+07 J/kg
  Flame temperature   : 1300 K

CALCULATED PROPERTIES
  Liquid compressibility factor : 0.015
  Liquid density   : 463.9 kg/cu m

RELEASE DATA
  Type of spill   : Continuous
  Substance release rate   : 19.97 kg/sec
  Surface type   : Dry soil
  Target distance   : 1000.0 m
  Elevation of target   : 0.5 m

LOCAL AMBIENT CONDITIONS
  Air temperature   : 28.2 °C
  Ambient pressure   : 1.01 bar
  Wind speed   : 1.59 m/s
  Relative humidity   : 75.0%

STEADY STATE RESULTS

Maximum emissive power : 140.0 kW/m²

Time Interval (s)	Burning Rate (kg/m² s)	Flame Length (m)	Flame tilt from vertical (deg)	Flame drag ratio	Effective emissive power (kW/m²)
60.00	0.090	20.34	37.27	1.17	134.25
120.00	0.090	19.95	37.62	1.18	133.83
180.00	0.090	19.95	37.62	1.18	133.83
240.00	0.090	19.95	37.62	1.18	133.83
300.00	0.090	19.95	37.62	1.18	133.83
360.00	0.090	19.95	37.62	1.18	133.83
420.00	0.090	19.95	37.62	1.18	133.83
480.00	0.090	19.95	37.62	1.18	133.83
540.00	0.090	19.95	37.62	1.18	133.83
600.00	0.090	19.95	37.62	1.18	133.83

Time Interval (s)	Pool Radius (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
60.00	4.54	0.00	0.00	0.00
120.00	4.43	0.00	0.00	0.00
180.00	4.43	0.00	0.00	0.00
240.00	4.43	0.00	0.00	0.00
300.00	4.43	0.00	0.00	0.00
360.00	4.43	0.00	0.00	0.00
420.00	4.43	0.00	0.00	0.00
480.00	4.43	0.00	0.00	0.00
540.00	4.43	0.00	0.00	0.00
600.00	4.43	0.00	0.00	0.00

Distance to Radiation Levels at Maximum Pool Size

Maximum pool radius : 4.43 m
Mass burning rate : 0.09 kg/m² s
Flame length : 19.95 m
Flame tilt from vertical : 37.62°
Flame drag ratio : 1.18
Maximum emissive power : 140.0 kW/m²
Effective emissive power : 133.83 kW/m²

Thermal flux (kW/m²)	Distance From center of Pool (m)
37.5	14.42
12.5	26.99
5.0	39.09

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BLEVE MODEL

INPUT DATA

Selected substance:	Jet A-1
Heat of combustion:	45200000.0 J/kg
Mass of fuel in the fireball:	11980.15 kg
Radiative fraction of heat of combustion:	0.4
Duration of exposure for dose calculation:	10.3 s

RESULTS

Diameter of Fireball:	132.71 m
Duration of Fireball:	10.3 s

CALCULATED RADIATION AT SPECIFIED DISTANCES

Specified Distance m	Radiation Level kW/m²	Radiation Dose 10.3 s Exposure (W/m²)**4/3 s	Radiation Dose 10.3 s Exposure (W/m²)**4/3 s
5.00	68397.62	2.8811E+11	2.88019E+11
10.00	17099.40	4.53745E+10	4.53602E+10
15.00	7599.74	1.53899E+10	1.5385E+10
20.00	4274.85	7.14604E+09	7.14378E+09
30.00	1899.93	2.42375E+09	2.42299E+09
40.00	1068.71	1.12543E+09	1.12507E+09
70.00	348.97	2.53056E+08	2.52976E+08
100.00	170.99	9.77564E+07	9.77255E+07
150.00	76.00	3.31565E+07	3.3146E+07
200.00	42.75	1.53957E+07	1.53908E+07

CALCULATED DISTANCE AT SPECIFIED RADIATION LEVELS

Specified Radiation Level kW/m²	Distance To Radiation Level m	Radiation Dose 10.3 s Exposure (W/m²)**4/3 s	Radiation Dose 10.3 s Exposure (W/m²)**4/3 s
5.00	584.80	8.80638E+05	8.80359E+05
12.50	369.86	2.98802E+06	2.98708E+06
37.50	213.54	1.29284E+07	1.29243E+07

CALCULATED DISTANCE AT SPECIFIED RADIATION DOSE LEVELS
Distance to radiation dose based on an exposure time = fireball duration =10.3 s

Specified Radiation Dose $(W/m^2)**4/3$ s	Distance To Radiation Dose Level m
880638.	584.73
2988023.	369.81
12928420.	213.51

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UNCONFINED VAPOR CLOUD EXPLOSION (TNT) MODEL

INPUT DATA

Selected substance:	Jet A-1
Heat of combustion:	45200001.24 J/kg
Mass of flammable vapor in cloud:	11980.15 kg
Yield factor (percent):	10.0

RESULTS

Equivalent TNT mass: 11565.89 kg

CALCULATED OVERPRESSURES AT SPECIFIED DISTANCES

Specified Distance m	Explosion Overpressure atm(g)
50.000	2.208
100.000	0.568
150.000	0.286
200.000	0.183
250.000	0.135
300.000	0.108
350.000	0.084
400.000	0.066
450.000	0.060
500.000	0.052

CALCULATED DISTANCES AT SPECIFIED OVERPRESSURES

Specified Overpressure atm(g)	Explosion Distance m
0.038	600.908
0.068	384.452
0.340	134.558

- กรณีถังกักเก็บถูกทำลายทันที Confined Pool Fire

CONFINED POOL FIRE MODEL

RECTANGULAR DIKE FIRE
 TRENCH FIRE

 FUEL
  Name   : JET A-1
  Pool temperature   : 28.2 °C

 CONSTANT PROPERTIES
  Molecular weight   : 170.0
  Boiling point   : 149.85 °C
  Critical temperature   : 677.8 K
  Critical pressure   : 15.49 bar
  Heat of combustion   : 4.52E+07 J/kg
  Flame temperature   : 1300 K

 CALCULATED PROPERTIES
  Liquid compressibility factor   : 0.015
  Liquid density   : 463.9 kg/cu m

 DIMENSIONS
  Pool width   : 100.0 m
  Pool length   : 100.0 m
  Pool Liquid Height   : 1.5 m
  Height of flame base   : 1.5 m
  Height for Radiation Calculations   : 0.5 m

 LOCAL AMBIENT CONDITIONS
  Air temperature   : 28.2 °C
  Ambient pressure   : 1.01 bar
  Wind speed   : 1.59 m/s
  Relative humidity   : 75.0%

 RESULTS
  Mass burning rate   : 0.097 kg/m² s
  Flame length   : 112.42 m
  Flame tilt from vertical (front view)   : 0.0°
  Flame tilt from vertical (side view)   : 0.0°
  Flame drag ratio (front view)   : 1.00
  Flame drag ratio (side view)   : 1.00
  Maximum emissive power   : 140.0 kW/m²
  Effective emissive power (front view)   : 140.0 kW/m²
  Effective emissive power (side view)   : 140.0 kW/m²

 Front view (view along dike/trench width)

  Thermal flux   Distance from center of pool
    (kW/m²)   (m)

     37.5   91.49
     12.5   173.68
      5.0   267.46

Side view (view along dike/trench length)

Thermal flux (kW/m²)	Distance from center of pool (m)
37.5	91.49
12.5	173.68
5.0	267.46

Maximum emissive power   : 44,380 Btu/ft² hr

Front view (view along dike/trench width)

Distance from center of pool (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
75.00	28.46	37.23	46.86
100.00	17.19	28.40	33.19
125.00	10.49	20.76	23.26
150.00	6.60	15.31	16.68
200.00	2.91	8.88	9.35
250.00	1.46	5.61	5.79
300.00	0.82	3.80	3.88
400.00	0.32	2.03	2.06
600.00	0.09	0.84	0.84
1,000	0.02	0.28	0.28

Side view (view along dike/trench length)

Distance from center of pool (m)	Thermal flux to horizontal target (kW/m²)	Thermal flux to vertical target (kW/m²)	Maximum flux to target (kW/m²)
75.00	28.46	37.23	46.86
100.00	17.19	28.40	33.19
125.00	10.49	20.76	23.26
150.00	6.60	15.31	16.68
200.00	2.91	8.88	9.35
250.00	1.46	5.61	5.79
300.00	0.82	3.80	3.88
400.00	0.32	2.03	2.06
600.00	0.09	0.84	0.84
1,000	0.02	0.28	0.28

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BLEVE MODEL

INPUT DATA

Selected substance:	Jet A-1
Heat of combustion:	45200000.0 J/kg
Mass of fuel in the fireball:	1473.26 kg
Radiative fraction of heat of combustion:	0.4
Duration of exposure for dose calculation:	5.12 s

RESULTS

Diameter of Fireball:	66.0 m
Duration of Fireball:	5.12 s

CALCULATED RADIATION AT SPECIFIED DISTANCES

Specified Distance m	Radiation Level kW/m²	Radiation Dose 5.1 s Exposure (W/m²)**4/3 s	Radiation Dose 5.1 s Exposure (W/m²)**4/3 s
5.00	16796.49	2.20239E+10	2.20257E+10
10.00	4199.12	3.46855E+09	3.46884E+09
15.00	1866.28	1.17644E+09	1.17654E+09
20.00	1049.78	5.46262E+08	5.46307E+08
30.00	466.57	1.85278E+08	1.85294E+08
40.00	262.45	8.60309E+07	8.6038E+07
70.00	85.70	1.93443E+07	1.93459E+07
100.00	41.99	7.47276E+06	7.47338E+06
150.00	18.66	2.53457E+06	2.53478E+06
200.00	10.50	1.17689E+06	1.17698E+06

CALCULATED DISTANCE AT SPECIFIED RADIATION LEVELS

Specified Radiation Level kW/m²	Distance To Radiation Level m	Radiation Dose 5.1 s Exposure (W/m²)**4/3 s	Radiation Dose 5.1 s Exposure (W/m²)**4/3 s
5.00	289.80	4.37754E+05	4.3779E+05
12.50	183.28	1.48531E+06	1.48543E+06
37.50	105.82	6.42656E+06	6.42709E+06

CALCULATED DISTANCE AT SPECIFIED RADIATION DOSE LEVELS
Distance to radiation dose based on an exposure time = fireball duration =5.12 s

Specified Radiation Dose (W/m²)**4/3 s	Distance To Radiation Dose Level m
437754.	289.81
1485308.	183.29
6426556.	105.82

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UNCONFINED VAPOR CLOUD EXPLOSION (TNT) MODEL

INPUT DATA

Selected substance:	Jet A-1
Heat of combustion:	45200001.24 J/kg
Mass of flammable vapor in cloud:	1473.26 kg
Yield factor (percent):	10.0

RESULTS

Equivalent TNT mass:	1422.32 kg

CALCULATED OVERPRESSURES AT SPECIFIED DISTANCES

Specified Distance m	Explosion Overpressure atm(g)
50.000	0.563
100.000	0.181
150.000	0.107
200.000	0.066
250.000	0.052
300.000	0.038
350.000	0.031
400.000	0.027
450.000	0.023
500.000	0.020

CALCULATED DISTANCES AT SPECIFIED OVERPRESSURES

Specified Overpressure atm(g)	Explosion Distance m
0.038	298.823
0.068	191.182
0.340	66.914