APPENDIX

EXPOSURE ESTIMATION DETAILS FOR SELECTED TASKS AT A SYNTHETIC RUBBER MANUFACTURING PLANT

Purging water from recycled BD tanks (tank farm)

The operator stood at the bottom of the BD tank. He opened the bottom drain of the tank and allowed the water to flow at about 20 gallons per minute. It took the operator about 10-30 seconds to detect the BD and close the valve. Once the BD was detected, it accounted for about 1-5% of the flow from the tank. The ditch was about 6.6 feet (2 meters) away from the breathing zone of the operator. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input)
C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1992 (BD):
1. Generation rate= draw off line drains at a rate of 20 gal/min; when BD is detected, it accounts for 1-5% of the flow from the pipe.
Q(L) = (1% BD)= 0.01(20 gal/min)=0.2 gal/min = 757 ml/min * 0.621(specific gravity)= 7.83 g/sec.
Q(U) = (5% BD)= 0.05(20 gal/min)=1 gal/min = 3,785 ml/min * 0.621(specific gravity)= 39.17 g/sec.

Duration of task (min) =5-10; Duration of exposure (min) =0.5-1; Frequency of exposure =1.5/shift

D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =1.45; u(m/sec) (UL) =1.04

Purging water from recycled STY tanks (tank farm)

The operator stood at the bottom of the STY tank. He opened the bottom drain of the tank and allowed the water to flow into a ditch until he smelled STY. The water flowed into a ditch and formed a pool of about 10 ft2 (the STY accounts for about of 10% of this mixture- equivalent to about 1 ft2). Exposure occurred because of evaporation of STY from the pool which was about 1.5 meters away from the breathing zone of the operator. It took about 0.5-1.0 minute to detect the STY. From 1943-1956 the tanks were located in a diked and in 1957, vertical tanks were installed outside of the diked area. The average wind speed values (lower and upper limit) for this task across all plants was used. In 1973, the frequency of exposure was reduced because a STY decanter was installed. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Evaporation from a liquid surface)
V)apor P)ress.=10 ** [p1 - p2 / (T + 235)] / 760
Q(lb/min)=(MW * K * (AREA/929.0304) * VP) /(0.7302 * ((TEMP*9/5)+32) + 460)
Q(g/sec)=(Q(lb/min) * 454) / 60
C(ppm)=1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1972 (STY):
1. Duration of exposure was increased (from original estimates) and given a range from 30 seconds to1 minute. The increase in time is because the operator had to first, recognize the STY smell and then close the bottom drain of the tank. The operator was assumed to be exposed for a least 30 seconds while performing these acts.
2. As compared to previous estimates, the frequency of exposure was increased to a range of 1 to 3 times per shift to compensate for the times when only one person was performing the task, instead of the regular two.
3. The bottom drain was opened and water was released into the ditch until STY odor was detected. STY evaporated from the surface of a water and STY mixture which was about 10 ft2; the STY in this mixture was equivalent to about 1 ft2 (1,000cm2).

Duration of task (min) =8-10; Duration of exposure (min) =0.5-1; Frequency of exposure =1-3/shift
Tg(C) (LL) = 25; Tg(C) (UL) = 25; A(cm2) (LL) =1000; A(cm2) (UL) =1000
D(m) (LL) = 1.5; D(m) (UL) = 1.5; u(m/sec) (LL) =1.37; u(m/sec) (UL) =0.77

1973-1992 (STY):
1. Frequency of the exposure is given a lower range (from one-half to once per shift) because the decanters were installed which reduced the frequency that the tanks needed to have water drawn off.
2. The exposure intensity is the same.

Frequency of exposure = 0.5-1/shift
Tg(C) (LL) = 25; Tg(C) (UL) = 25; A(cm2) (LL) = 1000; A(cm2) (UL) = 1000
D(m) (LL) =.5; D(m) (UL) = 1.5; u(m/sec) (LL) =1.37; u(m/sec) (UL) =0.77

Monitoring monomer shipments from pumphouse (tank farm)

The emission sources for BD was reduced to 20-50 lb/day (2-5 times the value for the average pump). STY emissions were reduced to 2-5 lb/day. The volume of the pump house was increased to 29,250 ft3 because the blueprints were obtained and the dimensions of the pumphouse were found to be 65' by 30' by 15'. The air changes per hour was given a range from 4-7 due to measurements taken by the Plant 3 Industrial Hygienist. The time frame of the change in technology was changed due to information obtained from Plant 3 employees.

Multiple source equation: PPM = 403,000,000 * Q(pt/min) * SG / (Vent. Rate * MW)

1943-1952 (BD):
1. Multiple emission sources from a single pump are considered to leak simultaneously. Examples include pipe connections, pump seals, valves, etc. During this period reciprocating pumps with packing were used in BD service. Assume that the multiple emission sources from a single pump collectively leaks at about 20-50 lb/day (0.02-0.05 pt/min, LA Study). Bleeding and priming pumps also adds to the multiple emission leakage. 2. 4-7 air changes per hour occurred in the old pumphouse (approximate size = 29,250 ft3). As a result, the ventilation rate of the building = 1,950-3,413 cfm. The majority of the year the wind blows from the south through a door with an area of 22.6 ft2. The louvers on the building are open most of the year. The louver area is 60.4 ft2 on the south side of the building. Wind speed at the door in August, 1997 measured 33-48 ft/min.

Duration of task (min) =240; Duration of exposure (min) =240; Frequency of exposure = 1/shift

LOWER LIMIT: Q (in pints per minute) =0.02; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) = 0.05; Ventilation Rate (cfm) =1950

1953-1976 (BD):
1. The change to centrifugal pumps with single mechanical seals and improvements in general working conditions resulted in a 1/3 reduction of emissions. Q(lower and upper) = 0.02-0.05 pt/min * 2/3 = 0.013-0.033 pt/min

LOWER LIMIT: Q (in pints per minute) =0.013; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) = 0.033; Ventilation Rate (cfm) =1950

1977-1989 (BD):
1. The change to centrifugal pumps with double mechanical seals and improvements in general working conditions decreased emissions by 90%. Q(lower and upper) = 0.013-0.033 pt/min * 0.10 = 0.0013-0.0033 pt/min

LOWER LIMIT: Q (in pints per minute) =0.0013; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) =0.0033; Ventilation Rate (cfm) =1950

1990-1992 (BD):
1. A new pumphouse was built away from pumps and the double seals were further improved which resulted in a 50% decrease in exposure (from the previous period). Q(lower and upper) = 0.0013-0.0033 * 0.5 = 0.00065-0.00165 pt/min

Duration of exposure (min) =158-202

LOWER LIMIT: Q (in pints per minute) =0.00065; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) = 0.00165; Ventilation Rate (cfm) =1950

1943-1952 (STY):
1. Multiple emission sources from a single pump are considered to leak simultaneously. Examples include pipe connections, pump seals, valves, etc. During this period reciprocating pumps with packing were used in STY service. Assume that the multiple emission sources from a single pump collectively leaks at about 2-5 lb (completely evaporated)/day (0.0015-0.0037 pt/min, LA Study). Bleeding and priming pumps also adds to the multiple emission leakage. 2. 4-7 air changes per hour occurred in the old pumphouse (approximate size = 29,250 ft3). As a result, the ventilation rate in the building = 1,950-3,413 cfm. The majority of the year the wind blows from the south through a door with an area of 22.6 ft2. The louvers on the building are open most of the year. The louver area is 60.4 ft2 on the south side of the building. Wind speed at the door in August, 1997 measured 33-48 ft/min.

Duration of exposure (min) =240

LOWER LIMIT: Q (in pints per minute) =0.0015; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) =0.0037; Ventilation Rate (cfm) =1950

1953-1976 (STY):
1. The change to centrifugal pumps with single mechanical seals and improvements in general working conditions resulted in a 1/3 reduction of emissions. Q(lower and upper) = 0.0015-0.0037 pt/min * 2/3 = 0.001-0.0025 pt/min

LOWER LIMIT: Q (in pints per minute) =0.001; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) =0.0025; Ventilation Rate (cfm) =1950

1977-1989 (STY):
1. The change to centrifugal pumps with double mechanical seals and improvements in general working conditions decreased emissions by 90%. Q(lower and upper) =0.001-0.0025 * 0.10 = 0.0001-0.00025pt/min

LOWER LIMIT: Q (in pints per minute) =0.0001; Ventilation Rate (cfm)=3413

UPPER LIMIT: Q (in pints per minute) =0.00025; Ventilation Rate (cfm) =1950

1990-1992 (STY):
1. A new pumphouse was built away from pumps and the double seals were further improved which resulted in a 50% decrease in exposure (from the previous period). Q(lower and upper) =0.0001-0.00025 = 0.00005-0.000125 pt/min

Duration of exposure (min) =158-202

LOWER LIMIT: Q (in pints per minute) = 0.00005; Ventilation Rate (cfm) =3413

UPPER LIMIT: Q (in pints per minute) =0.000125; Ventilation Rate (cfm) =1950

Charging reactors in batch mode (reactor)

During the batch operating era (1943-1949), valve racks were used by the operators to load the reactors. Because of sudden changes in pressure in the lines after manual opening or closing of valves, the racks leaked monomers. Also, plug type valves may have been used, which were more prone to leaking. For exposure estimation purposes, it was assumed that the valve racks leaked at the same rate as the pumps in the 1940's. The BD evaporated immediately from the pipe which was 0.5 meters away from the operator's face. The STY exposure corresponds to a continuous drip that generated a puddle 1.83 feet in diameter (equivalent to a generation rate of 2 drops/sec). The puddle was 5 feet (1.5 meters) away from the breathing zone of the operator. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Direct input of emission rate)

Q(g/sec) = (user input)

C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1949 (BD):

1.Valve racks were used by reactor area operators to load the reactors. Sudden changes in pressure after opening or closing the valves might have caused the leaking of monomers. Assume that the valves leak at 10 lb/day. Q= 10 lb/day= 4,540 g/day=0.085 g/sec

2. The valve racks were not used after 1949.

Duration of task (min) =5; Duration of exposure (min) =0.5-1; Frequency of exposure=3-6/shift

D(m) (LL)=0.5; D(m) (UL)=0.5; u(m/sec) (LL) =1.1; u(m/sec) (UL)=0.25

1943-1949 (STY):

1. Valve racks were used by reactor area operators to load the reactors. Sudden changes in pressureafter opening or closing the valves might have caused the leaking of monomers. Assume that the valves leak at 0.5 lb/day. Q= 0.5 lb/day= 227 g/day= 0.0026 g/sec Note: Distance for STY is larger because it is evaporating from the floor.

2. Valve racks were not used after 1949.

D(m) (LL)=1.5; D(m) (UL)=1.5; u(m/sec) (LL)=1.1; u(m/sec) (UL)=0.25

Minor maintenance of equipment (reactor)

Minor maintenance of the area included inspecting BD pumps and preparing the pumps for repair by a mechanic or pipefitter. In 1943-1952, there were reciprocating pumps with packing seals in place. In 1953, centrifugal pumps with single mechanical seals were added and in 1977 double mechanical seals were added (these seals were improved in 1990). Exposure is a function of the pump leak rate. For the period 1943-52, the average leak rate of a pump requiring maintenance was estimated at 10-20 lbs/day (this value is double the average leak rate for reciprocating pumps from the LA Study). The leak intensity was reduced as the pump technology improved. The average time it took for maintenance of the pumps was 10 minutes. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Minor maintenance of the area included inspecting STY pumps and preparing the pump for repair by a mechanic or pipefitter. In 1943-1952, there were reciprocating pumps with packing seals in place. In 1953, centrifugal pumps with single mechanical seals were added and in 1977 double mechanical seals were added (these seals were improved in 1990). Exposure is a function of the pump leak rate. For the period 1943-52, the average leak rate of a pump requiring maintenance was estimated at 0.5-1.0 lbs/day (this value is double the average leak rate for reciprocating pumps from the LA Study). The leak intensity was reduced as the pump technology improved. The average time it took for maintenance of the pumps was 10 minutes. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Direct input of emission rate)

Q(g/sec) = (user input)

C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1952 (BD):

1. Pumps (reciprocating with packing seals) leak at a rate of 10-20 pounds per day.

Q(L) = 10 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.05 g/sec

Q(U) = 20 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.10 g/sec

Duration of task (min) =10; Duration of exposure (min) =10; Frequency of exposure =1/shift

D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =0.91; u(m/sec) (UL) =0.22

1953-1976 (BD):

1. Changed to centrifugal pumps with single mechanical seals and improvement in general working conditions resulted in a 1/3 reduction of emissions.

Q(L) = 10 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.05 g/sec * 2/3 = 0.033 g/sec
Q(U) = 20 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.10 g/sec * 2/3 = 0.067 g/sec

Frequency of exposure = 0.5/shift
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) = 0.91; u(m/sec) (UL) =0.22

1977-1989 (BD):
1. Changed to centrifugal pumps with double mechanical seals and improvements in general workingconditions reduced emissions by 90%.
Q(L) = 0.033 * 0.10 = 0.0033 g/sec; Q(U) = 0.067 * 0.10 = 0.0067 g/sec

Frequency of exposure = 0.2/shift
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =0.91; u(m/sec) (UL) =0.22

1990-1992 (BD):
1. The double seals were further improved which resulted in a 50% decrease in exposure (from the previous period).
Q(L) = 0.0033 * 0.5 = 0.00165 g/sec; Q(U) = 0.0067 * 0.5 = 0.00335 g/sec

D(m) (LL) =0.5; D(m) (UL) = 0.5; u(m/sec) (LL) = 0.91; u(m/sec) (UL) =0.22

1943-1952 (STY):
1. Pumps (reciprocating with packing seals) leak at a rate of 0.5-1.0 pounds per day.
Q(L) = 0.5 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.0025 g/sec
Q(U) = 1.0 lb/day * 454grams/1lb * 1day/24hours * 1hour/3600seconds = 0.005 g/sec

Duration of task (min) = 10; Duration of exposure (min) =10; Frequency of exposure =1/shift
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) = 1.03; u(m/sec) (UL) =0.22

1953-1960 (STY):
1. Changed to centrifugal pumps with single mechanical seals and improvement in general working conditions resulted in a 1/3 reduction of emissions.
Q(L) = 0.0025 * 2/3 = 0.00165 g/sec; Q(U) = 0.005 * 2/3 = 0.0033 g/sec
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =1.03; u(m/sec) (UL) =0.22

1961-1976 (STY):
1961-1977 1. Frequency of task decreased to 0.2/shift.
Frequency of exposure=0.2/shift
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) = 1.03; u(m/sec) (UL) =0.22

1977-1989 (STY):
1. Changed to centrifugal pumps with double mechanical seals and improvements in general working conditions reduced emissions by 90%.
Q(L) = 0.00165 * 0.10 = 0.000165 g/sec; Q(U) = 0.0033 * 0.10 = 0.00033 g/sec
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =1.03; u(m/sec) (UL) =0.22

1990-1992 (STY):
1. The double seals were further improved which resulted in a 50% decrease in exposure(from the previous period).
Q(L) = 0.000165 * 0.5 = 0.0000825 g/sec; Q(U) = 0.00033 * 0.5 = 0.00017 g/sec
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =1.03; u(m/sec) (UL) =0.22

Inspection + minor maintenance of compressors (recovery)

The inspection and maintenance of the recovery compressors involved inspection of the area for compressor leaks and preparing the compressor for repair by a mechanic or pipefitter. Exposure is a function of the compressor leak rate. For the time period 1943-74 the leak rate for compressors was determined to be 20-30 lb per day (CMA Report). The leak intensity was reduced as the compressor technology improved. From 1943-74, reciprocating compressors with packing were used. From 1975-86, single mechanical seals were placed on compressors. Plant employees confirmed that the leak rate was reduced by a factor of 2-4 in 1975 and also that the material leaked was 90% BD. The average wind speed values (lower and upper limit) for this task across all plants was used. In 1987, the leaks from the compressors were sent to flare which reduced the exposure to a negligible amount. It is assumed that, during the inspection, the operator maintained an average distance of 1 meter from any one of the four compressor seals. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input)
C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1974 (BD):
1. Compressors leaked an H20/monomer mixture at a rate of 20-30 lb/day; 90% of this mixture was BD; thus 18 to 27 lb of BD were lost from each seal per compressor per day.

Q(L)= 18 lb/day *454 grams/1 lb *1 day/24 hours * 1 hour/3600 seconds = 0.09458 g/sec
Q(U) = 27 lb/day *454 grams/1 lb *1 day/24 hours * 1 hour/3600 seconds = 0.141875 g/sec
Note: Size of area was 40'(long) x 24'(wide) x 12'(high).
Duration of task (min) =10-20; Duration of exposure (min) =10-20; Frequency of exposure =4/shift
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.44; u(m/sec) (UL) = 0.42

1975-1986 (BD):
1. 4 compressors leaked at a rate of 2,000-2,500 lb/year each.
This reduction was because packing was replaced with single mechanical seals.
Q(L)= 2,000 lb/year =0.02879 g/sec; Q(U)= 2,500 lb/year = 0.03599 g/sec
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.44; u(m/sec) (UL) = 0.42

1943-1974 (STY):
1. STY evaporated from the surface of an H2O/STY mixture which was about 10 ft2; the STY in this mixture was equivalent to about 1 ft2 (1,000cm2). The temperature is 30oC because the compressor area was considered to have a higher ambient temperature than outdoors. The operator stands 2 meters from the puddle of STY on the ground.
Tg(C) (LL) = 30; Tg(C) (UL) =30; A(cm2) (LL) = 1000; A(cm2) (UL) =1000
D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =1.44; u(m/sec) (UL) =0.42

1975-1986 (STY):
1. Exposure decreased by a factor of 2 due to the introduction of single mechanical seals on compressors. To account for the reduction the spill size (surface area) was reduced by a factor of two.
Tg(C) (LL) = 30; Tg(C) (UL) =30; A(cm2) (LL) =500; A(cm2) (UL) =500
D(m) (LL) =2; D(m) (UL) = 2; u(m/sec) (LL) =1.44; u(m/sec) (UL) =0.42

Draining latex strainers between flash tanks and stripping columns (recovery)

To prevent plug-ups between the flash tanks and the stripper, berry traps were placed in line to collect coagulant. The traps had to be drained occasionally to prevent a buildup of latex in the strainer. The emulsion contained 5% STY, 25% polymer and 70% H2O. The traps were changed more frequently in the 1940s and 1950s. The traps were about 2 meters from the breathing zone of the operator. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Partial TWA = (PPM * Task Duration * Freq/Shift) / # of min. in a work shift
Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input)

C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1959 (STY):
1. Assume that 1 gallon of unstripped latex (BD is already stripped off) was released from the one inch diameter drain in the one minute it took for the operator to remove the plug on the drain. The operator pulled the plug and walked away until the trap was completely drained. The solution was 5% STY. Assume that 5% evaporated.
Q = 1 gallon/1 minute * 0.05 * 0.05 = 0.0025 gal/min = 0.14 g/sec

Duration of task (min) =3; Duration of exposure (min) =1; Frequency of exposure = 4-6/shift

D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =2.13; u(m/sec) (UL) =0.6

LOWER LIMIT: 1/8 of the dispersion model; Q (g/sec) =0.14;

UPPER LIMIT: 1/4 of the dispersion model; Q (g/sec) =0.14;

1. The frequency of exposure decreased; but the exposure intensity remained the same.

Frequency of exposure = 2-4/shift

1975-1984 (STY): 1. The frequency of exposure decreased; but the exposure intensity remained the same.

Frequency of exposure = 1-3/shift

1985-1992 The frequency of exposure decreased; but the exposure intensity remained the same.

Frequency of exposure =1/shift

Latex Coagulation Area Background

Background exposure was the likely exposure level experienced during that part of the work shift spent carrying out tasks that did not entail especially high exposures to monomers. According to Plant 3 and Plant 1 employees, the latex flowing through one building per shift was about 46,000 gallons. The volume of the finishing building was 1,300,000 ft3. For exposure estimation purposes, it was assumed that the exposure ratio for the coagulation:dryer:baler area was 3:2:1. The total amount of STY entering the building was estimated by multiplying the total volume of latex entering the building (46,000 gal/shift) by the residual STY. Fifteen percent of this amount was estimated to be released into the building in the coagulation area. Of the remaining STY in the coagulated rubber, 80% was captured by the dryers and 90% of the latter was released by the dryer stacks, while 10% was released into the building. From 1943-1961, the concentration of the STY in the rubber was about 1,000-2,000 ppm; in 1962-1979 the STY concentration was 750-1,000 ppm; in 1980-1989, the STY concentration was 400-600 ppm; in 1990-1992, the concentration of STY was reduced to 300-400 ppm.

Multiple source equation: PPM = 403,000,000 * Q(pt/min) * SG / (Vent. Rate * MW)

1943-1961 (STY):
1. The latex flowing through one building was 46,000 gallons per shift. Assume that the concentration in the blending tank is 1,000-2,000 ppm. Assume that 15% evaporates into the building.
Q(L) = 0.15 * 1,000 ppm = 150 ppm =0.11 pt/min.; Q(U)= 0.15 * 2,000 ppm = 300 ppm = 0.23 pt/min.
2. Assume that the dryer captured 80% of the remaining 850-1,700 ppm. 10% of the captured amount was released into the building. The remaining 90% was captured and released in the plume outside the building.
Q(L) = 0.80 * 850 ppm = 680 ppm * 0.10 = 68 ppm = 0.05 pt/min.
Q(U)= 0.80 * 1,700 ppm = 1,360 ppm * 0.10 = 136 ppm= 0.10 pt/min.
Q(L)-total = 0.11 pt/ min + 0.05 pt/min 0.16 pt/min; Q(U)-total = 0.23 pt/min + 0.10 pt/min = 0.33 pt/min.
3. Assume 10 air changes per hour in a 1,300,000 ft3 building. VR (cfm)=217,000 cfm
4. Assume that exposure ratio for coagulation:dryer:baler is 3:2:1.

Duration of task (min) = 480; Duration of exposure (min) = 480; Frequency of exposure = 1/shift

LOWER LIMIT: Q (in pints per minute) = 0.16; Ventilation Rate (cfm) = 217000
UPPER LIMIT: Q (in pints per minute) = 0.33; Ventilation Rate (cfm) = 217000

1962-1979 (STY):
1. Assume that the concentration in the blending tank was 750 - 1,000 ppm. The reduction is due to better stripping efficiency. Assume that 15% evaporated into the building.
Q(L) = 0.15 * 750 ppm = 112.5 ppm = 0.08 pt/min.; Q(U) = 0.15 * 1,000 ppm = 150 ppm = 0.11 pt/min.
2. Assume that the dryer captured 80% of the remaining 737.5 - 850 ppm. 10% of the captured amount was released into the building. The remaining 90% was captured and released in the plume outside the building.
Q(L) = 0.80 * 737.5 ppm = 590 ppm * 0.10 = 59 ppm =0.04 pt/min.
Q(U) = 0.80 * 850 ppm = 680 ppm * 0.10 = 68 ppm = 0.05 pt/min.
Q(L)-total = 0.08 pt/ min + 0.04 pt/min = 0.12 pt/min.; Q(U)-total = 0.11 pt/min + 0.05 pt/min = 0.16 pt/min.
3. Assume 15 air changes per hour in a 1,300,000 ft3 building. (Because of a better ventilation system). VR (cfm)= 325,000 cfm

LOWER LIMIT: Q (in pints per minute) =0.12; Ventilation Rate (cfm) = 325000
UPPER LIMIT: Q (in pints per minute) =0.16; Ventilation Rate (cfm) = 325000

1980-1989 (STY):
1. Assume that the concentration in the blending tank was 400 - 600 ppm. The reduction is due to better stripping efficiency. Assume that 15% evaporated into the building.
Q(L) = 0.15 * 400 ppm = 60 ppm =0.04 pt/min.; Q(U) = 0.15 * 600 ppm = 90 ppm = 0.07 pt/min.
2. Assume that the dryer captured 80% of the remaining 340 - 510 ppm. 10% of the captured amount is released into the building. The remaining 90% was captured and released in the plume outside thebuilding.
Q(L) = 0.80 * 340 ppm = 272 ppm * 0.10 = 27.2 ppm =0.02 pt/min.
Q(U) = 0.80 * 510 ppm = 408 ppm * 0.10 = 40.8 ppm =0.03 pt/min.
Q(L)-total = 0.04 pt/ min + 0.02 pt/min =0.06 pt/min; Q(U)-total = 0.07 pt/min + 0.03 pt/min =0.10 pt/min.
3. Assume 15 air changes per hour in a 1,300,000 ft3 building. (Because of a better ventilation system).
VR (cfm)= 325,000 cfm

LOWER LIMIT: Q (in pints per minute) =0.06; Ventilation Rate (cfm) =325000
UPPER LIMIT: Q (in pints per minute) =0.1; Ventilation Rate (cfm) =325000

1990-1992 (STY):
1. Assume that the concentration in the blending tank was 300 400 ppm. The reduction is due to better stripping efficiency. Assume that 15% evaporated into the building.
Q(L) = 0.15 * 300 ppm = 45 ppm =0.03 pt/min.; Q(U) = 0.15 * 400 ppm = 60 ppm =0.04 pt/min.
2. Assume that the dryer captured 80% of the remaining 255 - 340 ppm. 10% of the captured amount was released into the building. The remaining 90% was captured and released in the plume outside the building.
Q(L) = 0.80 * 255 ppm = 204 ppm * 0.10 = 20.4 ppm 0.015 pt/min.
Q(U) = 0.80 * 340 ppm = 272 ppm * 0.10 = 27.2 ppm 0.02 pt/min.
Q(L)-total = 0.03 pt/ min + 0.015 pt/min= 0.045 pt/min.; Q(U)-total = 0.04 pt/min + 0.02 pt/min =0.06 pt/min.
3. Assume 20 air changes per hour in a 1,300,000 ft3 building. (Because of a better ventilation system).
VR (cfm)= 433,000 cfm

LOWER LIMIT: Q (in pints per minute) = 0.045; Ventilation Rate (cfm) = 433000
UPPER LIMIT: Q (in pints per minute) = 0.06; Ventilation Rate (cfm) = 433000

Sampling BD shipments (process control lab)

BD is sampled in the plant in pressurized bombs. The bombs are connected to a sampling line in the tank and purged into the atmosphere before the sample was taken. From 1943-1963, one 500 ml sample of BD was taken per shift. Plant 3 employees report that 1/2 to 1 1/2 volumes of the bomb were purged into the atmosphere before the sample was taken. The sampler was standing 6.6 ft (2 meters) away from the generation point. The average wind speed values (lower and upper limit) for this task across all plants was used. In 1964, sampling frequency decreased to once per day (0.33/shift). Slip-tube gauging was added to this task from 1943-1963 in the tank car period; it was removed as a possible source of exposure when the BD shipments arrived via pipeline. The slip gauging added an additional 100 ml of liquid BD when the gauging was done on a full tank. An additional 100 ml of BD vapor was added to the task to represent the exposure when the slip gauging was done on a tank that was almost empty. The Instrument Lab took over this task in 1975. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input); C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1963 (BD):
1. Tank car period. Assume a 500 ml sample bomb, 1/2 to 1 1/2 volumes of the bomb are purged in 15 seconds into atmosphere (250ml/15 seconds to 750 ml/15 seconds). Slip-tube gauging the full tank contributed 100 ml (= 62.1 grams) of exposure. Slip-gauging the tank car that was almost empty contributed 100 ml of BD vapor (= 0.225 grams).
Q(L) = 250 ml + 100 ml = 350ml * 0.621g/ml = 217.35g/15 sec = 14.49 g/sec.
Q(U) = 750 ml + 100 ml = 850ml * 0.621g/ml = 527.85g/15 sec = 35.19 g/sec.

Duration of task (min) =10; Duration of exposure (min) =0.25; Frequency of exposure =1/shift
D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =2.17; u(m/sec) (UL) =0.85

1964-1974 (BD):
1. Pipeline period. Assume a 500 ml sample bomb, 1/2 to 1 1/2 volumes of the bomb are purged in 15 seconds into atmosphere (250ml/15 seconds to 750 ml/15 seconds). There was not slip gauging during the pipeline period.
Q(L)= 250 ml * 0.621g/ml = 155.25 g/15 sec = 10.35 g/sec.; Q(U)= 750 ml * 0.621g/ml = 465.8g/15 sec = 31.05 g/sec.

Frequency of exposure =0.33/shift
D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =2.17; u(m/sec) (UL) =0.85

1975-1979 (BD):
1. Assume a 500 ml sample bomb, 1/2 to 1 1/2 volumes of the bomb are purged in 15 seconds into atmosphere (250 ml/15 seconds to 750 ml/15 seconds). There was not slip gauging during the pipeline period.
Q(L)= 250 ml * 0.621g/ml = 155.25 g/15 sec = 10.35 g/sec.
Q(U)= 750 ml * 0.621g/ml = 465.8g/15 sec = 31.05 g/sec.

Duration of task (min) =10; Duration of exposure (min) =0.25; Frequency of exposure =2/shift

D(m) (LL) =2; D(m) (UL) =2; u(m/sec) (LL) =2.17; u(m/sec) (UL) =0.85; Q (g/sec) =10.35

1980-1988 (BD):
1. Exposure intensity is the same as in previous time period. Frequency of exposure decreased.
2. Assume closed loop sampling implemented after 1988- exposure negligible.

Frequency of exposure = 1-2/shift

Sampling unstripped latex (reactor control /rubber control laboratory)

During the batch mode era (1943-1949), two latex samples were taken every shift from each reactor. There were 48 reactors (~100 samples per shift) and three samplers, therefore, each sampler took about 33 samples per shift. At 60% conversion, the emulsion is in two phases- one phase is the monomer and the polymer and the other is the water phase. At 60% conversion, the BD is about 33% unreacted and the STY is about 50% unreacted. The mole fraction was calculated based on this two phase system. A Princeton correction factor of 0.9 was used to adjust the BD evaporation rate; and a factor of 0.6 was used to adjust for the STY evaporation rate. For calculation purposes, the monomers were assumed to evaporate from an area of about 0.54 ft2 (500 cm2), corresponding to the area of the container which contains the purged latex. The entire area of the sample is 500 cm2; the rubber phase accounts for 2/3 (333.3 cm2) of the surface and the BD molar fraction in the rubber phase is 76%. Partial pressures of BD and STY were calculated at 45oC (hot polymerization), In 1950, the process changed to continuous polymerization which reduced the number of samples to 16 per shift. In 1956, Plant 3 was added which increased the number of samples taken to 24 per shift. In 1956, the process changed to cold polymerization, the partial pressures were calculated at 10oC. In 1960 this task was taken over by the front lab (lab technician) due to the closing of the field lab. In 1988, respirators were worn during sampling which made the exposure negligible. The average wind speed values (lower and upper limit) for this task across all plants was used. The upper and lower limits were calculated based on the theory that the operator had a one in four (or eight) chance of standing directly in the plume.

Point source equations: (Evaporation from a mixture)
V)apor P)ress.=10 ** [p1 - p2 / (T + 235)] / 760
Q(lb/min)=(MW * K * (AREA/929.0304) * VP) /(0.7302 * ((TEMP*9/5)+32) + 460)
Q(g/sec)=(Q(lb/min) * 454) / 60
Q(g/sec)=(Q(g/sec) * Molar Fraction * Princeton Correction Factor
C(ppm)=1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1949 (BD): 1. Hot batch process in use.
Frequency of exposure = 33/shift
Duration of task (min) = 5-10; Duration of exposure (min) = 2; Frequency of exposure =33/shift
Tg(C) (LL) = 45; Tg(C) (UL) = 45; A(cm2) (LL) =166.67; A(cm2) (UL) =166.67
D(m) (LL) = 1; D(m) (UL) =1; u(m/sec) (LL) =1.59; u(m/sec) (UL) = 0.57
Princeton Correction Factor: 0.9; Molar Fraction: 0.7485; Q (g/sec) =0.517527

1950-1955 (BD): 1. Hot continuous process in use.
Frequency of exposure = 5.3/shift

1956-1959 (BD): 1. Cold continuous process introduced.
Frequency of exposure =8/shift
Tg(C) (LL) = 10; Tg(C) (UL) =10;

1943-1949 (STY): 1. Hot batch process in use.
Frequency of exposure = 33/shift
Tg(C) (LL) = 45; Tg(C) (UL) =45; A(cm2) (LL) =166.67; A(cm2) (UL) =166.67
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.59; u(m/sec) (UL) = 0.57

LOWER LIMIT: 1/8 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.2407; Q (g/sec) =0.00086;
UPPER LIMIT: 1/4 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.2407; Q (g/sec) =0.00086

1950-1955 (STY): 1. Hot continuous process in use.
Frequency of exposure = 5.3/shift

1956-1959 (STY): 1. Cold continuous process introduced.
Frequency of exposure =8/shift

Tg(C) (LL) =10; Tg(C) (UL) =10;

LOWER LIMIT: 1/8 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.2407

Q (g/sec) =0.000125
UPPER LIMIT: 1/4 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.2407; Q (g/sec) =0.000125

1960-1987 (BD):
1. Frequency increases slightly (as compared to previous time period) due to addition of plant 3.

Duration of task (min) =5-10; Duration of exposure (min) =5-10; Frequency of exposure =8/shift
Tg(C) (LL) =10; Tg(C) (UL) =10; A(cm2) (LL) =166.67; A(cm2) (UL) =166.67; D(m) (LL) =1; D(m) (UL) =1
u(m/sec) (LL) =1.59; nu(m/sec) (UL) =0.57

LOWER LIMIT: 1/8 of the dispersion model; Princeton Correction Factor: 0.9; Molar Fraction: 0.76; Q (g/sec) =0.199459;
UPPER LIMIT: 1/4 of the dispersion model; Princeton Correction Factor: 0.9; Molar Fraction: 0.76; Q (g/sec) =0.199459

1960-1987 (STY):
1. Frequency increases slightly (as compared to previous time period) due to addition of plant 3.

Tg(C) (LL) =10; Tg(C) (UL) =10; A(cm2) (LL) =66.67; A(cm2) (UL) =66.67; D(m) (LL) = 1
D(m) (UL) = 1; u(m/sec) (LL) = 1.59; u(m/sec) (UL) = 0.57

LOWER LIMIT: 1/8 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.24; Q (g/sec) =0.000125
UPPER LIMIT: 1/4 of the dispersion model; Princeton Correction Factor: 0.6; Molar Fraction: 0.24; Q (g/sec) =0.000125;

Coagulating unstripped latex (reactor control /rubber control laboratory)

Unstripped latex was coagulated in the lab for Mooney samples. The latex with an antioxidant was added to acidified brine and alcohol. The sample was agitated slowly in a blender to make the crumb. Ventilation improvements were made over time. Assume that all the residual BD evaporates during this operation. In 1960 the front lab took over this task (due to the closing of the field lab). The upper and lower limits were calculated based on the theory that the operator had a one in one chance of standing directly in the plume.

Partial TWA = (PPM * Task Duration * Freq/Shift) / # of min. in a work shift
Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input)
C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)
1943-1949 (BD):

1. Assume latex sample is weathered 30-35 minutes after the sample is collected. Only 1-2% of the original BD amount is remaining in the sample. Assume that 30% of the BD is captured by the hood and the remaining BD is released into the lab.
200 ml (sample)= 15.6 g (BD)*0.01= 0.156 g
200 ml (sample)= 15.6 g (BD)*0.02= 0.312 g
Q(lower)= 0.156 g/300 seconds = 0.0005 *0.7= 0.00035 g/sec
Q(upper)= 0.312 g/120 seconds = 0.0026 *0.7= 0.00182 g/sec
2. Assume ventilation rate from hood is approximately 40-50 fpm (0.2-0.25 meters/sec)

Duration of task (min) =2-5; Duration of exposure (min) =2-5; Frequency of exposure =25/shift
D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =0.25; u(m/sec) (UL) =0.2; Q (g/sec) =0.00035

1950-1955 (BD):
1. Sampling frequency decreases (as compared to previous time period).
Frequency of exposure = 4/shift

D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =0.25; u(m/sec) (UL) =0.2

1956-1959 (BD):
1. Sampling frequency increases slightly (as compared to previous time period).

1943-1949 (STY):
1.Assume surface area of blender equals 250 cm2. Temperature of coagulation is approximately 155 degrees F (68 degrees C). The rubber phase accounts for 2/3 of the surface area therefore 250 cm2 is reduced to 1/3 for this task. Assume that 30% of the STY is captured by the hood and the remaining STY is released into the lab. Assume a princeton correction factor of 0.6 and a molar fraction for STY of 0.24 in the rubber phase.

Frequency of exposure = 25/shift

Tg(C) (LL) =68; Tg(C) (UL) =68; A(cm2) (LL) =83; A(cm2) (UL) =83; D(m) (LL) =0.5; D(m) (UL) =0.5;
u(m/sec) (LL) =0.25; u(m/sec) (UL) = 0.2; Q (g/sec) =0.001174

1950-1955 (STY):
1. Frequency of sampling decreases (as compared to previous time periods).

Frequency of exposure = 4/shift

Tg(C) (LL) =68; Tg(C) (UL) =68; A(cm2) (LL) =83; A(cm2) (UL) =83; D(m) (LL) =0.5; D(m) (UL) =0.5;
u(m/sec) (LL) =0.25; u(m/sec) (UL) =0.2

1956-1959 (STY):
1. Sampling frequency increases (as compared to previous time period).

Frequency of exposure =3-4/shift

1960-1985 (BD):
1. Sampling frequency increases slightly (as compared to previous time period).
2. Assume latex sample is weathered 30-35 minutes after the sample is collected. Only 1-2% of the original BD amount is remaining in the sample. Assume that 30% of the BD is captured by the hood and the remaining BD is released into the lab.
200 ml (sample)= 15.6 g (BD)*0.01= 0.156 g; 200 ml (sample)= 15.6 g (BD)*0.02= 0.312 g;Q(lower)= 0.156 g/300 seconds=0.0005 *0.7= 0.00015 g/sec; Q(upper)= 0.312 g/120 seconds=0.0026 *0.7= 0.00078 g/sec
3. Assume ventilation rate from hood is approximately 40-50 fpm (0.2-0.25 meters/sec)

Duration of task (min) = 2-5; Duration of exposure (min) =2-5; Frequency of exposure =3-4/shift

D(m) (LL) = 0.5; D(m) (UL) = 0.5; u(m/sec) (LL) = 0.25; u(m/sec) (UL) = 0.2; Q (g/sec) =0.00015;

1986-1992 (BD):
1. Ventilation improves to 80-100 fpm increasing hood efficiency to 90%.
2. Q(Lower)= 0.156 g/300 seconds= 0.0005*0.10= 0.00005 g/sec
Q(Upper)= 0.312 g/120 seconds= 0.0026*0.10=0.00026 g/sec

D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =0.5; u(m/sec) (UL) =0.4

1960-1985 (STY):
1. Sampling frequency increases slightly (as compared to previous time period).
2.Assume surface area of blender equals 250 cm2. Temperature of coagulation is approximately 155 degrees F (68 degrees C). The rubber phase accounts for 2/3 of the surface area therefore 250 cm2 is reduced to 1/3 for this task. Assume that 30% of the STY is captured by the hood and the remaining STY is released into the lab. Assume a princeton correction factor of 0.6 and a molar fraction for STY of 0.24 in the rubber phase.

Tg(C) (LL) = 68; Tg(C) (UL) =68; A(cm2) (LL) =83; A(cm2) (UL) =83
D(m) (LL) = 0.5; D(m) (UL) =0.5;u(m/sec) (LL) =0.25;u(m/sec) (UL) =0.2

1986-1992 (STY):
1. Ventilation improves to 80-100 fpm (0.4-0.5 m/s) due to installation of a new ventilation system.

2. Hood efficiency increases to 90%.
u(m/sec) (LL) =0.5; u(m/sec) (UL) =0.4

Reactor cleaning (maintenance-unskilled labor)

From 1943-1969, the reactor vessels were opened to allow the vessel to vent before entry. The level of the remaining monomer was checked with a canary. (Birds were use to do safety checks in vessels until the early 1970's). Chipping hammers and butcher knives were used to remove the rubber from the vessel. For each man in the vessel, another person was outside to assist with emptying rubber buckets and to bring necessary tools. The vessels were 9 feet high and 8 feet in diameter. From 1943-1955, hot polymerization was ran in the plant. The estimated amount of coagulum left in thevessel when it was cleaned was 160-320 pounds. The amount of coagulum found in the vessel duringhot polymerization was less than cold polymerization because it did not take a lot of coagulum to have a hot process reactor foul up. The reason for needing reactor cleaning was loss in thermal conductivity. In hot batches, this loss was achieved by a thin layer of polymer stuck to the lining of the reactor. The transition to the cold polymerization process, in 1956, produced an increase in the amount of coagulum found upon opening the reactors. An estimated 500-1,000 pounds was found in the reactors during cold polymerization. From 1943-1959, the ventilation rate inside the reactor was 500 cfm. In 1960, it was improved to 1,000 cfm. In 1970, there was a vacuum pulled on the vessel before entry. Also in 1970, the exposure was decreased by 30-40% due to the use of respirators and hydroblasting the vessel when cleaning the reactor. In 1980, the vessels were steamed before entry and exposure was decreased an additional 10% due to the use of a spray ball on the outside of the vessel to remove the coagulum. For exposure estimation purposes, all of the BD in the rubber was assumed to evaporate in 3-4 shifts. Ninety percent of the STY exposure came from the evaporation of 5-10% of STY in rubber that was removed in one shift- the remaining 10% of exposure was from the release of STY from the rubber that remained in the vessel. The amount of monomers in the rubber (under various conditions) was determined from the mass balance program (from Plant 1).

Partial TWA = (PPM * Task Duration * Freq/Shift) / # of min. in a work shift
Multiple source equation: PPM = 403,000,000 * Q(pt/min) * SG / (Vent. Rate * MW)

1943-1955 (BD):
1. Assume that the vessel is opened and allowed to vent before entry. Hot polymerization. There is
160-320 pounds of coagulum left in the vessel.
2. Princeton adjustment factor=0.47 (for lower estimate only).
3. Pounds of BD = 20-40
4. Shifts to clean = 3- 4
5. Ventilation Rate (cfm)= 500
6. Q(pounds/min)= (pounds monomer*princeton adjustment factor)/(shifts to clean * 480)
7. Q(pints/min)= (pounds monomer per min*454*8)/(specific gravity*3785)
8. Q(lower)= 0.00756 pints/min, Q(upper)= 0.04292 pints/min

Duration of task (min) =240;Duration of exposure (min) =240; Frequency of exposure = 0.17-0.37/shift

LOWER LIMIT: Q (in pints per minute)=0.00756; Ventilation Rate (cfm) =500

1956-1959 (BD):
1. Assume that the vessel is opened and allowed to vent before entry. Cold polymerization. There is
500-1,000 pounds of coagulum left in the vessel.
2. Princeton adjustment factor = 0.47 (for lower estimate only)
3. Pounds of BD = 62-123
4. Shifts to clean =3- 4
5. Q(pounds/min)= (pounds monomer*princeton adjustment factor)/(shifts to clean * 480)
6. Q(pints/min)= (pounds monomer per min*454*8)/(specific gravity*3785)
7. Q(lower)= 0.02345 pints/min, Q(upper)= 0.13199 pints/min

LOWER LIMIT: Q (in pints per minute) =0.02345; Ventilation Rate (cfm) =500

UPPER LIMIT: Q (in pints per minute)=0.13199; Ventilation Rate (cfm)=500

1960-1969 (BD):
1. Assume that the vessel is opened and allowed to vent before entry. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. Ventilation rate improved to 1000 cfm.
2. Ventilation Rate (cfm)=1000

LOWER LIMIT: Q (in pints per minute) =0.02345; Ventilation Rate (cfm) =1000

UPPER LIMIT:
Q (in pints per minute)=0.13199; Ventilation Rate (cfm) =1000

1970-1979 (BD):
1. Assume that the vessel is under 5 psia of vacuum before cleaning. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. The exposure was decreased by 30-40% due to hydroblasting (20-30%) and the use of respirators (10%).
2. Princeton adjustment factor = 0.35 (lower estimate only)
3. Pounds of BD = 11-22
4. Shifts to clean =3- 4
5. Q(pounds/min)= (pounds monomer*princeton adjustment factor)/(shifts to clean * 480)
6. Q(pints/min)= (pounds monomer per min*454*8)/(specific gravity*3785)
7. Q (lower) = 0.003098474 * 0.6 = 0.0018590
Q (upper) =0.023607421 * 0.7 =0.016525

LOWER LIMIT: Q (in pints per minute) =0.001859; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.0165525; Ventilation Rate (cfm) =1000

1980-1992 (BD):
1. Assume that the vessel was under 5 psia of vacuum before cleaning and it is steamed (at 130oF) before entry. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. There is an additional 10% reduction in exposure due to the use of a spray ball on the outside of the vessel to remove the rubber. Total reduction from 1960's is 40-50%.
2. Princeton adjustment factor = 0.2 (for lower estimate only)
3. Pounds of BD = 2-4
4. Shifts to clean =3-4
5. Q(pounds/min)= (pounds monomer*princeton adjustment factor)/(shifts to clean * 480)
6. Q(pints/min)= (pounds monomer per min*454*8)/(specific gravity*3785)
7. Q (lower) = 0.000321919 * 0.5 = 0.00016096
Q (upper) = 0.004292258 * 0.6 = 0.00257535

LOWER LIMIT: Q (in pints per minute) = 0.00016096; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.002575358; Ventilation Rate (cfm) =1000

1943-1955 (STY):
1. Assume that the vessel is opened and allowed to vent before entry. Hot polymerization. There is 160-320 pounds of coagulum left in the vessel. Assume that 5-10% of the STY evaporated in one shift.
2. Pounds of STY = 35-70
3. Shifts to clean =3-4
4. Q(pounds/min)= % evaporated STY/480
5. Q(pints/min)= pounds per min STY*454*8/Specific Gravity*3785
6. Q (lower) = 0.001016167, Q (upper) = 0.005419556

LOWER LIMIT: Q (in pints per minute) =0.001016; Ventilation Rate (cfm) =500

UPPER LIMIT: Q (in pints per minute) =0.005419658; Ventilation Rate (cfm) =500

1956-1959 (STY):
1. Assume that the vessel is opened and allowed to vent before entry. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. There is 110-219 lbs of STY remaining in the vessel. Assume that 5-10% of the STY evaporated in one shift.
2. Pounds of STY =110-219
3. Shifts to clean =3-4
4. Q(pounds/min)= % evaporated STY/480
5. Q(pints/min)= pounds per min STY*454*8/Specific Gravity*3785
6. Q (lower) = 0.003193667, Q (upper) = 0.016955468

LOWER LIMIT: Q (in pints per minute) =0.00319366; Ventilation Rate (cfm) =500

UPPER LIMIT: Q (in pints per minute) =0.016955458; Ventilation Rate (cfm) =500

1960-1969 (STY):
1. Assume that the vessel is opened and allowed to vent before entry. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. There is 110-219 lbs of STY remaining in the vessel. Assume that 5-10% of the STY evaporated in one shift.
2. Ventilation rate improves to 1000 cfm

LOWER LIMIT:Q (in pints per minute) =0.00319366; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.016955458; Ventilation Rate (cfm) =1000

1970-1979 (STY):
1. Assume that the vessel was under 5 psia of vacuum before cleaning. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. Assume that 5-10% of the STY evaporated in one shift. The exposure was decreased by 30-40% due to hydroblasting (20-30%) and the use of respirators (10%).
2. Pounds of STY =109-219
3. Shifts to clean =3-4
4. Q(pounds/min)= % evaporated STY/480
5. Q(pints/min)= pounds per min STY*454*8/Specific Gravity*3785
6. Q (lower) =0.003164634 * 0.6 = 0.001898, Q (upper) = 0.016955468 * 0.7 = 0.0118685

LOWER LIMIT: Q (in pints per minute) =0.00189866; Ventilation Rate (cfm) =1000

UPPER LIMIT:Q (in pints per minute) =0.011868558; Ventilation Rate (cfm) =1000

1980-1992 (STY):
1. Assume that the vessel was under 5 psia of vacuum before cleaning and it is steamed (at 130oF) before entry. Cold polymerization. There is 500-1,000 pounds of coagulum left in the vessel. Assume that 5-10% of the STY evaporated in one shift. There is an additional 10% reduction in exposure due to the use of a spray ball on the outside of the vessel to remove the rubber. Total reduction from 1960's is 40-50%.
2. Pounds of STY = 107-213
3. Shifts to clean =3-4
4. Q(pounds/min)= % evaporated STY/480
5. Q(pints/min)= pounds per min STY*454*8/Specific Gravity*3785
6. Q (lower) = 0.003106567 * 0.5 = 0.0015828, Q (upper) =0.016490934 * 0.6 = 0.00989420

LOWER LIMIT: Q (in pints per minute) =0.0015828; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.009894205; Ventilation Rate (cfm) =1000

Stripping column cleaning (maintenance-unskilled labor)

Recovery operators cleaned the columns during the early 1940's. Columns were flushed with water and steamed, the manways were opened to allow the column to air out. The level of the remaining monomer was checked with a canary. (Birds were use to do safety checks in vessels until the early 1970's). Chipping hammers and butcher knives were used to remove the rubber from the column. For each man in the column, another person was outside to assist with emptying rubber buckets and to bring necessary tools. The columns were 35 feet high and 9 feet in diameter. Each column had 12 trays; the area of each tray was 64 ft2. The mass balance program (from Plant 1) shows that, if the column was steamed, the STY in the top tray of the column was about 1,000-2,000 ppm and the STY was reduced by 39% with each tray.

Partial TWA = (PPM * Task Duration * Freq/Shift) / # of min. in a work shift
Multiple source equation: PPM = 403,000,000 * Q(pt/min) * SG / (Vent. Rate * MW)

1945-1959 (STY):
1. The vessel was always steamed (at 130oF) before entry. There was 1,500 pounds of coagulum left in the vessel. The STY in the top tray of the stripping column was 1,000-2,000 ppm the STY in the coagulum was decreased by 39% with each tray. Assume that 5-10% of the STY evaporated in one shift. 4-5 shifts to clean.
2. Pounds of STY = 1-3
3. Shifts to clean = 4-5
4. Q(pounds/min)= % evaporated STY/480
5. Q(pints/min)= pounds per min STY*454*8/Specific Gravity*3785
6. Q (lower) 3.484E-05, Q (upper) =0.0001742
7. Ventilation Rate (cfm)= 500

Duration of task (min) =240; Duration of exposure (min) =240; Frequency of exposure =0.2-0.43/shift

LOWER LIMIT: Q (in pints per minute) =0.00003484; Ventilation Rate (cfm) =500

UPPER LIMIT: Q (in pints per minute) =0.0001742; Ventilation Rate (cfm) =500

1960-1969 (STY):
1. The vessel was always steamed (at 130oF) before entry. There was 1,500 pounds of coagulum left in the vessel. The STY in the top tray of the stripping column was 1,000-2,000 ppm the STY in the coagulum was decreased by 39% with each tray. Assume that 5-10% of the STY evaporated in one shift. Ventilation rate improved to 1000 cfm.
2. Ventilation Rate (cfm)= 1000

LOWER LIMIT: Q (in pints per minute) =0.00003484; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.0001742; Ventilation Rate (cfm) =1000

1970-1979 (STY):
1. The vessel was always steamed (at 130oF) before entry. There was 1,500 pounds of coagulum left in the vessel. The STY in the top tray of the stripping column was 1,000-2,000 ppm the STY in the coagulum was decreased by 39% with each tray. Assume that 5-10% of the STY evaporated in one shift. The exposure was decreased by 30-40% due to hydroblasting (20-30%) and the use of respirators (10%).
2. Q (lower) =3.484E-05*0.6=0.0000209 pints/min, Q (upper)=0.0001742*0.7=0.00012194 pints/min

LOWER LIMIT: Q (in pints per minute) =0.00003209; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.00012194; Ventilation Rate (cfm) =1000

1980-1992 (STY):

1. The vessel was always steamed (at 130oF) before entry. There was 1,500 pounds of coagulum left in the vessel. The STY in the top tray of the stripping column was 1,000-2,000 ppm the STY in the coagulum was decreased by 39% with each tray. Assume that 5-10% of the STY evaporated in one shift. The exposure was decreased by 30-40% due to hydroblasting (20-30%) and the use of respirators (10%). There was an additional 10% reduction in exposure due to the use of a spray ball on the outside of the vessel to remove the rubber. Total reduction from 1960's is 40-50%.
2. Q(lower)=3.484E-05*0.5=0.0000174, Q(upper)=0.0001742*0.6=0.0001045

LOWER LIMIT:; Q (in pints per minute) =0.000017; Ventilation Rate (cfm) =1000

UPPER LIMIT: Q (in pints per minute) =0.0001045; Ventilation Rate (cfm) =1000

Opening lines, vessels (maintenance-skilled trades)

Pipefitters are responsible for blinding BD an STY vessels and opening lines to pumps, compressors and unstripped latex pumps. The equipment must be blinded and opened in order to make necessary repairs (i.e. change out leaking pumps, etc.). The pipefitter is responsible for opening lines and blinding vessels in the tank farm, the reactor area, and the recovery area. Purging and cleaning procedures were poor from 1943 until 1959. For calculation purposes, it was assumed that 30 ml of BD (or of STY) was in the line when the pipefitter opened it. The time of exposure was 2-5 minutes. The breathing zone of the pipefitter was 1.64 feet (0.5 meters) away from the open pipe. The average wind speed values (lower and upper limit) for this task across all plants was used. In 1960, there was safer work practices and better cleaning of the lines, contributed to a 50% reduction in emissions from the previous period. Again in 1980, safer work practices, and more careful cleaning of the lines resulted in a 50% decrease in emissions from the previous period. The upper and lower limits were calculated based on the theory that the operator had a one in two (or four) chance of standing directly in the plume.

Partial TWA = (PPM * Task Duration * Freq/Shift) / # of min. in a work shift
Point source equations: (Direct input of emission rate)
Q(g/sec) = (user input)
C(ppm) = 1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1959 (BD):
1. Assume that there are 30 ml of BD in the line when it is opened. Assume the duration of exposure is 2 minutes.
Q= 15 ml/min * 0.621g/ml = 9.315g/min = 0.155 g/sec

Duration of task (min) =10-20; Duration of exposure (min) =2-5; Frequency of exposure =4/shift

D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =1.09; u(m/sec) (UL) =0.22
Q (g/sec) =0.155.

Point source equations: (Evaporation from a liquid surface)
V)apor P)ress.=10 ** [p1 - p2 / (T + 235)] / 760
Q(lb/min)=(MW * K * (AREA/929.0304) * VP) /(0.7302 * ((TEMP*9/5)+32) + 460)
Q(g/sec)=(Q(lb/min) * 454) / 60
C(ppm)=1000 * 24.45 * Q(g/sec) / (MW * 0.136 * D**1.84 * u)

1943-1959 (STY):
1. Assume about 30 ml STY in the line while the pipefitter opens it, evaporating from a 500-1000 cm2 area.

Duration of task (min) =10-20; Duration of exposure (min) =2-5; Frequency of exposure =6/shift
Tg(C) (LL) =25; Tg(C) (UL) =25; A(cm2) (LL) =500; A(cm2) (UL) =1000
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.33; u(m/sec) (UL) =0.33; Q (g/sec) =0.006352

1960-1979 (BD):
1. Assume a 50% reduction (from previous period) in the exposure to BD due to safer work practices and better cleaning of lines by operators prior to turning over to maintenance.
Q=15 ml/min*0.621g/ml= 9.315g/min =0.155 g/sec*0.5=0.0775 g/sec

Frequency of exposure =   3/shift

D(m) (LL) =0.5; D(m) (UL) =0.5; u(m/sec) (LL) =1.09; u(m/sec) (UL) =0.22; Q (g/sec) =0.

1960-1979 (STY):
1. Assume a 50% decrease in emissions of STY (due to safer work practices and better cleaning of the lines by operators before turning over to maintenance). Assume about 15 ml STY in the line while the pipefitter opens it, evaporating from a 250-500 cm2 area.

Frequency of exposure =3/shift
Tg(C) (LL) =25; Tg(C) (UL) =25; A(cm2) (LL) =250; A(cm2) (UL) =500
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.33; u(m/sec) (UL) =0.33

1980-1992 (BD):
1. Assume a 50% reduction (from previous period) in the exposure to BD due to safer work practices and better cleaning of lines by operators prior to turning over to maintenance.
Q= 0.0775 g/sec * 0.5 = 0.03875 g/sec

Frequency of exposure =   2/shift; Q (g/sec) =0.03875

1980-1992 (STY):
1. Assume a 2/3 decrease in emissions of STY from previous period (due to better cleaning of the lines by operators before turning over to maintenance). Assume about 10 ml STY in the line while the pipefitter opens it, evaporating from a 166-533 cm2 area.

Frequency of exposure =2/shift
Tg(C) (LL) =25; Tg(C) (UL) =25; A(cm2) (LL) =133; A(cm2) (UL) =333
D(m) (LL) =1; D(m) (UL) =1; u(m/sec) (LL) =1.33; u(m/sec) (UL) = 0.33; Q (g/sec) =0.00169