5/18/90	North Chey	18.7	20.87	2.82	16.0	0.47	2.7
5/18/90	Cloud Peak	18.6	20.86	2.88	16.4	0.39	2.2
5/20/90	Devil's To	14.7	27.60	2.50	10.4	1.04	4.3
5/23/90	North Chey	19.0	20.93	2.82	16.0	0.53	3.0
5/27/90	Badlands N	12.1	26.98	0.00	0.0	2.91	12.1
5/28/90	North Chey	27.5	22.42	3.50	19.9	1.34	7.6
5/28/90	Cloud Peak	29.8	22.82	4.76	27.1	0.48	2.7
5/29/90	Cloud Peak	16.1	20.41	2.80	15.9	0.03	0.2
5/30/90	North Chey	12.3	19.73	2.12	12.0	0.04	0.2
6/ 5/90	Badlands N	10.3	26.39	1.87	7.8	0.59	2.5
6/14/90	Cloud Peak	11.0	20.95	1.72	9.1	0.36	1.9
6/15/90	North Chey	14.7	21.64	2.18	11.5	0.59	3.1
6/15/90	Cloud Peak	16.4	21.96	2.40	12.7	0.69	3.7
6/16/90	Devil's To	15.1	27.53	3.16	13.2	0.44	1.9
6/29/90	Devil's To	11.0	26.56	2.36	9.9	0.27	1.1
6/30/90	Cloud Peak	14.4	21.59	2.65	14.1	0.07	0.4
7/ 5/90	Cloud Peak	14.5	21.61	2.45	13.0	0.29	1.5
7/ 9/90	North Chey	13.8	21.47	2.30	12.2	0.29	1.6
7/24/90	North Chey	17.3	22.13	3.25	17.2	0.01	0.0
8/ 1/90	Devil's To	10.5	26.43	2.50	10.4	0.01	0.0
8/ 4/90	Cloud Peak	16.1	21.91	3.02	16.0	0.02	0.1
8/ 6/90	North Chey	11.4	21.02	2.08	11.0	0.07	0.4
8/ 7/90	Devil's To	12.9	27.00	3.05	12.7	0.03	0.1
8/16/90	North Chey	10.5	20.86	1.94	10.3	0.05	0.2
8/21/90	North Chey	10.5	20.86	1.95	10.4	0.03	0.2
8/26/90	Cloud Peak	10.6	20.87	2.00	10.6	0.00	0.0
9/17/90	North Chey	10.6	17.98	1.70	10.5	0.02	0.1
9/19/90	North Chey	24.4	20.23	3.50	21.5	0.47	2.9
9/19/90	Cloud Peak	11.1	18.06	1.55	9.5	0.26	1.6
9/21/90	Blackelk W	12.2	24.66	2.68	12.2	0.01	0.0
9/21/90	Mt. Rushmo	11.6	24.51	2.53	11.5	0.01	0.0
9/21/90	Wind Cave	12.7	24.76	2.77	12.6	0.02	0.1
9/21/90	Jewel Cave	10.5	24.28	2.29	10.4	0.02	0.1
9/23/90	Devil's To	15.3	25.33	3.33	15.2	0.03	0.1
9/24/90	Devil's To	13.7	24.99	3.02	13.7	0.00	0.0
9/25/90	Devil's To	13.6	24.96	2.99	13.6	0.00	0.0
9/26/90	Devil's To	15.5	25.38	3.41	15.5	0.00	0.0
9/30/90	Blackelk W	10.0	24.18	1.57	7.2	0.63	2.9
9/30/90	Wind Cave	12.4	24.69	2.14	9.7	0.59	2.7
9/30/90	Jewel Cave	14.1	25.07	2.53	11.5	0.57	2.6
9/30/90	Devil's To	14.0	25.05	2.85	13.0	0.23	1.0
10/ 8/90	Devil's To	11.9	24.59	2.28	10.4	0.33	1.5
10/ 9/90	Blackelk W	19.0	26.14	3.97	18.1	0.20	0.9
10/ 9/90	Mt. Rushmo	18.6	26.05	3.90	17.8	0.18	0.8
10/ 9/90	Wind Cave	15.2	25.31	3.10	14.1	0.24	1.1
10/ 9/90	Jewel Cave	19.4	26.23	4.13	18.8	0.14	0.6
10/ 9/90	Devil's To	10.9	24.37	2.39	10.9	0.00	0.0
10/10/90	Blackelk W	13.3	24.89	2.85	13.0	0.07	0.3
10/10/90	Mt. Rushmo	11.3	24.45	2.39	10.9	0.09	0.4
10/10/90	Devil's To	12.0	24.61	2.64	12.0	0.00	0.0
10/13/90	Wind Cave	11.3	24.45	1.92	8.7	0.55	2.5
10/13/90	Jewel Cave	12.0	24.60	2.23	10.1	0.40	1.8
10/13/90	Devil's To	11.1	24.41	2.44	11.1	0.00	0.0
10/16/90	Devil's To	15.4	25.36	3.26	14.8	0.13	0.6
10/21/90	Blackelk W	12.9	24.81	2.77	12.6	0.07	0.3
10/21/90	Wind Cave	15.2	25.32	3.28	14.9	0.07	0.3
10/21/90	Jewel Cave	20.5	26.47	4.43	20.2	0.07	0.3

10/24/90	Devil's To	18.3	26.00	3.96	18.0	0.07	0.3
10/25/90	Jewel Cave	13.6	24.97	2.93	13.3	0.06	0.3
10/25/90	Devil's To	15.5	25.37	3.39	15.4	0.01	0.1
10/29/90	Badlands N	10.4	24.25	1.56	7.1	0.71	3.2
10/29/90	Blackelk W	13.7	24.97	2.64	12.0	0.36	1.6
10/29/90	Mt. Rushmo	13.0	24.83	2.51	11.4	0.35	1.6
10/29/90	Wind Cave	12.2	24.66	2.23	10.2	0.45	2.1
10/29/90	Jewel Cave	14.1	25.06	2.64	12.0	0.45	2.1
10/29/90	Devil's To	11.1	24.40	2.38	10.8	0.05	0.2
10/30/90	Devil's To	15.8	25.43	3.27	14.9	0.19	0.9
11/ 4/90	Badlands N	10.2	24.21	1.44	6.5	0.81	3.7
11/ 4/90	Blackelk W	11.0	24.38	1.86	8.5	0.55	2.5
11/ 4/90	Mt. Rushmo	10.9	24.37	1.85	8.4	0.55	2.5
11/ 4/90	Devil's To	22.8	26.99	4.77	21.7	0.25	1.1
11/ 5/90	Badlands N	12.7	24.76	2.17	9.9	0.62	2.8
11/ 5/90	Blackelk W	12.8	24.79	2.44	11.1	0.38	1.7
11/ 5/90	Mt. Rushmo	12.4	24.70	2.31	10.5	0.42	1.9
11/ 5/90	Wind Cave	15.5	25.38	3.08	14.0	0.32	1.5
11/ 5/90	Jewel Cave	16.1	25.50	3.30	15.0	0.22	1.0
11/ 7/90	Devil's To	13.3	24.88	2.83	12.9	0.08	0.4
11/ 9/90	Devil's To	10.6	24.29	2.32	10.5	0.00	0.0
11/12/90	Devil's To	13.6	24.95	2.98	13.5	0.01	0.0
11/15/90	Jewel Cave	13.4	24.90	2.93	13.3	0.01	0.0
11/16/90	Wind Cave	10.7	24.31	2.29	10.4	0.06	0.3
11/16/90	Jewel Cave	11.9	24.58	2.56	11.6	0.05	0.2
11/16/90	Devil's To	11.0	24.39	2.36	10.8	0.06	0.3
11/18/90	Wind Cave	12.1	24.62	2.46	11.2	0.19	0.9
11/18/90	Jewel Cave	15.1	25.28	3.12	14.2	0.19	0.9
11/18/90	Devil's To	20.7	26.53	4.33	19.7	0.22	1.0
11/19/90	Badlands N	13.2	24.86	0.48	2.2	2.41	11.0
11/19/90	Devil's To	42.8	31.37	8.58	39.1	0.82	3.7
11/25/90	Devil's To	25.5	27.57	5.49	25.0	0.11	0.5
11/27/90	Wind Cave	10.2	24.20	1.85	8.4	0.39	1.8
11/27/90	Jewel Cave	10.7	24.32	2.06	9.4	0.28	1.3
12/ 4/90	Devil's To	11.0	23.59	2.34	11.0	0.00	0.0
12/ 6/90	Jewel Cave	10.7	23.53	2.21	10.4	0.07	0.3
12/ 8/90	Devil's To	26.2	26.82	5.53	26.0	0.04	0.2
12/ 9/90	Devil's To	17.2	24.91	3.61	17.0	0.05	0.2
12/10/90	Blackelk W	10.6	23.50	2.03	9.5	0.23	1.1
12/10/90	Mt. Rushmo	10.3	23.44	1.97	9.3	0.22	1.1
12/10/90	Devil's To	14.8	24.40	3.08	14.5	0.08	0.4
12/11/90	Badlands N	29.1	27.44	3.17	14.9	3.02	14.2
12/11/90	Blackelk W	19.5	25.38	3.20	15.0	0.94	4.4
12/11/90	Mt. Rushmo	19.5	25.38	3.20	15.0	0.94	4.4
12/11/90	Wind Cave	20.7	25.65	3.31	15.6	1.09	5.1
12/11/90	Jewel Cave	15.4	24.51	2.63	12.4	0.63	3.0
12/11/90	Devil's To	21.4	25.79	4.46	21.0	0.08	0.4
12/13/90	Devil's To	10.2	23.41	1.92	9.0	0.25	1.2
12/17/90	Badlands N	12.4	23.88	1.06	5.0	1.57	7.4
12/17/90	Blackelk W	14.3	24.29	2.41	11.3	0.64	3.0
12/17/90	Mt. Rushmo	14.1	24.25	2.31	10.9	0.69	3.3
12/17/90	Jewel Cave	12.0	23.80	2.23	10.5	0.32	1.5
12/17/90	Devil's To	17.8	25.03	3.70	17.4	0.08	0.4
12/22/90	Badlands N	13.7	24.16	1.82	8.6	1.10	5.2
12/22/90	Blackelk W	17.7	25.00	2.94	13.8	0.81	3.8
12/22/90	Mt. Rushmo	17.7	25.00	2.95	13.9	0.80	3.8
12/22/90	Wind Cave	13.8	24.18	2.29	10.8	0.64	3.0

12/22/90	Jewel Cave	17.3	24.92	3.09	14.6	0.57	2.7
12/22/90	Devil's To	12.1	23.81	2.56	12.1	0.01	0.0
12/25/90	Badlands N	12.6	23.92	1.63	7.7	1.05	4.9
12/26/90	Badlands N	26.5	26.88	3.67	17.3	1.96	9.2
12/26/90	Blackelk W	18.2	25.12	2.97	14.0	0.91	4.3
12/26/90	Mt. Rushmo	18.2	25.11	2.94	13.8	0.92	4.3
12/26/90	Wind Cave	19.8	25.46	3.62	17.0	0.60	2.8
12/26/90	Jewel Cave	17.8	25.04	3.36	15.8	0.43	2.0
12/26/90	Devil's To	28.5	27.30	5.78	27.2	0.27	1.3

EXHIBIT A

Example CALMET Input Control File for a January CALMET Simulation and the PRBEP DM&E Railway Expansion Project

Exhibit A. Example CALMET input control file for a January CALMET simulation and the PRBEP DM&E railway expansion project.

```
PRBEP DM&E Railway
MM4: January 1990 Initial Guess
134 X 94 Points (5 km Grid Spacing) 5 Surface/2 Upper Air Stations
---------------- Run title (3 lines) ------------------------------------------
--

                    CALMET MODEL CONTROL FILE
                    --------------------------

------------------------------------------------------------------------------
--

INPUT GROUP: 0 -- Input and Output File Names


Subgroup (a)
------------
Default Name  Type          File Name
------------  ----          ---------
GEO.DAT       input    ! GEODAT=/disk22/calmet/geowyo.dat       !
SURF.DAT      input    ! SRFDAT=/disk22/calmet/surf.dat      !
CLOUD.DAT     input    * CLDDAT=              *
PRECIP.DAT    input    ! PRCDAT=/disk22/calmet/precip.dat    !
MM4.DAT       input    ! MM4DAT=/disk22/calmet/jandec90.dat    !
WT.DAT        input    * WTDAT=               *

CALMET.LST    output   ! METLST=/tmp/CALMET1.LST     !
CALMET.DAT    output   ! METDAT=/tmp/CALMET1.DAT     !
PACOUT.DAT    output   * PACDAT=              *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

    Number of upper air stations (NUSTA)  No default     ! NUSTA =  2  !
    Number of overwater met stations
                                 (NOWSTA) No default     ! NOWSTA =  0  !

                         !END!
------------------------------------------------------------------------------
---
Subgroup (b)
---------------------------------
Upper air files (one per station)
---------------------------------
Default Name  Type       File Name
------------  ----       ---------
UP1.DAT       input     1  ! UPDAT=/disk22/calmet/up1.dat !    !END!
UP2.DAT       input     2  ! UPDAT=/disk22/calmet/up2.dat !    !END!
------------------------------------------------------------------------------
---
Subgroup (c)
-----------------------------------------
```

```
Overwater station files (one per station)
------------------------------------------
Default Name  Type        File Name
------------  ----        ---------
------------------------------------------------------------------------------
---
Subgroup (d)
----------------
Other file names
----------------

Default Name  Type        File Name
------------  ----        ---------
DIAG.DAT      input       * DIADAT=                 *
PROG.DAT      input       * PRGDAT=                 *

TEST.PRT      output      * TSTPRT=                 *
TEST.OUT      output      * TSTOUT=                 *
TEST.KIN      output      * TSTKIN=                 *
TEST.FRD      output      * TSTFRD=                 *
TEST.SLP      output      * TSTSLP=                 *

------------------------------------------------------------------------------
---
NOTES: (1) File/path names can be up to 70 characters in length
       (2) Subgroups (a) and (d) must have ONE 'END' (surround by
           delimiters) at the end of the group
       (3) Subgroups (b) and (c) must have an 'END' (surround by
           delimiters) at the end of EACH LINE

                        !END!


------------------------------------------------------------------------------
--

INPUT GROUP: 1 -- General run control parameters
--------------

     Starting date:   Year (IBYR) -- No default       ! IBYR=  90  !
                     Month (IBMO) -- No default       ! IBMO=  1  !
                       Day (IBDY) -- No default       ! IBDY=  5  !
                      Hour (IBHR) -- No default       ! IBHR=  5  !

     Base time zone        (IBTZ) -- No default       ! IBTZ=  7  !
        PST = 08, MST = 07
        CST = 06, EST = 05

     Length of run (hours) (IRLG) -- No default       ! IRLG=  644  !

     Run type            (IRTYPE) -- Default: 1       ! IRTYPE=  1  !

        0 = Computes wind fields only
        1 = Computes wind fields and micrometeorological variables
            (u*, w*, L, zi, etc.)
        (IRTYPE must be 1 to run CALPUFF or CALGRID)

     Compute special data fields required
     by CALGRID (i.e., 3-D fields of W wind
     components and temperature)
```

```
     in additional to regular          Default: T     ! LCALGRD = F !
     fields ? (LCALGRD)
     (LCALGRD must be T to run CALGRID)

      Flag to stop run after
      SETUP phase (ITEST)           Default: 2        ! ITEST=  2   !
      (Used to allow checking
      of the model inputs, files, etc.)
      ITEST = 1 - STOPS program after SETUP phase
      ITEST = 2 - Continues with execution of
                  COMPUTATIONAL phase after SETUP

!END!

--------------------------------------------------------------------------------
--

INPUT GROUP: 2 -- Grid control parameters
--------------

     HORIZONTAL GRID DEFINITION:

            No. X grid cells (NX)      No default      ! NX =   134  !
            No. Y grid cells (NY)      No default      ! NY =   94  !

     GRID SPACING (DGRIDKM)            No default      ! DGRIDKM = 5. !
                                       Units: km

     REFERENCE COORDINATES
     of SOUTHWEST corner of grid cell (1,1)

        X coordinate (XORIGKM)         No default      ! XORIGKM = -350.000 !
        Y coordinate (YORIGKM)         No default      ! YORIGKM = -250.000 !
                                       Units: km
        Latitude  (XLAT0)              No default      ! XLAT0 = 41.586 !
        Longitude (XLON0)              No default      ! XLON0 = 109.350 !

     UTM ZONE (IUTMZN)                 Default: 0      ! IUTMZN =  13  !

     LAMBERT CONFORMAL PARAMETERS

     Rotate input winds from true north to
     map north using a Lambert conformal
     projection? (LLCONF)              Default: F      ! LLCONF = T !

     Latitude of 1st standard parallel   Default: 30.    ! XLAT1 = 30.000 !
     Latitude of 2nd standard parallel   Default: 60.    ! XLAT2 = 60.000 !
     (XLAT1 and XLAT2; + in NH, - in SH)

        Longitude (RLON0)                Default = 90.   ! RLON0 = 105.000 !
        (used only if LLCONF = T)
        (Positive = W. Hemisphere;
         Negative = E. Hemisphere)
        Origin Latitude (RLAT0)          Default = 40.   ! RLAT0 = 44.000 !
        (used only if IPROG > 2)
        (Positive = N. Hemisphere;
         Negative = S. Hemisphere)

     Vertical grid definition:
```

```
        No. of vertical layers (NZ)    No default     ! NZ =  8  !

        Cell face heights in arbitrary
        vertical grid (ZFACE(NZ+1))    No defaults
                                       Units: m
        ! ZFACE = 0.,20.,50.,100.,250.,500.,750.,1000.,3000. !

!END!

-------------------------------------------------------------------------------
--

INPUT GROUP: 3 -- Output Options
--------------

   DISK OUTPUT OPTION

      Save met. fields in an unformatted
      output file ?              (LSAVE)  Default: T     ! LSAVE = T !
      (F = Do not save, T = Save)

      Type of unformatted output file:
      (IFORMO)                            Default: 1    ! IFORMO =  1  !

           1 = CALPUFF/CALGRID type file (CALMET.DAT)
           2 = MESOPUFF-II type file     (PACOUT.DAT)


   LINE PRINTER OUTPUT OPTIONS:

      Print met. fields ?  (LPRINT)       Default: F     ! LPRINT = T !
      (F = Do not print, T = Print)
      (NOTE: parameters below control which
             met. variables are printed)

      Print interval
      (IPRINF) in hours                   Default: 1     ! IPRINF =  24  !
      (Meteorological fields are printed
       every  24  hours)


      Specify which layers of U, V wind component
      to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
      (0=Do not print, 1=Print)
      (used only if LPRINT=T)         Defaults: NZ*0
      ! IUVOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !
      -----------------------


      Specify which levels of the W wind component to print
      (NOTE: W defined at TOP cell face --  8  values)
      (IWOUT(NZ)) -- NOTE: NZ values must be entered
      (0=Do not print, 1=Print)
      (used only if LPRINT=T & LCALGRD=T)
      -----------------------------------
                                          Defaults: NZ*0
       ! IWOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !
```

```
Specify which levels of the 3-D temperature field to print
(ITOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print)
(used only if LPRINT=T & LCALGRD=T)
-----------------------------------
                                      Defaults: NZ*0
 ! ITOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !

Specify which meteorological fields
to print
(used only if LPRINT=T)               Defaults: 0 (all variables)
-----------------------


  Variable            Print ?
                  (0 = do not print,
                   1 = print)
  --------        ------------------

!  STABILITY  =          0           ! - PGT stability class
!  USTAR      =          0           ! - Friction velocity
!  MONIN      =          0           ! - Monin-Obukhov length
!  MIXHT      =          0           ! - Mixing height
!  WSTAR      =          0           ! - Convective velocity scale
!  PRECIP     =          0           ! - Precipitation rate
!  SENSHEAT   =          0           ! - Sensible heat flux
!  CONVZI     =          0           ! - Convective mixing ht.


Testing and debug print options for micrometeorological module

   Print input meteorological data and
   internal variables (LDB)          Default: F       ! LDB = F !
   (F = Do not print, T = print)
   (NOTE: this option produces large amounts of output)

   First time step for which debug data
   are printed (NN1)                 Default: 1       ! NN1 =  1  !

   Last time step for which debug data
   are printed (NN2)                 Default: 1       ! NN2 =  24  !


Testing and debug print options for wind field module
(all of the following print options control output to
 wind field module's output files: TEST.PRT, TEST.OUT,
 TEST.KIN, TEST.FRD, and TEST.SLP)

   Control variable for writing the test/debug
   wind fields to disk files (IOUTD)
   (0=Do not write, 1=write)         Default: 0       ! IOUTD =  0  !

   Number of levels, starting at the surface,
   to print (NZPRN2)                 Default: 1       ! NZPRN2 =  0  !

   Print the INTERPOLATED wind components ?
   (IPR0) (0=no, 1=yes)              Default: 0       !  IPR0 =  0  !

   Print the TERRAIN ADJUSTED surface wind
```

```
        components ?
        (IPR1) (0=no, 1=yes)              Default: 0        !  IPR1 =  0  !

        Print the SMOOTHED wind components and
        the INITIAL DIVERGENCE fields ?
        (IPR2) (0=no, 1=yes)              Default: 0        !  IPR2 =  0  !

        Print the FINAL wind speed and direction
        fields ?
        (IPR3) (0=no, 1=yes)              Default: 0        !  IPR3 =  0  !

        Print the FINAL DIVERGENCE fields ?
        (IPR4) (0=no, 1=yes)              Default: 0        !  IPR4 =  0  !

        Print the winds after KINEMATIC effects
        are added ?
        (IPR5) (0=no, 1=yes)              Default: 0        !  IPR5 =  0  !

        Print the winds after the FROUDE NUMBER
        adjustment is made ?
        (IPR6) (0=no, 1=yes)              Default: 0        !  IPR6 =  0  !

        Print the winds after SLOPE FLOWS
        are added ?
        (IPR7) (0=no, 1=yes)              Default: 0        !  IPR7 =  0  !

        Print the FINAL wind field components ?
        (IPR8) (0=no, 1=yes)              Default: 0        !  IPR8 =  0  !

!END!


------------------------------------------------------------------------------
--

INPUT GROUP: 4 -- Meteorological data options
--------------


    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA =  5  !
       Number of precipitation stations
                                    (NPSTA)  No default     ! NPSTA =  4  !

    CLOUD DATA OPTIONS
       Griddid cloud fields:
                                   (ICLOUD)  Default: 0     ! ICLOUD =  0  !
       ICLOUD = 0 - Gridded clouds not used
       ICLOUD = 1 - Gridded CLOUD.DAT generated as OUTPUT
       ICLOUD = 2 - Gridded CLOUD.DAT read as INPUT

    FILE FORMATS

       Surface meteorological data file format
                                   (IFORMS)  Default: 2     ! IFORMS =  2  !
       (1 = unformatted (e.g., SMERGE output))
       (2 = formatted   (free-formatted user input))

       Precipitation data file format
```

```
                               (IFORMP)  Default: 2     ! IFORMP =  2  !
     (1 = unformatted (e.g., PMERGE output))
     (2 = formatted   (free-formatted user input))

     Cloud data file format
                               (IFORMC)  Default: 2     ! IFORMC =  1  !
     (1 = unformatted - CALMET unformatted output)
     (2 = formatted   - free-formatted CALMET output or user input)

!END!


-------------------------------------------------------------------------------
--

INPUT GROUP: 5 -- Wind Field Options and Parameters
--------------


   WIND FIELD MODEL OPTIONS
     Model selection variable (IWFCOD)     Default: 1      ! IWFCOD =  1  !
        0 = Objective analysis only
        1 = Diagnostic wind module

     Compute Froude number adjustment
     effects ? (IFRADJ)                    Default: 1      ! IFRADJ =  1  !
     (0 = NO, 1 = YES)

     Compute kinematic effects ? (IKINE)   Default: 1      ! IKINE  =  1  !
     (0 = NO, 1 = YES)

     Use O'Brien procedure for adjustment
     of the vertical velocity ? (IOBR)     Default: 0      ! IOBR =  0  !
     (0 = NO, 1 = YES)

     Compute slope flow effects ? (ISLOPE) Default: 1      ! ISLOPE  =  1
!
     (0 = NO, 1 = YES)

     Extrapolate surface wind observations
     to upper layers ? (IEXTRP)            Default: -4     ! IEXTRP =  1  !
     (1 = no extrapolation is done,
      2 = power law extrapolation used,
      3 = user input multiplicative factors
          for layers 2 - NZ used (see FEXTRP array)
      4 = similarity theory used
     -1, -2, -3, -4 = same as above except layer 1 data
          at upper air stations are ignored

     Extrapolate surface winds even
     if calm? (ICALM)                      Default: 0      ! ICALM  =  0  !
     (0 = NO, 1 = YES)

     Layer-dependent biases modifying the weights of
     surface and upper air stations (BIAS(NZ))
       -1<=BIAS<=1
     Negative BIAS reduces the weight of upper air stations
       (e.g. BIAS=-0.1 reduces the weight of upper air stations
     by 10%; BIAS= -1, reduces their weight by 100 %)
     Positive BIAS reduces the weight of surface stations
```

```
  (e.g. BIAS= 0.2 reduces the weight of surface stations
by 20%; BIAS=1 reduces their weight by 100%)
Zero BIAS leaves weights unchanged (1/R**2 interpolation)
Default: NZ*0
                       ! BIAS = -1 , -.25 ,  0 ,  0 ,  0 ,  0 ,  0 ,
0  !

Minimum distance from nearest upper air station
to surface station for which extrapolation
of surface winds at surface station will be allowed
(RMIN2: Set to -1 for IEXTRP = 4 or other situations
 where all surface stations should be extrapolated)
                                        Default: 4.    ! RMIN2 = 1.0 !

Use gridded prognostic wind field model
output fields as input to the diagnostic
wind field model (IPROG)                Default: 0     ! IPROG =  4  !
(0 = No, [IWFCOD = 0 or 1]
 1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
 2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
 3 = Yes, usr MM4 prog. winds as Step 1 field [IWFCOD = 0]
 4 = Yes, use MM4 prog. winds as initial guess field [IWFCOD = 1]
 5 = Yes, use MM4 prog. winds as observations [IWFCOD = 1]

RADIUS OF INFLUENCE PARAMETERS

Use varying radius of influence         Default: F     ! LVARY =  T!
(if no stations are found within RMAX1,RMAX2,
 or RMAX3, then the closest station will be used)

Maximum radius of influence over land
in the surface layer (RMAX1)            No default     ! RMAX1 = 10. !
                                        Units: km
Maximum radius of influence over land
aloft (RMAX2)                           No default     ! RMAX2 = 50. !
                                        Units: km
Maximum radius of influence over water
(RMAX3)                                 No default     ! RMAX3 = 500. !
                                        Units: km


OTHER WIND FIELD INPUT PARAMETERS

Minimum radius of influence used in
the wind field interpolation (RMIN)     Default: 0.1   ! RMIN = 0.1 !
                                        Units: km
Radius of influence of terrain
features (TERRAD)                       No default     ! TERRAD = 10. !

                                        Units: km
Relative weighting of the first
guess field and observations in the
SURFACE layer (R1)                      No default     ! R1 = 10. !
(R1 is the distance from an             Units: km
observational station at which the
observation and first guess field are
equally weighted)

Relative weighting of the first
guess field and observations in the
```

```
        layers ALOFT (R2)                      No default      ! R2 = 25. !
        (R2 is applied in the upper layers     Units: km
        in the same manner as R1 is used in
        the surface layer).

        Relative weighting parameter of the
        prognostic wind field data (RPROG)     No default      ! RPROG = 0. !
        (Used only if IPROG = 1)               Units: km
        ------------------------

        Maximum acceptable divergence in the
        divergence minimization procedure
        (DIVLIM)                               Default: 5.E-6  ! DIVLIM= 5.0E-
06 !

        Maximum number of iterations in the
        divergence min. procedure (NITER)      Default: 50     ! NITER =  1  !

        Number of passes in the smoothing
        procedure (NSMTH(NZ))
        NOTE: NZ values must be entered
             Default: 2,(mxnz-1)*4 ! NSMTH =
 1 ,  1 ,  1 ,  1 ,  1 ,  1 ,  1 ,  1  !

        Maximum number of stations used in
        each layer for the interpolation of
        data to a grid point (NINTR2(NZ))
        NOTE: NZ values must be entered        Default: 99.    ! NINTR2 =
 3 ,  3 ,  3 ,  3 ,  3 ,  3 ,  3 ,  3  !

        Critical Froude number (CRITFN)        Default: 1.0    ! CRITFN = 1. !

        Empirical factor controlling the
        influence of kinematic effects
        (ALPHA)                                Default: 0.1    ! ALPHA = 0.1 !

        Multiplicative scaling factor for
        extrapolation of surface observations
        to upper layers (FEXTR2(NZ))           Default: NZ*0.0
        ! FEXTR2 = 0., 0., 0., 0., 0., 0., 0., 0. !
        (Used only if IEXTRP = 3 or -3)


     BARRIER INFORMATION

        Number of barriers to interpolation
        of the wind fields (NBAR)              Default: 0      ! NBAR =  0  !

        THE FOLLOWING 4 VARIABLES ARE INCLUDED
        ONLY IF NBAR > 0
        NOTE: NBAR values must be entered      No defaults
              for each variable                Units: km

           X coordinate of BEGINNING
           of each barrier (XBBAR(NBAR))       ! XBBAR = 0. !
           Y coordinate of BEGINNING
           of each barrier (YBBAR(NBAR))       ! YBBAR = 0. !

           X coordinate of ENDING
           of each barrier (XEBAR(NBAR))       ! XEBAR = 0. !
```

```
      Y coordinate of ENDING
      of each barrier (YEBAR(NBAR))      ! YEBAR = 0. !


  DIAGNOSTIC MODULE DATA INPUT OPTIONS

     Surface temperature (IDIOPT1)        Default: 0       ! IDIOPT1 =  0
!
        0 = Compute internally from
            hourly surface observations
        1 = Read preprocessed values from
            a data file (DIAG.DAT)

        Surface met. station to use for
        the surface temperature (ISURFT)   No default      ! ISURFT =  1  !
        (Must be a value from 1 to NSSTA)
        (Used only if IDIOPT1 = 0)
        --------------------------

     Domain-averaged temperature lapse
     rate (IDIOPT2)                       Default: 0      ! IDIOPT2 =  0  !
        0 = Compute internally from
            twice-daily upper air observations
        1 = Read hourly preprocessed values
            from a data file (DIAG.DAT)

        Upper air station to use for
        the domain-scale lapse rate (IUPT) No default      ! IUPT   =  1  !
        (Must be a value from 1 to NUSTA)
        (Used only if IDIOPT2 = 0)
        --------------------------

        Depth through which the domain-scale
        lapse rate is computed (ZUPT)      Default: 200.  ! ZUPT = 200. !
        (Used only if IDIOPT2 = 0)         Units: meters
        --------------------------

     Domain-averaged wind components
     (IDIOPT3)                            Default: 0      ! IDIOPT3 =  0  !
        0 = Compute internally from
            twice-daily upper air observations
        1 = Read hourly preprocessed values
            a data file (DIAG.DAT)

        Upper air station to use for
        the domain-scale winds (IUPWND)    Default: -1     ! IUPWND = -1  !
        (Must be a value from -1 to NUSTA)
        (Used only if IDIOPT3 = 0)
        --------------------------

        Bottom and top of layer through
        which the domain-scale winds
        are computed
        (ZUPWND(1), ZUPWND(2))        Defaults: 1., 1000. ! ZUPWND= 1.,
1500. !
        (Used only if IDIOPT3 = 0)    Units: meters
        --------------------------

     Observed surface wind components
     for wind field module (IDIOPT4)  Default: 0     ! IDIOPT4 =  0  !
```

```
   0 = Read WS, WD from a surface
       data file (SURF.DAT)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)

Observed upper air wind components
for wind field module (IDIOPT5)  Default: 0     ! IDIOPT5 =  0  !
   0 = Read WS, WD from an upper
       air data file (UP1.DAT, UP2.DAT, etc.)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)

LAKE BREEZE INFORMATION

   Use Lake Breeze Module  (LLBREZE)
                                    Default: F      ! LLBREZE = F !

    Number of lake breeze regions (NBOX)            ! NBOX =  0   !

  X Grid line 1 defining the region of interest
                                                ! XG1 = 0. !
  X Grid line 2 defining the region of interest
                                                ! XG2 = 0. !
  Y Grid line 1 defining the region of interest
                                                ! YG1 = 0. !
  Y Grid line 2 defining the region of interest
                                                ! YG2 = 0. !

   X Point defining the coastline (Straight line)
            (XBCST)  (KM)   Default: none    ! XBCST = 0. !

   Y Point defining the coastline (Straight line)
            (YBCST)  (KM)   Default: none    ! YBCST = 0. !

   X Point defining the coastline (Straight line)
            (XECST)  (KM)   Default: none    ! XECST = 0. !

   Y Point defining the coastline (Straight line)
            (YECST)  (KM)   Default: none    ! YECST = 0. !


Number of stations in the region     Default: none  NLB = *1 *
(Surface stations + upper air stations)

Station ID's  in the region   (METBXID(NLB))
(Surface stations first, then upper air stations)
   METBXID = *0 *

!END!


-------------------------------------------------------------------------------
--

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
--------------

    EMPIRICAL MIXING HEIGHT CONSTANTS

       Neutral, mechanical equation
```

(CONSTB)	Default: 1.41	! CONSTB = 1.41
!		
Convective mixing ht. equation (CONSTE)	Default: 0.15	! CONSTE = 0.15
!		
Stable mixing ht. equation (CONSTN)	Default: 2400.	! CONSTN =
2400.!		
Overwater mixing ht. equation (CONSTW)	Default: 0.16	! CONSTW = 0.16
!		
Absolute value of Coriolis parameter (FCORIOL)	Default: 1.E-4	! FCORIOL =
1.0E-04!	Units: (1/s)	

SPATIAL AVERAGING OF MIXING HEIGHTS

Conduct spatial averaging (IAVEZI) (0=no, 1=yes)	Default: 1	! IAVEZI = 1 !
Max. search radius in averaging process (MNMDAV)	Default: 1 Units: Grid cells	! MNMDAV = 1 !
Half-angle of upwind looking cone for averaging (HAFANG)	Default: 30. Units: deg.	! HAFANG = 30. !
Layer of winds used in upwind averaging (ILEVZI) (must be between 1 and NZ)	Default: 1	! ILEVZI = 6 !

OTHER MIXING HEIGHT VARIABLES

Minimum potential temperature lapse rate in the stable layer above the current convective mixing ht.	Default: 0.001	! DPTMIN = 0.001
!		
(DPTMIN)	Units: deg. K/m	
Depth of layer above current conv. mixing height through which lapse rate is computed (DZZI)	Default: 200. Units: meters	! DZZI = 200. !
Minimum overland mixing height (ZIMIN)	Default: 50. Units: meters	! ZIMIN = 50. !
Maximum overland mixing height	Default: 3000.	! ZIMAX = 3000.
!		
(ZIMAX)	Units: meters	
Minimum overwater mixing height	Default: 50.	! ZIMINW = 100.
!		
(ZIMINW) -- (Not used if observed overwater mixing hts. are used)	Units: meters	
Maximum overwater mixing height	Default: 3000.	! ZIMAXW = 3000.
!		
(ZIMAXW) -- (Not used if observed overwater mixing hts. are used)	Units: meters	

TEMPERATURE PARAMETERS

```
      Interpolation type
      (1 = 1/R ; 2 = 1/R**2)                 Default:1           ! IRAD =  1  !

      Radius of influence for temperature
      interpolation (TRADKM)                 Default: 500.       ! TRADKM =
100. !
                                             Units: km

      Maximum Number of stations to include
      in temperature interpolation (NUMTS)  Default: 5          ! NUMTS = 5  !

      Conduct spatial averaging of temp-
      eratures (IAVET)  (0=no, 1=yes)         Default: 1        ! IAVET =  1  !
      (will use mixing ht MNMDAV,HAFANG
       so make sure they are correct)

      Default temperature gradient         Default: -.0098 ! TGDEFB = -0.0098
!
      below the mixing height over
      water (K/m) (TGDEFB)

      Default temperature gradient         Default: -.0045 ! TGDEFA = -0.0045
!
      above the mixing height over
      water (K/m) (TGDEFA)

      Beginning (JWAT1) and ending (JWAT2)
      land use categories for temperature                   ! JWAT1 =  999
!
      interpolation over water -- Make                      ! JWAT2 =  999
!
      bigger than largest land use to disable

   PRECIP INTERPOLATION PARAMETERS

      Method of interpolation (NFLAGP)       Default = 2     ! NFLAGP =  3  !
       (1=1/R,2=1/R**2,3=EXP/R**2)
      Radius of Influence (km) (SIGMAP)      Default = 100.0  ! SIGMAP = 100.
!
       (0.0 => use half dist. btwn
        nearest stns w & w/out
        precip when NFLAGP = 3)
      Minimum Precip. Rate Cutoff (mm/hr)    Default = 0.01  ! CUTP = 0.01 !
       (values < CUTP = 0.0 mm/hr)
!END!


-----------------------------------------------------------------------------
--

INPUT GROUP: 7 -- Surface meteorological station parameters
--------------

     SURFACE STATION VARIABLES
     (One record per station --  5  records in all)


             1     2
         Name    ID             X coord.   Y coord.   Time   Anem.
                                  (km)       (km)     zone   Ht.(m)
```

```
        ----------------------------------------------------------
! SS1  ='CASP'   24089         -115.47     -115.30     7    10  !
! SS2  ='LAN'    24021         -294.23     -120.25     7    10  !
! SS3  ='RAPI'   24090          149.20       7.172     7    10  !
! SS4  ='SCOT'   24028          112.17     -228.29     7    10  !
! SS5  ='SHER'   24029         -149.93       84.21     7    10  !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


------------------------------------------------------------------------------
--

INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  2  records in all)

             1      2
         Name     ID       X coord.   Y coord.  Time zone
                             (km)       (km)
        ---------------------------------------------------
! US1  ='LAN'   24021     -294.23   -120.25     7  !
! US2  ='RAP'   24090      149.20     7.172     7  !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


------------------------------------------------------------------------------
--

INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
     (One record per station --  4  records in all)
     (NOT INCLUDED IF NPSTA = 0)

           1          2
         Name    Station    X coord.  Y coord.
                  Code       (km)      (km)
         ------------------------------------

! PS1  ='SCOT'   257665    112.17    -228.29         !
! PS2  ='RAPI'   396937    149.20      7.172         !
```

```
! PS3  ='CASP'   481570   -115.47    -115.30        !
! PS4  ='LAN '   485390   -294.23    -120.25        !

-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit station code composed of state
        code (first 2 digits) and station ID (last
        4 digits)

!END!
```

EXHIBIT B

Example CALPUFF Input File
(Route C DM&E Sources, January, 1990)

Exhibit B. Example CALPUFF input file (Route C DM&E Sources, January 1990).

```
CALPUFF Input File
Route C, 50MNT DM&E sources
January, 1990.
---------------- Run title (3 lines) ----------------------------------------
--

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

-----------------------------------------------------------------------------
--

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT =/disk22/wyodak/calmet/calmet1.dat   !
    or
ISCMET.DAT    input    * ISCDAT =                *
    or
PLMMET.DAT    input    * PLMDAT =                *
    or
PROFILE.DAT   input    * PRFDAT =                *
SURFACE.DAT   input    * SFCDAT =                *
RESTARTB.DAT  input    * RSTARTB=
/disk25/dme/calpuff/outputs/restart/restart.rtc-50mnt.90xxx.dat  *
-----------------------------------------------------------------------------
---
CALPUFF.LST   output   ! PUFLST = /disk25/dme/calpuff/outputs/calpuff.rtc-
50mnt.90jan.lst  !
CONC.DAT      output   ! CONDAT = /disk25/dme/calpuff/outputs/conc/conc.rtc-
50mnt.90jan.dat !
DFLX.DAT      output   ! DFDAT  = /disk25/dme/calpuff/outputs/ddep/dflx.rtc-
50mnt.90jan.dat     !
WFLX.DAT      output   ! WFDAT  = /disk25/dme/calpuff/outputs/wdep/wflx.rtc-
50mnt.90jan.dat     !

VISB.DAT      output   * VISDAT =                *
RESTARTE.DAT  output   ! RSTARTE=
/disk25/dme/calpuff/outputs/restart/restart.rtc-50mnt.90jan.dat  !
-----------------------------------------------------------------------------
---
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =                *
VOLEM.DAT     input    * VOLDAT =                *
BAEMARB.DAT   input    ! ARDAT  =
/disk11/dme/emiss/data/barea_dme_c.50mnt.all1.dat !
LNEMARB.DAT   input    * LNDAT  =                *
-----------------------------------------------------------------------------
---
Other Files
-----------
OZONE.DAT     input    * OZDAT  = BLANK             *
VD.DAT        input    * VDDAT  =                *
CHEM.DAT      input    * CHEMDAT=                *
```

```
HILL.DAT       input    * HILDAT=              *
HILLRCT.DAT    input    * RCTDAT=              *
COASTLN.DAT    input    * CSTDAT=              *
DEBUG.DAT      output   * DEBUG =              *
-----------------------------------------------------------------------------
---
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 70 characters in length

!END!
-----------------------------------------------------------------------------
---

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file(s)  (METRUN)   Default: 0       ! METRUN = 1  !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file(s)

     Starting date:   Year (IBYR) -- No default       ! IBYR =  90  !
     (used only if   Month (IBMO) -- No default       ! IBMO =  1  !
      METRUN = 0)      Day (IBDY) -- No default       ! IBDY =  0  !
                      Hour (IBHR) -- No default       ! IBHR =  0  !

     Length of run (hours) (IRLG) -- No default       ! IRLG =  0  !

     Number of chemical species (NSPEC)
                                    Default: 5       ! NSPEC =  12   !

     Number of chemical species
     to be emitted  (NSE)           Default: 3       ! NSE =  9   !

     Flag to stop run after
     SETUP phase (ITEST)            Default: 2       ! ITEST = 2   !
     (Used to allow checking
     of the model inputs, files, etc.)
           ITEST = 1 - STOPS program after SETUP phase
           ITEST = 2 - Continues with execution of program
                       after SETUP

     Restart Configuration:

        Control flag (MRESTART)     Default: 0       ! MRESTART =  2   !

           0 = Do not read or write a restart file
           1 = Read a restart file at the beginning of
               the run
           2 = Write a restart file during run
           3 = Read a restart file at beginning of run
               and write a restart file during run

        Number of periods in Restart
        output cycle (NRESPD)       Default: 0       ! NRESPD =  0   !

           0 = File written only at last period
```

```
        >0 = File updated every NRESPD periods

    Meteorological Data Format (METFM)
                                    Default: 1       ! METFM =  1   !

         METFM = 1 - CALMET binary file (CALMET.MET)
         METFM = 2 - ISC ASCII file (ISCMET.MET)
         METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
         METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                     surface parameters file (SURFACE.DAT)

    Averaging Time (minutes) (AVET)
                                    Default: 60.0    ! AVET = 60. !
    PG sigma-y is adjusted by the equation
    (AVET/60.0)**0.2


!END!


-------------------------------------------------------------------------------
--

INPUT GROUP: 2 -- Technical options
--------------


    Vertical distribution used in the
    near field (MGAUSS)                  Default: 1     ! MGAUSS =  1   !
       0 = uniform
       1 = Gaussian

    Terrain adjustment method
    (MCTADJ)                             Default: 3     ! MCTADJ =  3   !
       0 = no adjustment
       1 = ISC-type of terrain adjustment
       2 = simple, CALPUFF-type of terrain
           adjustment
       3 = partial plume path adjustment

    Subgrid-scale complex terrain
    flag (MCTSG)                         Default: 0     ! MCTSG =  0   !
       0 = not modeled
       1 = modeled

    Near-field puffs modeled as
    elongated 0 (MSLUG)                  Default: 0     ! MSLUG =  0   !
       0 = no
       1 = yes (slug model used)

    Transitional plume rise modeled ?
    (MTRANS)                             Default: 1     ! MTRANS =  1   !
       0 = no  (i.e., final rise only)
       1 = yes (i.e., transitional rise computed)

    Stack tip downwash? (MTIP)           Default: 1     ! MTIP =  1  !
       0 = no  (i.e., no stack tip downwash)
       1 = yes (i.e., use stack tip downwash)

    Vertical wind shear modeled above
    stack top? (MSHEAR)                  Default: 0     ! MSHEAR =  0  !
```

```
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)      Default: 0      ! MSPLIT =  1  !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)       Default: 3      ! MCHEM =  3   !
   0 = chemical transformation not
       modeled
   1 = transformation rates computed
       internally (MESOPUFF II scheme)
   2 = user-specified transformation
       rates used
   3 = transformation rates computed
       internally (RIVAD/ARM3 scheme)

Wet removal modeled ? (MWET)          Default: 1      ! MWET =  1    !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)       Default: 1      ! MDRY =  1    !
   0 = no
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)

Method used to compute dispersion
coefficients (MDISP)                  Default: 3      ! MDISP =  3   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5)         Default: 3      ! MTURBVW =  3  !
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4)
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

Back-up method used to compute dispersion
```

```
when measured turbulence data are
missing (MDISP2)                    Default: 3      ! MDISP2 =  3  !
(used only if MDISP = 1 or 5)
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.

PG sigma-y,z adj. for roughness?    Default: 0      ! MROUGH =  0  !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of        Default: 0      ! MPARTL =  1  !
elevated inversion?
(MPARTL)
   0 = no
   1 = yes

Strength of temperature inversion   Default: 0      ! MTINV =  0  !
provided in PROFILE.DAT extended records?
(MTINV)
   0 = no (computed from measured/default gradients)
   1 = yes

PDF used for dispersion under convective conditions?
                                    Default: 0      ! MPDF =  0  !
(MPDF)
   0 = no
   1 = yes

Sub-Grid TIBL module used for shore line?
                                    Default: 0      ! MSGTIBL = 0  !
(MSGTIBL)
   0 = no
   1 = yes

Test options specified to see if
they conform to regulatory
values? (MREG)                      Default: 0      ! MREG =  0   !

   0 = NO checks are made
   1 = Technical options must conform to USEPA values for
       short-range modeling (e.g. ISC-type applications)
   2 = Technical options must conform to USEPA values for
       long-range modeling (e.g. visibility-type applications)
   3 = Other constraints

!END!

------------------------------------------------------------------------------
--

INPUT GROUP: 3a, 3b -- Species list
-------------------
```

```
------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC =          SO2 !         !END!
! CSPEC =          SO4 !         !END!
! CSPEC =           NO !         !END!
! CSPEC =          NO2 !         !END!
! CSPEC =         HNO3 !         !END!
! CSPEC =          NO3 !         !END!
! CSPEC =         PM10 !         !END!
! CSPEC =           EC !         !END!
! CSPEC =           OC !         !END!
! CSPEC =         PM25 !         !END!
! CSPEC =          VOC !         !END!
! CSPEC =           CO !         !END!

                                                              Dry
OUTPUT GROUP
    SPECIES          MODELED          EMITTED          DEPOSITED
NUMBER
     NAME         (0=NO, 1=YES)    (0=NO, 1=YES)     (0=NO,
(0=NONE,
   (Limit: 12                                         1=COMPUTED-GAS
1=1st CGRUP,
    Characters                                        2=COMPUTED-PARTICLE
2=2nd CGRUP,
    in length)                                        3=USER-SPECIFIED)     3=
etc.)

!         SO2  =          1,               1,            1,               0
!
!         SO4  =          1,               1,            2,               0
!
!          NO  =          1,               1,            1,               0
!
!         NO2  =          1,               1,            1,               0
!
!        HNO3  =          1,               0,            1,               0
!
!         NO3  =          1,               0,            2,               0
!
!        PM10  =          1,               0,            2,               0
!
!          EC  =          1,               1,            2,               0
!
!          OC  =          1,               1,            2,               0
!
!        PM25  =          1,               1,            2,               0
!
!         VOC  =          1,               1,            0,               0
!
!          CO  =          1,               1,            0,               0
!

!END!

-------------
```

```
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.



-------------------------------------------------------------------------------
--


INPUT GROUP: 4 -- Grid control parameters
--------------
METEOROLOGICAL grid:

            No. X grid cells (NX)      No default     ! NX =  134   !
            No. Y grid cells (NY)      No default     ! NY =  94   !
         No. vertical layers (NZ)      No default     ! NZ =  8   !

           Grid spacing (DGRIDKM)      No default     ! DGRIDKM = 5. !
                                       Units: km

                Cell face heights
                    (ZFACE(nz+1))      No defaults
                                       Units: m
   ! ZFACE = 0., 20., 50., 100., 250., 500., 750., 1000., 3000. !

            Reference Coordinates
           of SOUTHWEST corner of
                 grid cell(1, 1):

            X coordinate (XORIGKM)     No default     ! XORIGKM = -350. !
            Y coordinate (YORIGKM)     No default     ! YORIGKM = -250. !
                                      Units: km

                 UTM zone (IUTMZN)     No default     ! IUTMZN =  13   !

   Reference coordinates of CENTER
        of the domain (used in the
    calculation of solar elevation
                           angles)

            Latitude  (deg.) (XLAT)    No default     ! XLAT  = 43.86  !
           Longitude (deg.) (XLONG)    No default     ! XLONG = 105.19   !
             Time zone        (XTZ)    No default     ! XTZ   = 7.0  !
         (PST=8, MST=7, CST=6, EST=5)


Computational grid:

     The computational grid is identical to or a subset of the MET. grid.
     The lower left (LL) corner of the computational grid is at grid point
     (IBCOMP, JBCOMP) of the MET. grid.  The upper right (UR) corner of the
     computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
     The grid spacing of the computational grid is the same as the MET. grid.
```

```
        X index of LL corner (IBCOMP)      No default      ! IBCOMP =  1   !
                  (1 <= IBCOMP <= NX)

        Y index of LL corner (JBCOMP)      No default      ! JBCOMP =  1   !
                  (1 <= JBCOMP <= NY)


        X index of UR corner (IECOMP)      No default      ! IECOMP =  134   !
                  (1 <= IECOMP <= NX)

        Y index of UR corner (JECOMP)      No default      ! JECOMP =  94   !
                  (1 <= JECOMP <= NY)


SAMPLING GRID (GRIDDED RECEPTORS):

     The lower left (LL) corner of the sampling grid is at grid point
     (IBSAMP, JBSAMP) of the MET. grid.  The upper right (UR) corner of the
     sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
     The sampling grid must be identical to or a subset of the computational
     grid.  It may be a nested grid inside the computational grid.
     The grid spacing of the sampling grid is DGRIDKM/MESHDN.

        Logical flag indicating if gridded
        receptors are used (LSAMP)          Default: T      ! LSAMP = F !
        (T=yes, F=no)

        X index of LL corner (IBSAMP)      No default      ! IBSAMP =  1   !
         (IBCOMP <= IBSAMP <= IECOMP)

        Y index of LL corner (JBSAMP)      No default      ! JBSAMP =  1   !
         (JBCOMP <= JBSAMP <= JECOMP)


        X index of UR corner (IESAMP)      No default      ! IESAMP =  134   !
         (IBCOMP <= IESAMP <= IECOMP)

        Y index of UR corner (JESAMP)      No default      ! JESAMP =  94   !
         (JBCOMP <= JESAMP <= JECOMP)


       Nesting factor of the sampling
        grid (MESHDN)                       Default: 1      ! MESHDN =  1  !
        (MESHDN is an integer >= 1)

!END!

-----------------------------------------------------------------------------
--

INPUT GROUP: 5 -- Output Options
--------------
                                                *                          *
     FILE                          DEFAULT VALUE             VALUE THIS RUN
     ----                          -------------             --------------

   Concentrations (ICON)                 1                   !  ICON =  1   !
   Dry Fluxes (IDRY)                     1                   !  IDRY =  1   !
   Wet Fluxes (IWET)                     1                   !  IWET =  1   !
```

```
   Relative Humidity (IVIS)          1                    !  IVIS =  0   !
    (relative humidity file is
     required for visibility
     analysis)
   Use data compression option in output file?
   (LCOMPRS)                           Default: T         ! LCOMPRS = F  !

   *
    0 = Do not create file, 1 = create file


    LINE PRINTER OUTPUT OPTIONS:

       Print concentrations (ICPRT)    Default: 0         ! ICPRT =  0   !
       Print dry fluxes (IDPRT)        Default: 0         ! IDPRT =  0   !
       Print wet fluxes (IWPRT)        Default: 0         ! IWPRT =  0   !
       (0 = Do not print, 1 = Print)

       Concentration print interval
       (ICFRQ) in hours                Default: 1         ! ICFRQ =  1   !
       Dry flux print interval
       (IDFRQ) in hours                Default: 1         ! IDFRQ =  1   !
       Wet flux print interval
       (IWFRQ) in hours                Default: 1         ! IWFRQ =  1   !

       Units for Line Printer Output
       (IPRTU)                         Default: 1         ! IPRTU =  1   !
                        for             for
                   Concentration    Deposition
           1 =        g/m**3         g/m**2/s
           2 =       mg/m**3        mg/m**2/s
           3 =       ug/m**3        ug/m**2/s
           4 =       ng/m**3        ng/m**2/s
           5 =      Odour Units

       Messages tracking progress of   Default: 1         ! IMESG =  1   !
       run written to the screen ?
       (IMESG) -- 0=no, 1=yes


     SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

                   -------- CONCENTRATIONS ---------   ----------- DRY FLUXES --
---------    --------- WET FLUXES ----------
   SPECIES
   /GROUP             PRINTED ?       SAVED ON DISK ?      PRINTED ?        SAVED
ON DISK ?     PRINTED ?     SAVED ON DISK ?
   -------         ---------------------------------   -------------------------
---------    -------------------------------
!         SO2 =          0,                1,                0,
1,             0,              1    !
!         SO4 =          0,                1,                0,
1,             0,              1    !
!          NO =          0,                1,                0,
1,             0,              1    !
!         NO2 =          0,                1,                0,
1,             0,              1    !
!        HNO3 =          0,                1,                0,
1,             0,              1    !
!         NO3 =          0,                1,                0,
1,             0,              1    !
```

```
!        PM10 =          0,               1,               0,
1,            0,               1   !
!          EC =          0,               1,               0,
1,            0,               1   !
!          OC =          0,               1,               0,
1,            0,               1   !
!        PM25 =          0,               1,               0,
1,            0,               1   !
!         VOC =          0,               0,               0,
0,            0,               0   !
!          CO =          0,               0,               0,
0,            0,               0   !

     OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

       Logical for debug output
       (LDEBUG)                                 Default: F      ! LDEBUG = F !

       Number of puffs to track
       (NPFDEB)                                 Default: 1      ! NPFDEB =  1
!

       Met. period to start output
       (NN1)                                    Default: 1      ! NN1 =  1    !

       Met. period to end output
       (NN2)                                    Default: 10     ! NN2 =  10   !

!END!


-----------------------------------------------------------------------------
--


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)       Default: 0      ! NHILL =  0
!

       Number of special complex terrain
       receptors  (NCTREC)                      Default: 0      ! NCTREC =  0
!

       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                  No Default      ! MHILL =  2
!
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0    ! XHILL2M = 1.
!
```

```
        to meters (MHILL=1)

        Factor to convert vertical dimensions    Default: 1.0    ! ZHILL2M = 1.
!
        to meters (MHILL=1)

        X-origin of CTDM system relative to      No Default      ! XCTDMKM =
0.0E00 !
        CALPUFF coordinate system, in Kilometers (MHILL=1)

        Y-origin of CTDM system relative to      No Default      ! YCTDMKM =
0.0E00 !
        CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                                  1 **
     HILL information


HILL          XC         YC        THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2
SCALE 1    SCALE 2    AMAX1      AMAX2
 NO.          (km)       (km)       (deg.)   (m)     (m)      (m)       (m)
(m)         (m)        (m)        (m)
----          ----       ----       ------  -----  ------    ------    ------
-------    -------    -----      -----

---------------
Subgroup (6c)
---------------

    COMPLEX TERRAIN RECEPTOR INFORMATION

                              XRCT          YRCT         ZRCT          XHH
                              (km)          (km)          (m)
                             ------         -----        ------        ----


-------------------
1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
```

```
         XHH     = Hill number associated with each complex terrain receptor
                    (NOTE: MUST BE ENTERED AS A REAL NUMBER)

   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group
terminator.

------------------------------------------------------------------------------
--


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

      SPECIES     DIFFUSIVITY      ALPHA STAR      REACTIVITY    MESOPHYLL
RESISTANCE     HENRY'S LAW COEFFICIENT
       NAME        (cm**2/s)
(s/cm)                (dimensionless)
      -------     -----------      ----------      ----------    ------------
--------     -----------------------

!          SO2 =     0.1509,         1000.,           8.,                 0.,
0.04 !
!           NO =     0.1656,            1.,           8.,                 5.,
3.5 !
!          NO2 =     0.1656,            1.,           8.,                 5.,
3.5 !
!         HNO3 =     0.1628,            1.,         180.,                 0.,
8.0e-8 !

!END!


------------------------------------------------------------------------------
--


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

     For SINGLE SPECIES, the mean and standard deviation are used to
     compute a deposition velocity for NINT (see group 9) size-ranges,
     and these are then averaged to obtain a mean deposition velocity.

     For GROUPED SPECIES, the size distribution should be explicitly
     specified (by the 'species' in the group), and the standard deviation
     for each should be entered as 0.  The model will then use the
     deposition velocity for the stated mean diameter.

      SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
       NAME             DIAMETER                   DEVIATION
                        (microns)                  (microns)
      -------      -------------------        ------------------
!          SO4 =          0.48,                    2.    !
!          NO3 =          0.48,                    2.    !
!         PM10 =           2.0,                   2.0    !
!           EC =          0.48,                    2.    !
!           OC =          0.48,                    2.    !
!         PM25 =          0.48,                    2.    !
```

```
!END!


-------------------------------------------------------------------------------
--


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance    (RCUTR)  (s/cm)    !  RCUTR = 30. !
     Reference ground resistance     (RGR)    (s/cm)    !    RGR = 10. !
     Reference pollutant reactivity (REACTR)            ! REACTR = 8. !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                             Default: 9      !   NINT =  9  !

     Vegetation state in unirrigated areas (IVEG)       !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!


-------------------------------------------------------------------------------
--


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------


                      Scavenging Coefficient -- Units: (sec)**(-1)

       Pollutant      Liquid Precip.      Frozen Precip.
       ---------      --------------      --------------
!          SO2 =         3.0E-05,            0.0E00 !
!          SO4 =         1.0E-04,           3.0E-05 !
!           NO =         0.0    ,            0.0    !
!          NO2 =         0.0    ,            0.0    !
!         HNO3 =         6.0E-05,            0.0E00 !
!          NO3 =         1.0E-04,           3.0E-05 !
!         PM10 =         1.0E-04,           3.0E-05 !
!           EC =         1.0E-04,           3.0E-05 !
!           OC =         1.0E-04,           3.0E-05 !
!         PM25 =         1.0E-04,           3.0E-05 !

!END!


-------------------------------------------------------------------------------
--


INPUT GROUP: 11 -- Chemistry Parameters
---------------

     Ozone data input option (MOZ)     Default: 1            ! MOZ =  0   !
     (Used only if MCHEM = 1 or 3)
```

```
        0 = use a constant background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Background ozone concentration
     (BCKO3) in ppb                     Default: 80.          ! BCKO3 = 40. !
     (Used only if MCHEM = 1 or 3 and
      MOZ = 0 or (MOZ = 1 and all hourly
      O3 data missing)

     Background ammonia concentration
     (BCKNH3) in ppb                    Default: 10.          ! BCKNH3 = 5. !

     Nighttime SO2 loss rate (RNITE1)
     in percent/hour                    Default: 0.2          ! RNITE1 = 0.2 !

     Nighttime NOx loss rate (RNITE2)
     in percent/hour                    Default: 2.0          ! RNITE2 = 2. !

     Nighttime HNO3 formation rate (RNITE3)
     in percent/hour                    Default: 2.0          ! RNITE3 = 2. !

!END!


------------------------------------------------------------------------------
--


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                            Default: 550.    ! SYTDEP =
5.5E02 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                    Default: 0       ! MHFTSZ =  0
!

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                                Default: 5       ! JSUP =  5
!

     Vertical dispersion constant for stable
     conditions (k1 in Eqn. 2.7-3)  (CONK1)      Default: 0.01    ! CONK1 =
0.01 !

     Vertical dispersion constant for neutral/
     unstable conditions (k2 in Eqn. 2.7-4)
     (CONK2)                                     Default: 0.1     ! CONK2 = 0.1
!

     Factor for determining Transition-point from
     Schulman-Scire to Huber-Snyder Building Downwash
     scheme (SS used for Hs < Hb + TBD * HL)
     (TBD)                                       Default: 0.5     ! TBD = 0.5 !
```

```
        TBD < 0   ==> always use Huber-Snyder
        TBD = 1.5 ==> always use Schulman-Scire
        TBD = 0.5 ==> ISC Transition-point

     Range of land use categories for which
     urban dispersion is assumed
     (IURB1, IURB2)                          Default: 10     ! IURB1 =  10
!
                                                      19     ! IURB2 =  19
!

     Site characterization parameters for single-point Met data files -------
--
     (needed for METFM = 2,3,4)

        Land use category for modeling domain
        (ILANDUIN)                           Default: 20     ! ILANDUIN =
20  !

        Roughness length (m) for modeling domain
        (Z0IN)                               Default: 0.25   ! Z0IN = 0.25
!

        Leaf area index for modeling domain
        (XLAIIN)                             Default: 3.0    ! XLAIIN = 3.
!

        Elevation above sea level (m)
        (ELEVIN)                             Default: 0.0    ! ELEVIN = 0.
!

        Latitude (degrees) for met location
        (XLATIN)                             Default: -999.  ! XLATIN = -
999. !

        Longitude (degrees) for met location
        (XLONIN)                             Default: -999.  ! XLONIN = -
999. !

     Specialized information for interpreting single-point Met data files ---
--

        Anemometer height (m) (Used only if METFM = 2,3)
        (ANEMHT)                             Default: 10.    ! ANEMHT =
10. !

        Form of lateral turbulance data in PROFILE.DAT file
        (Used only if METFM = 4 or MTURBVW = 1 or 3)
        (ISIGMAV)                            Default: 1      ! ISIGMAV =
1  !
            0 = read sigma-theta
            1 = read sigma-v

        Choice of mixing heights (Used only if METFM = 4)
        (IMIXCTDM)                           Default: 0      ! IMIXCTDM =
0  !
            0 = read PREDICTED mixing heights
            1 = read OBSERVED mixing heights

     Maximum length of a slug (met. grid units)
```

```
     (XMXLEN)                                      Default: 1.0     ! XMXLEN = 1.
!

     Maximum travel distance of a puff/slug (in
     grid units) during one sampling step
     (XSAMLEN)                                     Default: 1.0     ! XSAMLEN =
1. !

     Maximum Number of slugs/puffs release from
     one source during one time step
     (MXNEW)                                       Default: 99      ! MXNEW =  99
!

     Maximum Number of sampling steps for
     one puff/slug during one time step
     (MXSAM)                                       Default: 99      ! MXSAM =  99
!

     Number of iterations used when computing
     the transport wind for a sampling step
     that includes gradual rise (for CALMET
     and PROFILE winds)
     (NCOUNT)                                      Default: 2       ! NCOUNT =  2
!

     Minimum sigma y for a new puff/slug (m)
     (SYMIN)                                       Default: 1.0     ! SYMIN = 1.
!

     Minimum sigma z for a new puff/slug (m)
     (SZMIN)                                       Default: 1.0     ! SZMIN = 1.
!

     Default minimum turbulence velocities
     sigma-v and sigma-w for each
     stability class (m/s)
     (SVMIN(6) and SWMIN(6))      Default SVMIN : .50,  .50,  .50,  .50,  .50,
.50
                                  Default SWMIN : .20,  .12,  .08,  .06,  .03,
.016

                                Stability Class :  A     B     C     D     E
F
                                                  ---   ---   ---   ---   ---
---
                                       ! SVMIN = 0.500, 0.500, 0.500, 0.500,
0.500, 0.500!
                                       ! SWMIN = 0.200, 0.120, 0.080, 0.060,
0.030, 0.016!

     Divergence criterion for dw/dz in met cell
     used to initiate adjustment for horizontal
     convergence (1/s)
     (CDIV)                                        Default: 0.010  ! CDIV = 0.01
!

     Minimum wind speed (m/s) allowed for
     non-calm conditions. Also used as minimum
     speed returned when using power-law
     extrapolation toward surface
```

```
     (WSCALM)                                Default: 0.5     ! WSCALM = 1.
!

     Maximum mixing height (m)
     (XMAXZI)                                Default: 3000.   ! XMAXZI =
3000. !

     Minimum mixing height (m)
     (XMINZI)                                Default: 50.     ! XMINZI =
50. !

     Default wind speed classes --
     5 upper bounds (m/s) are entered;
     the 6th class has no upper limit
     (WSCAT(5))                  Default     :
                                 ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10,8
(10.8+)

                          Wind Speed Class :  1     2     3     4     5
6
                                             ---   ---   ---   ---   ---
---
                                ! WSCAT = 1.54, 3.09, 5.14, 8.23,
10.80 !

     Default wind speed profile power-law
     exponents for stabilities 1-6
     (PLX0(6))                   Default     : ISC RURAL values
                                 ISC RURAL : .07, .07, .10, .15, .35, .55
                                 ISC URBAN : .15, .15, .20, .25, .30, .30

                           Stability Class :  A     B     C     D     E
F
                                             ---   ---   ---   ---   ---
---
                                 ! PLX0 = 0.07, 0.07, 0.10, 0.15,
0.35, 0.55 !

     Default potential temperature gradient
     for stable classes E, F (degK/m)
     (PTG0(2))                   Default: 0.020, 0.035
                                 ! PTG0 = 0.020,   0.035 !

     Default plume path coefficients for
     each stability class (used when option
     for partial plume height terrain adjustment
     is selected -- MCTADJ=3)
     (PPC(6))              Stability Class :  A     B     C     D     E
F
                             Default  PPC : .50,  .50,  .50,  .50,  .35,
.35
                                             ---   ---   ---   ---   ---
---
                                 !  PPC = 0.50, 0.50, 0.50, 0.50,
0.35, 0.35 !

     Slug-to-puff transition criterion factor
     equal to sigma-y/length of slug
     (SL2PF)                            Default: 10.       ! SL2PF = 10.
!
```

```
     Puff-splitting control variables ------------------------

       Number of puffs that result every time a puff
       is split - nsplit=2 means that 1 puff splits
       into 2
       (NSPLIT)                            Default:   3        ! NSPLIT =  3
!

       Time(s) of a day when split puffs are eligible to
       be split once again; this is typically set once
       per day, around sunset before nocturnal shear develops.
       24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
       0=do not re-split    1=eligible for re-split
       (IRESPLIT(24))                      Default:  Hour 17 = 1
       !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

       Split is allowed only if last hour's mixing
       height (m) exceeds a minimum value
       (ZISPLIT)                           Default: 100.       ! ZISPLIT =
100. !

       Split is allowed only if ratio of last hour's
       mixing ht to the maximum mixing ht experienced
       by the puff is less than a maximum value (this
       postpones a split until a nocturnal layer develops)
       (ROLDMAX)                           Default: 0.25       ! ROLDMAX =
0.25 !

     Integration control variables ------------------------

       Fractional convergence criterion for numerical SLUG
       sampling integration
       (EPSSLUG)                           Default:   1.0e-04  ! EPSSLUG =
1.0E-04 !

       Fractional convergence criterion for numerical AREA
       source integration
       (EPSAREA)                           Default:   1.0e-06  ! EPSAREA =
1.0E-06 !
!END!


-----------------------------------------------------------------------------
--


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
--------------------------------


---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  !  NPT1 =   0  !

     Units used for point source
     emissions below                (IPTU)  Default: 1  !  IPTU =   1  !
          1 =      g/s
          2 =     kg/hr
          3 =     lb/hr
```

```
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0   !  NSPT1 =  0  !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default   !  NPT2 =  0  !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
Subgroup (13b)
---------------
                                              a
          POINT SOURCE: CONSTANT DATA
          -----------------------------

b         c
  Source      X UTM      Y UTM     Stack   Base      Stack    Exit  Exit
Bldg.  Emission
   No.     Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.
Dwash   Rates
                (km)       (km)       (m)      (m)        (m)  (m/s) (deg. K)
  ------   ---------- ---------- ------  ------   --------- ----- -------- ---
-- --------

--------

     a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

     b
     0. = No building downwash modeled, 1. = downwash modeled
     NOTE: must be entered as a REAL number (i.e., with decimal point)

     c
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IPTU
     (e.g. 1 for g/s).

---------------
Subgroup (13c)
---------------

          BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
          -----------------------------------------------------

Source                                                                    a
 No.       Effective building width and height (in meters) every 10 degrees
------     -------------------------------------------------------------
```

```
--------

    a
     Each pair of width and height values is treated as a separate input
     subgroup and therefore must end with an input group terminator.

---------------
Subgroup (13d)
---------------
                                                  a
          POINT SOURCE: VARIABLE EMISSIONS DATA
          ---------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 13b.  Factors entered multiply the rates in 13b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)


--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-----------------------------------------------------------------------------------
--


INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters
--------------------------------

---------------
Subgroup (14a)
---------------

     Number of polygon area sources with
     parameters specified below (NAR1)       No default  !  NAR1 =  0 !

     Units used for area source
     emissions below            (IARU)       Default: 1  !  IARU =   1  !
           1 =        g/m**2/s
           2 =        kg/m**2/hr
```

```
            3 =      lb/m**2/hr
            4 =     tons/m**2/yr
            5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
            6 =     Odour Unit * m/min

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (14d)        (NSAR1) Default: 0  !  NSAR1 =  0  !

     Number of buoyant polygon area sources
     with variable location and emission
     parameters (NAR2)                      No default  !  NAR2 =  167   !
     (If NAR2 > 0, ALL parameter data for
     these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                                           a
          AREA SOURCE: CONSTANT DATA
          ----------------------------
                                                                 b
Source           Effect.   Base      Initial    Emission
 No.             Height  Elevation   Sigma z     Rates
                   (m)      (m)        (m)
-------          ------   ------     --------   ---------

--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IARU
     (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

           COORDINATES (UTM-km) FOR EACH VERTEX(4) OF EACH POLYGON
           --------------------------------------------------------
Source                                                                a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------

---------------
Subgroup (14d)
---------------
                                                     a
          AREA SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 14b.  Factors entered multiply the rates in 14b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use BAEMARB.DAT and NAR2 > 0.
```

```
     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                 Default: 0
           0 =      Constant
           1 =      Diurnal cycle (24 scaling factors: hours 1-24)
           2 =      Monthly cycle (12 scaling factors: months 1-12)
           3 =      Hour & Season (4 groups of 24 hourly scaling factors,
                                   where first group is DEC-JAN-FEB)
           4 =      Speed & Stab. (6 groups of 6 scaling factors, where
                                   first group is Stability Class A,
                                   and the speed classes have upper
                                   bounds (m/s) defined in Group 12
           5 =      Temperature   (12 scaling factors, where temperature
                                   classes have upper bounds (C) of:
                                   0, 5, 10, 15, 20, 25, 30, 35, 40,
                                   45, 50, 50+)


--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


------------------------------------------------------------------------------
--

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters
---------------------------

---------------
Subgroup (15a)
---------------

     Number of buoyant line sources
     with variable location and emission
     parameters (NLN2)                              No default   !  NLN2 =  0
!

     (If NLN2 > 0, ALL parameter data for
      these sources are read from the file: LNEMARB.DAT)

     Number of buoyant line sources (NLINES)        No default    ! NLINES =
0  !

     Units used for line source
     emissions below               (ILNU)           Default: 1  !  ILNU =   1
!
           1 =       g/s
           2 =      kg/hr
           3 =      lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (15c)        (NSLN1) Default: 0  !  NSLN1 =  0  !
```

```
     Maximum number of segments used to model
     each line (MXNSEG)                              Default: 7    ! MXNSEG =
7  !

     The following variables are required only if NLINES > 0.  They are
     used in the buoyant line source plume rise calculations.

        Number of distances at which                 Default: 6    ! NLRISE =
6  !
        transitional rise is computed

        Average line source length (XL)              No default    ! XL = 0. !
                                                     (in meters)

        Average height of line source height (HBL)   No default    ! HBL = 0. !
                                                     (in meters)

        Average building width (WBL)                 No default    ! WBL = 0. !
                                                     (in meters)

        Average line source width (WML)              No default    ! WML = 0. !
                                                     (in meters)

        Average separation between buildings (DXL)   No default    ! DXL = 0. !
                                                     (in meters)

        Average buoyancy parameter (FPRIMEL)         No default    ! FPRIMEL =
0. !
                                                     (in m**4/s**3)

!END!

---------------
Subgroup (15b)
---------------

          BUOYANT LINE SOURCE: CONSTANT DATA
          ----------------------------------

a
Source    Beg. X      Beg. Y      End. X     End. Y      Release     Base
Emission
 No.    Coordinate  Coordinate  Coordinate Coordinate  Height     Elevation
Rates
           (km)        (km)        (km)       (km)        (m)         (m)
------  ----------  ----------  ---------  ----------  -------   ---------
---------

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by ILNTU
     (e.g. 1 for g/s).

---------------
```

```
Subgroup (15c)
---------------
                                                            a
          BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
          ----------------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 15b.  Factors entered multiply the rates in 15b.
     Skip sources here that have constant emissions.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                    Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)


--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


------------------------------------------------------------------------------
--


INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
---------------------------

---------------
Subgroup (16a)
---------------

     Number of volume sources with
     parameters provided in 16b,c (NVL1)     No default  !  NVL1 =  0   !

     Units used for volume source
     emissions below in 16b       (IVLU)     Default: 1  !  IVLU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (16c)      (NSVL1)    Default: 0  !  NSVL1 =  0  !
```

```
     Gridded volume source data
     used ? (IGRDVL)                        No default  ! IGRDVL =  0   !
        0 = no
        1 = yes (gridded volume source
            emissions read from the file:
            VOLEM.DAT)

     The following parameters apply to the data in the
     gridded volume source emissions file (VOLEM.DAT)

       -  Effective height of emissions
          (VEFFHT) in meters                No default  ! VEFFHT =  0. !

       -  Initial sigma y (VSIGYI) in
          meters                            No default  ! VSIGYI =  0. !

       -  Initial sigma z (VSIGZI) in
          meters                            No default  ! VSIGZI =  0. !

!END!

---------------
Subgroup (16b)
---------------
                                          a
           VOLUME SOURCE: CONSTANT DATA
           ------------------------------

b
        X UTM       Y UTM      Effect.    Base      Initial    Initial
Emission
     Coordinate  Coordinate   Height   Elevation  Sigma y    Sigma z
Rates
        (km)        (km)        (m)       (m)        (m)        (m)
     ----------  ----------   ------    ------    --------   --------   -----
---
--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IVLU
     (e.g. 1 for g/s).

---------------
Subgroup (16c)
---------------
                                                     a
          VOLUME SOURCE: VARIABLE EMISSIONS DATA
          ----------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 16b.  Factors entered multiply the rates in 16b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use VOLEM.DAT and IGRDVL = 1.

     IVARY determines the type of variation, and is source-specific:
```

```
    (IVARY)                                Default: 0
          0 =       Constant
          1 =       Diurnal cycle (24 scaling factors: hours 1-24)
          2 =       Monthly cycle (12 scaling factors: months 1-12)
          3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                   where first group is DEC-JAN-FEB)
          4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                   first group is Stability Class A,
                                   and the speed classes have upper
                                   bounds (m/s) defined in Group 12
          5 =       Temperature   (12 scaling factors, where temperature
                                   classes have upper bounds (C) of:
                                   0, 5, 10, 15, 20, 25, 30, 35, 40,
                                   45, 50, 50+)
```

----

a
Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

--

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
----

Subgroup (17a)

Number of non-gridded receptors (NREC) No default ! NREC = 195 !

!END!

Subgroup (17b)

NON-GRIDDED (DISCRETE) RECEPTOR DATA [a]

Receptor No.		X UTM Coordinate (km)	Y UTM Coordinate (km)	Ground Elevation (m)	
1	! X=	163.8,	-49.9,	916.2!	!END!
2	! X=	163.8,	-45.1,	916.2!	!END!
3	! X=	163.8,	-40.3,	920.2!	!END!
4	! X=	163.8,	-35.4,	966.3!	!END!
5	! X=	168.7,	-49.9,	910.2!	!END!
6	! X=	168.7,	-45.1,	910.2!	!END!
7	! X=	168.7,	-40.2,	907.9!	!END!
8	! X=	168.6,	-35.4,	918.2!	!END!
9	! X=	173.5,	-45.1,	908.2!	!END!
10	! X=	173.5,	-40.2,	876.7!	!END!
11	! X=	173.5,	-35.4,	906.5!	!END!

12	! X=	173.5,	-30.6,	899.8!	!END!
13	! X=	178.3,	-45.1,	917.6!	!END!
14	! X=	178.3,	-40.2,	877.3!	!END!
15	! X=	178.3,	-35.4,	870.0!	!END!
16	! X=	178.3,	-30.6,	899.8!	!END!
17	! X=	183.1,	-45.1,	919.2!	!END!
18	! X=	183.1,	-40.2,	890.8!	!END!
19	! X=	183.1,	-35.4,	830.0!	!END!
20	! X=	183.1,	-30.6,	869.8!	!END!
21	! X=	187.9,	-49.9,	899.5!	!END!
22	! X=	187.9,	-45.1,	899.5!	!END!
23	! X=	187.9,	-40.2,	877.0!	!END!
24	! X=	187.9,	-35.4,	834.0!	!END!
25	! X=	187.9,	-30.6,	832.2!	!END!
26	! X=	187.9,	-25.7,	806.7!	!END!
27	! X=	192.8,	-49.9,	835.6!	!END!
28	! X=	192.7,	-45.1,	835.6!	!END!
29	! X=	192.7,	-30.6,	715.2!	!END!
30	! X=	192.7,	-25.7,	725.4!	!END!
31	! X=	197.6,	-49.9,	770.7!	!END!
32	! X=	197.5,	-20.9,	851.3!	!END!
33	! X=	197.5,	-11.2,	859.0!	!END!
34	! X=	197.5,	-6.4,	861.6!	!END!
35	! X=	202.4,	-49.9,	762.8!	!END!
36	! X=	202.3,	-20.9,	817.5!	!END!
37	! X=	202.3,	-16.0,	834.5!	!END!
38	! X=	202.3,	-11.2,	864.1!	!END!
39	! X=	202.3,	-6.4,	857.0!	!END!
40	! X=	207.2,	-49.9,	838.6!	!END!
41	! X=	207.2,	-45.0,	838.6!	!END!
42	! X=	207.2,	-20.9,	876.2!	!END!
43	! X=	207.2,	-16.0,	859.8!	!END!
44	! X=	207.2,	-11.2,	863.7!	!END!
45	! X=	207.1,	-6.4,	806.5!	!END!
46	! X=	212.0,	-49.9,	863.5!	!END!
47	! X=	212.0,	-45.0,	863.5!	!END!
48	! X=	212.0,	-16.0,	870.4!	!END!
49	! X=	212.0,	-11.2,	809.7!	!END!
50	! X=	212.0,	-6.4,	797.7!	!END!
51	! X=	216.8,	-16.0,	853.8!	!END!
52	! X=	216.8,	-11.2,	808.7!	!END!
53	! X=	221.6,	-20.9,	810.6!	!END!
54	! X=	221.6,	-16.0,	834.5!	!END!
55	! X=	226.4,	-20.9,	800.0!	!END!
56	! X=	226.4,	-16.0,	800.0!	!END!
57	! X=	231.2,	-20.9,	789.7!	!END!
58	! X=	231.2,	-16.0,	807.5!	!END!
59	! X=	236.1,	-20.8,	785.0!	!END!
60	! X=	240.9,	-20.8,	767.0!	!END!
61	! X=	115.6,	-10.5,	1630.2!	!END!
62	! X=	111.8,	-13.0,	1782.1!	!END!
63	! X=	119.0,	-14.7,	1630.2!	!END!
64	! X=	120.0,	-14.8,	1515.4!	!END!
65	! X=	114.9,	-17.6,	1833.3!	!END!
66	! X=	117.1,	-15.6,	1648.7!	!END!
67	! X=	120.5,	-13.2,	1515.4!	!END!
68	! X=	118.5,	-11.0,	1630.2!	!END!
69	! X=	114.2,	-12.7,	1782.1!	!END!
70	! X=	116.6,	-12.7,	1630.2!	!END!
71	! X=	115.6,	-14.7,	1630.2!	!END!
72	! X=	119.5,	-12.0,	1630.2!	!END!

73	! X=	115.7,	-50.0,	1440.9!	!END!
74	! X=	120.5,	-50.0,	1338.5!	!END!
75	! X=	120.5,	-45.1,	1338.5!	!END!
76	! X=	120.5,	-40.3,	1357.1!	!END!
77	! X=	125.3,	-40.3,	1219.7!	!END!
78	! X=	125.3,	-45.1,	1193.4!	!END!
79	! X=	116.6,	-45.1,	1440.9!	!END!
80	! X=	116.6,	-40.3,	1464.9!	!END!
81	! X=	119.0,	-36.4,	1470.4!	!END!
82	! X=	127.7,	-42.7,	1219.7!	!END!
83	! X=	127.7,	-45.1,	1193.4!	!END!
84	! X=	129.1,	-40.3,	1219.7!	!END!
85	! X=	114.7,	-49.0,	1571.0!	!END!
86	! X=	90.6,	-28.2,	2008.4!	!END!
87	! X=	21.9,	63.6,	1380.6!	!END!
88	! X=	-151.2,	148.2,	1867.4!	!END!
89	! X=	-149.3,	148.2,	2230.0!	!END!
90	! X=	-144.5,	148.2,	2162.1!	!END!
91	! X=	-139.6,	148.2,	2089.8!	!END!
92	! X=	-134.8,	148.2,	2129.8!	!END!
93	! X=	-130.0,	148.2,	2129.8!	!END!
94	! X=	-151.2,	153.0,	1828.3!	!END!
95	! X=	-149.3,	153.0,	1965.4!	!END!
96	! X=	-144.5,	153.0,	2022.2!	!END!
97	! X=	-139.6,	153.0,	2069.4!	!END!
98	! X=	-134.8,	153.0,	2174.5!	!END!
99	! X=	-130.0,	153.0,	2174.5!	!END!
100	! X=	-125.2,	153.0,	2227.9!	!END!
101	! X=	-120.4,	153.0,	2247.2!	!END!
102	! X=	-115.6,	153.0,	2240.9!	!END!
103	! X=	-110.8,	153.0,	2252.0!	!END!
104	! X=	-151.2,	157.9,	1854.5!	!END!
105	! X=	-149.3,	157.9,	1859.0!	!END!
106	! X=	-144.5,	157.9,	1946.8!	!END!
107	! X=	-139.6,	157.9,	2102.4!	!END!
108	! X=	-134.8,	157.9,	2230.9!	!END!
109	! X=	-130.0,	157.9,	2230.9!	!END!
110	! X=	-125.2,	157.9,	2396.2!	!END!
111	! X=	-120.4,	157.9,	2258.1!	!END!
112	! X=	-115.6,	157.9,	2187.2!	!END!
113	! X=	-110.8,	157.9,	2175.1!	!END!
114	! X=	-105.9,	157.9,	2167.5!	!END!
115	! X=	-151.2,	162.7,	2041.9!	!END!
116	! X=	-149.3,	162.7,	1974.0!	!END!
117	! X=	-144.5,	162.7,	2071.0!	!END!
118	! X=	-139.6,	162.7,	2284.2!	!END!
119	! X=	-134.8,	162.7,	2398.3!	!END!
120	! X=	-130.0,	162.7,	2398.3!	!END!
121	! X=	-125.2,	162.7,	2565.0!	!END!
122	! X=	-120.4,	162.7,	2389.3!	!END!
123	! X=	-115.6,	162.7,	2208.5!	!END!
124	! X=	-110.8,	162.7,	2249.3!	!END!
125	! X=	-105.9,	162.7,	2171.5!	!END!
126	! X=	-101.1,	162.7,	2153.6!	!END!
127	! X=	-151.2,	167.5,	2080.6!	!END!
128	! X=	-149.3,	167.5,	2105.2!	!END!
129	! X=	-144.5,	167.5,	2237.9!	!END!
130	! X=	-139.6,	167.5,	2264.0!	!END!
131	! X=	-134.8,	167.5,	2494.8!	!END!
132	! X=	-130.0,	167.5,	2494.8!	!END!
133	! X=	-125.2,	167.5,	2590.6!	!END!

134	! X=	-120.4,	167.5,	2610.7!	!END!
135	! X=	-115.6,	167.5,	2375.1!	!END!
136	! X=	-110.8,	167.5,	2352.0!	!END!
137	! X=	-105.9,	167.5,	2282.7!	!END!
138	! X=	-101.1,	167.5,	2232.6!	!END!
139	! X=	-96.3,	167.5,	2118.4!	!END!
140	! X=	-151.2,	172.4,	2000.0!	!END!
141	! X=	-149.3,	172.4,	1963.8!	!END!
142	! X=	-144.5,	172.4,	2039.3!	!END!
143	! X=	-139.6,	172.4,	2124.0!	!END!
144	! X=	-134.8,	172.4,	2349.7!	!END!
145	! X=	-130.0,	172.4,	2349.7!	!END!
146	! X=	-125.2,	172.4,	2342.2!	!END!
147	! X=	-120.4,	172.4,	2243.8!	!END!
148	! X=	-115.6,	172.4,	2210.5!	!END!
149	! X=	-110.8,	172.4,	2173.1!	!END!
150	! X=	-105.9,	172.4,	2217.4!	!END!
151	! X=	-101.1,	172.4,	2314.6!	!END!
152	! X=	-96.3,	172.4,	2192.1!	!END!
153	! X=	-187.8,	61.3,	1837.7!	!END!
154	! X=	-183.0,	46.8,	1903.0!	!END!
155	! X=	-183.0,	51.6,	1841.3!	!END!
156	! X=	-183.0,	56.4,	1851.8!	!END!
157	! X=	-183.0,	61.3,	1872.7!	!END!
158	! X=	-183.0,	66.1,	1894.0!	!END!
159	! X=	-178.2,	41.9,	2156.7!	!END!
160	! X=	-178.2,	46.8,	1958.5!	!END!
161	! X=	-178.2,	51.6,	1877.7!	!END!
162	! X=	-178.2,	56.4,	1860.7!	!END!
163	! X=	-178.2,	61.3,	1901.0!	!END!
164	! X=	-178.2,	66.1,	1888.5!	!END!
165	! X=	-173.4,	37.1,	2271.2!	!END!
166	! X=	-173.4,	41.9,	2112.7!	!END!
167	! X=	-173.4,	46.8,	2035.7!	!END!
168	! X=	-173.4,	51.6,	1883.8!	!END!
169	! X=	-173.4,	56.4,	1826.5!	!END!
170	! X=	-173.4,	61.3,	1888.3!	!END!
171	! X=	-168.6,	27.4,	2411.6!	!END!
172	! X=	-168.6,	32.3,	2212.4!	!END!
173	! X=	-168.6,	37.1,	2035.5!	!END!
174	! X=	-168.6,	41.9,	2002.0!	!END!
175	! X=	-168.6,	46.8,	2041.2!	!END!
176	! X=	-168.6,	51.6,	1901.3!	!END!
177	! X=	-168.6,	56.4,	1788.0!	!END!
178	! X=	-163.8,	27.4,	2252.7!	!END!
179	! X=	-163.8,	32.3,	2003.7!	!END!
180	! X=	-163.8,	37.1,	1997.9!	!END!
181	! X=	-163.8,	41.9,	1900.8!	!END!
182	! X=	-163.8,	46.8,	1877.3!	!END!
183	! X=	-163.8,	51.6,	1853.2!	!END!
184	! X=	-163.8,	56.4,	1784.8!	!END!
185	! X=	-159.0,	27.4,	1995.3!	!END!
186	! X=	-159.0,	32.3,	1895.6!	!END!
187	! X=	-159.0,	37.1,	1936.7!	!END!
188	! X=	-158.9,	41.9,	1866.7!	!END!
189	! X=	-158.9,	46.8,	1783.6!	!END!
190	! X=	-158.9,	51.6,	1749.5!	!END!
191	! X=	-158.9,	56.4,	1747.1!	!END!
192	! X=	-154.1,	27.4,	1844.7!	!END!
193	! X=	-154.1,	32.3,	1919.5!	!END!
194	! X=	-154.1,	37.1,	1914.0!	!END!

```
  195  ! X=      -167.6,        39.8,      2035.5! !END!
-------------
    a
     Data for each receptor are treated as a separate input subgroup
     and therefore must end with an input group terminator.
```

APPENDIX F

Noise and Vibration

[THIS PAGE INTENTIONALLY LEFT BLANK]

Noise Analysis Methodology

[THIS PAGE INTENTIONALLY LEFT BLANK]

APPENDIX F
NOISE ANALYSIS

This appendix presents the methods that the Section of Environmental Analysis (SEA) of the Surface Transportation Board (the Board) used to define the noise analysis for the Draft Environmental Impact Statement (Draft EIS) of the proposed Dakota, Minnesota and Eastern Railroad Corporation (DM&E) construction and operation. The following sections discuss the process by which SEA evaluated potential noise effects and identified areas would require mitigation.

F.1 DEFINITION OF RAILROAD NOISE

The principal sources of noise SEA considered in evaluation of rail line segments are wayside noise and horn noise. Wayside train noise refers collectively to all train-related operational noise adjacent to the right-of-way, excluding warning horn noise. Wayside noise results from steel train wheels contacting steel rails and from locomotive exhaust and engine noise. The amount of noise created by the wheels on the rails is dependent on the train speed, and the amount of noise created by the locomotive is dependent on the throttle setting. Horn noise occurs in the vicinity of highway/rail at-grade crossings to warn motorists and pedestrians of approaching trains.

Potential sources of noise associated with rail yards include locomotives, rail cars and retarders. Since the rail yards have not been defined, only the methodology is described in this Appendix. Detailed noise calculations will be performed after complete rail yard information is obtained.

F.2 SCREENING PROCESS

The overall goal of the noise study is to identify noise sensitive areas and recommend mitigation, if necessary, where the projected change in operations could result in noise exposure increases that meet or exceed the STB thresholds. The STB regulations (49CFR Part 1105.7(e)(6)) specify that a noise analysis be done for any rail segment where rail traffic will increase by at least 100% as measured by annual gross tons miles or at least 8 trains per day. The regulations specify two types of noise level thresholds:

- An increase in community noise exposure as measured by the Day-Night equivalent sound level (abbreviated L_{dn} or DNL) of 3 decibels (dBA) or more and,
- An L_{dn} of 65 dBA or greater.

The STB used the following approach to determine if the community noise exposure was a 3 dBA increase and the noise levels were expected to be 65 dBA or greater.

1. Develop noise models: A noise model for estimating existing wayside and horn noise was developed based on measurements from existing DM&E trains. The noise model results are sensitive to the horn, locomotive and rail car noise, train length, and train speed. Expected noise levels were developed based on projected noise levels from the expected locomotive noise levels at throttle setting 8 and based on existing train noise measurements.

   Rail yard noise levels are highly variable depending on the types of operations, location of the operation within the rail yard and the frequency of the activity. All of the models used for rail yard noise are common acoustic models defined in acoustics literature. Most of the available data on rail yards is from the Environmental Protection Agency (EPA), Department of Transportation (DOT) and Federal Railroad Administration (FRA) studies. Data from EPA document EPA 550/9-79-21"Background Document for Final Interstate Rail Carrier Noise Emission Regulation: Source Standards, Dec. 1979 and DOT/FRA document DOT/FRA/ORD-82/02-H, Handbook for the Measurement, Analysis and Abatement of Railroad Noise, Jan. 1982 were used for this analysis.

2. Project existing and future noise exposure: Information on distances and noise propagation paths to sensitive receptors and existing and future operation plans have been used to estimate noise exposure in terms of the L_{dn}. The L_{dn} represents an energy average of the A-weighted noise levels occurring during a complete 24 hour period. In calculating L_{dn}, nighttime adjustments are made to reflect most people being more sensitive to nighttime noise. In calculating L_{dn}, the nighttime adjustment makes one event, such as a train passing by between 10 pm and 7 am equivalent to ten of the same events during the daytime hours.

   All existing wayside and horn noise projections were made on noise measurements from four separate locations along the existing rail. For future wayside noise levels, the average train was assumed to be 7,400 feet long, traveling 49 mph, and pulled by 4 locomotives.

   Train horn noise was assumed to start 1/4 mile before all grade crossing and continuing until the locomotive is through the grade crossing. Buildings along the track may act as acoustical shielding for buildings farther from the tracks. Adjustments for shielding can be made using the Federal Highway Administration (FHWA) approach that is summarized in Table F-1. While the FHWA approach accounts for multiple rows of shielding, this evaluation conservatively considered no acoustical shielding.

Table F-1
Adjustments for Acoustical Shielding by Rows of Buildings

Percent of Row Occupied by Buildings	First Row Attenuation	Subsequent Rows Attenuation	Maximum Attenuation
Less than 40%	0 dB	0 dB	0 dB
40 to 65%	3 dB	1.5 dB	10 dB
65 to 90%	5 dB	1.5 dB	10 dB
Greater than 90%	*Analyze using standard barrier attenuation models*		

Source: *Federal Highway Traffic Noise Prediction Model*, T.M. Barry and J.A. Reagan, Federal Highway Administration, report No. FHWA-RD-77-108, Dec. 1978.

Rail yard noise measurements assumed the following noise sources:

- local train operations
- switch engine
- retarders
- rail car impacts
- idling locomotives
- locomotive engine load tests

The distance to the 65 L_{dn} contour for each source was projected to the property boundary. In most cases, the 65 L_{dn} contour was well within the rail yard facility.

3. Count noise sensitive receptors: First, determine whether the projected change in activity is likely to cause a 2 dBA or greater change in L_{dn}. Noise variations of 2 dBA are common near railroads because of the operating conditions, weather, time of day, and equipment maintenance. If the project noise levels are less than 2 dBA, no additional noise study was performed.

Next, estimate the number of noise sensitive receptors within the 65 dBA L_{dn} contour for existing and projected future volumes of activity or where L_{dn} will increase by at least 3 dBA. Instead of doing noise projections for each sensitive receptor, 65 dBA L_{dn} contours were drawn on aerial photographs and USGS 7.5 minute maps. Approximate counts were made of the number of sensitive noise receptors, including residences, schools, and churches within the 65 dBA L_{dn} contour for both the pre- and post-construction train volumes using maps and aerial photographs. The final result of this analysis is an estimate of the total number of sensitive receptors likely to be affected by noise exposure above the 65 dBA L_{dn} levels due to proposed DM&E operation.

F.3 DEVELOPMENT OF WAYSIDE AND HORN NOISE MODELS

Noise measurements of existing DM&E equipment were taken to provide a solid basis for the noise projections. The measurements included train noise from rail lines and noise near grade crossings to document noise levels due to sounding train horns prior to grade crossings.

The measurement data provide a realistic picture of train noise in communities. Details of the measurements and noise model are provided below. The measurements of DM&E trains were performed by Wyle Laboratories the week of August 17, 1998 at four locations in South Dakota determined to be typical of current and proposed operation.

The measurement program consisted of measuring slow-response, A-Weighted sound levels at one second intervals for two trackage and four train speed configurations. Sound level meters were set up at three locations and at perpendicular distances of 50, 100 and 200 feet from the track centerline at each measurement location. The instrumentation used were three Larson-Davis Model 700 Integrating Sound Level meters. Calibration was traceable to the National Institute of Standards and Technology using a Bruel and Kjaer Type 4231 Acoustical Calibrator. During the measurement period, a record was kept of the time and portions of each train passing event (locomotives vs. freight cars) for subsequent data analysis.

After the conclusion of each measurement period, the data logged into each of the sound level meters was downloaded into a laptop computer. Further data analysis allowed the computation of Single Event Levels (SEL) for each of the four measured train passing event. SEL is a logarithmic measurement of the total (time integrated) sound energy of a single noise event. The time limits on the integration typically correspond to the levels that are within 10 dBA of the maximum level of the entire event, or what is commonly termed the 10 dBA down points. SEL is defined by the following equation:

$$\mathbf{SEL = L_{eq} + 10\log(t)}$$

Where $\mathbf{L_{eq}}$ is the measured equivalent energy level during the event and **t,** the time of the event measured in seconds.

F.3.1 Results of Noise Measurements

Site 1 - West of Huron, South Dakota

This site was a rural location approximately 5 miles west of Huron. Passing event noise measurements of a single westbound train were completed at this site on Tuesday, August 18, 1998 at approximately 1 pm. The weather conditions were mostly clear and hot (90 degrees F). Wind speed were between 10 to 15 miles per hour (mph), gusting to 20 mph, throughout the measurement period.

The measured train consisted of three locomotives (SD40-2, GP40Q and SD40-2) along with 62 freight cars. The train speed ranged from 10 to 25 mph during the measurement period as the train was accelerating during the measurement. The trackage configuration was jointed rail on flat grade. The locomotive throttle setting varied from 3 to 4. The locomotive horn was sounded as the train approached the measurement site, which was located near a grade crossing.

Site 2 - De Smet, South Dakota

The second chosen measurement site was a rural location further west of Huron, just outside of De Smet. Site 2 measured the passing event noise measurements of the same single westbound train that was measure at Site 1. The measurements were made on Tuesday, August 18, 1998 at approximately 3 pm. The weather conditions were again mostly clear and hot (93 degrees F). Wind speeds were between 10 to 15 mph, gusting to 20 mph, throughout the measurement period.

The measured train consisted of three locomotives (SD40-2, GP40Q and SD40-2) along with 62 freight cars. The train speed was a consistent 12 mph. The trackage configuration was jointed rail built on 1.3% grade. The locomotive throttle setting was fixed at 8 during the passing event. The locomotive horn was sounded as the train approached the measurement site, which was located near a grade crossing.

Site 3 - Wessington, South Dakota

The measurement site was a rural location east of Huron, just outside the town of Wessington. Passing event noise measurements of a single westbound train were completed on Thursday, August 20, 1998 at approximately 9 am. The weather conditions were clear and warm (80 degrees F). Wind speeds were below 10 mph throughout the entire measurement period.

The measured train consisted of three locomotives (SD40-3, GP38-3 and SD40) along with 41 freight cars. The train speed was 25 mph. The trackage configuration was welded rail on flat grade. The locomotive throttle setting varied between 7 and 8. The locomotive horn was not sounded at this site.

Site 4 - Wessington, South Dakota

The measured train was the same unit measured at Site 3, which consisted of SD40-3, GP38-3, and SD40 locomotives and 41 cars. The train speed was 45 mph and the train had turned around and was headed eastbound. The trackage configuration was again welded rail on flat grade. The locomotive throttle setting varied between 7 and 8. The locomotive horn was not sounded at this site.

Data Summary

There were four train passing events that were measured. Two passing events were on jointed track and two passing events were on welded track, each at a different train speed. Passing events 1 and 2 contained horn noise as the train approached and passed the measurement locations, whereas passing events 3 and 5 did not contain horn noise. Table F-2 shows the SEL for the train passing events.

Table F-2
Railroad Passing Event Noise Measurement Results

Pass by	Trackage Type & Horn Sounding	Locomotive Duration (seconds)	SEL (dBA) at 50 feet	SEL (dBA) at 100 feet	SEL (dBA) at 200 feet
1	Jointed with Horn	13	117.9	111.5	102.9
2	Jointed with Horn	20	117.8	112.7	108.2
3	Welded without Horn	15	101.8	99.3	97.3
4	Welded without Horn	15	101.0	97.4	95.9

F.3.2 Noise Model

The SEL of a single event can be defined in terms of the total passing time, **t**, and the average energy sound level over total passing time, $\mathbf{L_{eq}}$, by the following equation:

$$\mathbf{SEL = L_{eq} + 10\log(t)} \quad \textbf{(Equation 1)}$$

The total SEL of a train passing event can be defined in terms of the combination of two distinct noise elements: noise emission from the locomotive and noise emission from the freight cars. The total SEL of a train passing event is described by the following equation:

$$\mathbf{SEL_{total} = 10\log\{10^{SEL(Loc)/10} + 10^{SEL(cars)/10}\}} \quad \textbf{(Equation 2)}$$

Where **SEL(Loc)** represents the SEL of the locomotive and **SEL(cars)** is the SEL of the freight cars.

The field data indicates that, for the noise measurements made, the horn noise, when present, dominates the total SEL of the passing event. The length of the train, which accounts for the freight car SEL, and the locomotive portion of the total SEL have a negligible contributions to the total SEL of the passing event. Therefore, for a single passing event 100 feet from the track centerline, the total SEL can be represented by :

$$\mathbf{SEL_{total}\text{ (100 feet)} = 112.5} \textbf{ (with horn noise)} \quad \textbf{(Equation 3)}$$

The field data for noise measurements conducted where horn noise is not present, the SEL of singe pass bys of a locomotive and cars, 100 feet from the track centerline can be represented by the following two equations:

$$\mathbf{SEL_{loc}\text{ (100 ft)} = 98.3} \textbf{ (without horn noise)} \quad \textbf{(Equation 4)}$$

$$\mathbf{SEL_{cars}\text{(100 ft)} = 48.5 + 18.2\ LOG\ V + 10\ LOG\ T} \textbf{ (without horn noise)} \quad \textbf{(Equation 5)}$$

Where **V** is the average train speed (mph) and **T** is the train passing event time (seconds).

The passing event time, **T**, can be approximated by the following equation:

$$\mathbf{T = 0.68\ (X/V)} \quad \textbf{(Equation 6)}$$

Where **X** is the average train length (feet) and **V** is the average train speed (mph) on the rail line segment.

The Day-Night average sound level, DNL or L_{dn}, 100 feet from the track centerline can be defined in terms of the average SEL energy for all operations occurring over the course of the day, SEL_{mean}, the total number of daytime operations, N_d, and the total number of nighttime operations, N_n, by the following equation:

$$L_{dn}\ (100\ feet) = SEL_{mean}(100\ ft) + 10 \log [N_d + N_n] - 49.4 \quad \text{(Equation 7)}$$

Where SEL_{mean} is obtained from Equation (3) if the horn is sounded at the location of interest or from Equations (2), (4), (5) and (6) if the horn is not sounded.

Further analysis of the data indicates that the overall SEL near the trackage decays at a rate of 4.5 dBA per doubling, including consideration for excess ground attenuation and distance losses. This is represented by the following equation:

$$L_2 = L_1 + 15 \log[D_1/D_2] \quad \text{(Equation 8)}$$

The distance to the 65 dBA L_{dn} contour, in feet, from the track centerline is given by:

$$D = (100)\ [10^{(Ldn(100\ ft) - 65)/15}] \quad \text{(Equation 9)}$$

Table F-3 presents an example of the computation of the data.

Table F-3
Example Calculation of Distance to 65 dBA L_{dn} Contour

	Grade Crossing Pass by (with horn)	Train Pass by (without horn)
Average Train Speed (mph)	-	12
Average Train Length (ft)	-	4000
Average pass by time (seconds)	-	227
Average Locomotive SEL @ 100 ft.	112.5	98.3
Average Car SEL @ 100 ft.	-	91.7
Average Total SEL @ 100 ft.	112.5	99.2
Number of daytime operations	8	8
Number of nighttime operations	2	2
L_{dn} @ 100 feet	77.6	64.2
Predicted distance to 65 dBA L_{dn} (assumes 4.5 dB loss per doubling distance)	689	89

F.3.3 Future Noise Measurements

The equations used above to measure the distance to the 65 dBA L_{dn} contour depend on the following variables: train speed, train length, and SEL for the horn noise, locomotive, and rail cars. The equations above already account for the change in train speed and train length. The predicted SEL for the future train horn noise was assumed to be equivalent to the existing train horn noise. The locomotives used during the noise measurements, namely the SD40s and the GP40s have L_{eq} values shown in Table F-4. Currently, DM&E proposes to use either 4 locomotives in the 4,000 to 4,400 horsepower engine range or 3 locomotives in the 6,000 horsepower range. The number and size of the engines will depend on the number of rail cars used. The L_{eq} values for the proposed engines are shown in Table F-4.

Table F-4
Locomotive L_{eq} Values at Throttle Setting 8 (without horn)*

Locomotive	Horsepower	L_{eq} at 100 feet (dBA)
SD40-2	unknown	91.5
GP40	unknown	94.5
SD70MAC	4000	85.7
AC4400	4400	83.9
SD90MAC	6000	88.1

* Noise data was supplied by the engine manufacturers (General Electric and General Motors)

As can been seen in Table F-4, the L_{eq} from the future locomotive noise is expected to be less than the existing locomotive noise. Noise measurements for existing trains all had three locomotives. Under the measured noise conditions, the L_{eq} for the three existing locomotives (2 SD40s and 1 GP40) is 97.5 dBA [10 log $(10^{(91.5/10)} + 10^{(91.5/10)} + 10^{(94.5/10)})$]. However, for the future noise predictions, four SD70MAC or AC4400 locomotives could be used under a worst case noise scenario. Under the worst case future operating conditions, the L_{eq} for four SD70MAC engines is 91.7 dBA. The future locomotive passing event time would be increased by 4/3 over the measured locomotive passing event time due to the change from three existing locomotives to four future locomotives.

Using equation (1) above, the net change in SEL can be calculated. The L_{eq} will be decreased from 97.5 dBA to 91.7 dBA or 5.8 dBA. The locomotive length would be increased from about 180 feet (3 locomotives, 60 feet long) to 320 feet (4 locomotives, 80 feet long). Using equation (7) above, and a 30 mph speed, the passing event time is increased by 3 seconds (0.68 (140 feet/30 mph)). Therefore, the net change in SEL is:

$$\text{SEL(change)} = -5.8 + 10 \log (3)$$

or a decrease in SEL of approximately 1 dBA. Conservatively, it was assumed that there was no decrease in locomotive noise between existing and future trains.

The rail cars measured were primarily freight cars. The majority of rail cars in the future would be carrying coal. Data from previous rail car noise measurements made by Harris, Miller, Miller and Hanson (HMMH) during the Conrail, CSX and Norfolk Southern (NS) merger do not show any significant differences in noise between coal trains, merchandise trains, or intermodal trains.

For sake of conservatism, the same equations were used for both the existing and future predicted noise levels.

F.3.4 Rail Yard Noise Projection Model

At this time, the rail yard design is not complete enough to perform a noise analysis. In previous rail acquisitions, the rail yard noise has often been below 65 dBA L_{dn} at the rail yard property boundary. In DM&E's case it is also expected that the rail yard noise will be near 65 dBA L_{dn} at the property boundary. If the 65 dBA L_{dn} extends beyond the property boundary, it is unlikely that residences will be affected since the rail yards are being constructed in rural areas. However, once the rail yard configuration is complete, a noise analysis will be performed according to the following methodology.

This section describes the noise model used for rail yards. The model described in this section is a common acoustic model defined in acoustics literature and has been used extensively for previous STB projects requiring analysis of rail yard noise. The model projects noise from a specific source, such as switch engines or retarders, based on a reference noise level derived from measurements performed on previous STB projects or data available in the literature. Most of the data on rail yards is from EPA or DOT/FRA sponsored studies performed 15 to 20 years ago. The loudest noise sources, such as squeal from hump yard retarders, have not substantially changed since these studies were performed. Changes in equipment noise have been toward lower noise emissions. Data from EPA document 550/9-79-21, "Background Document for Final Interstate Rail Carrier Noise Emission Regulation: Source Standards," Dec. 1979 and DOT/FRA/ORD-82/02-H, "Handbook for the Measurement, Analysis and Abatement of Railroad Noise," Jan. 1982 were used for this analysis. Projections of rail yard noise for the new construction of rail yards and any increase in noise from existing rail yards that meet the STB criteria have been based on this model. The model allows the calculation of L_{dn} for a variety of sources based on empirically-derived source noise levels, yard activity levels, and distance. The model has been developed to project L_{dn} based on the following yard noise sources:

- local train operations
- switch engine
- retarders
- rail car impacts
- idling locomotives
- locomotive engine load tests

Three general equations were used to calculate L_{dn} at a given location depending on the source characteristics. The first equation (Equation 10) listed below is for moving or stationary sources that are transient in nature. Local train operations, switch engine operations, retarders and rail car impacts will be modeled according to the equation as follows:

$$\mathbf{L_{dn} = SEL + 10 \log (N_d + 10N_n) - 49.4 - 10 \log (D/100)^n - k(D-100)} \quad \textbf{(Equation 10)}$$

Where:
SEL = Single Event Level at 100 feet, dBA
N_d = Number of daytime noise events (7am to 10 pm)
N_n = Number of nighttime noise events (10 pm to 7 am)
n = 1 for moving sources; 2 for stationary sources
D = distance from noise source, feet
K = combined air/ground sound absorption coefficient, dBA/ft

F.3.5 Local Train Operations

For local train operations, the speed is assumed to be 5 mph, dominated by locomotive engine noise. The SEL (from the EPA document) is assumed to be 95 dBA. The parameters N_d and N_n will be determined at a later time. The parameter n is 1 for moving sources, and k is 0.0020 dBA/ft. The variable D will be determined based on the various inputs assuming a L_{dn} of 65 dBA. It is assumed that local and road haul train arrivals and departures are uniformly distributed over the daytime and nighttime periods. Thus:

N_d = 15/24[(x)(# Road haul trains/day) + # local trains/day]
N_n = 9/24 [(x)(# Road haul trains/day) + # local trains/day]

F.3.6 Switch Engine Operations

For the switch engine operations, the speed is assumed to be 4 mph, with operations uniformly distributed over the daytime and nighttime periods. Thus:

$$N_d = 15/24[(x/C)(\# \text{ of cars classified/day})]$$
$$N_n = 9/24 [(x/C)(\# \text{ of cars classified/day})]$$

The SEL (from the EPA document) is assumed to be 95 dBA. The parameters N_d and N_n will be determined at a later time. The parameter n is 1 for moving sources, and k is 0.0010 dBA/ft. The variable D will be determined based on the various inputs assuming a L_{dn} of 65 dBA.

For hump switch engine operations, located in the receiving yard, the speed is assumed to be 4 mph, with operations uniformly distributed over the daytime and nighttime periods. The average cut of cars to be humped will be determined at a later date as will engine pass-bys per operation. The SEL is 95 dBA. The parameters N_d and N_n will be determined at a later date. The parameter n is 1 for moving sources, and k is 0.0010 dBA/ft. The variable D will be determined based on the various inputs assuming a L_{dn} of 65 dBA.

For switch engine operations in hump yards, assumed to be located in the departure area, the number of cars handled per switch engine and engine pass-bys per operation will be determined at a later time. For switch engine operations in flat yards, the cars handled per switch engine and the pass-bys per operation will be determined at a later time. The SEL is 98 dBA. The parameter n is 1 for moving sources, and k is 0.0010 dBA/ft. The variable D will be determined based on the various inputs assuming a L_{dn} of 65 dBA.

F.3.7 Retarders

For retarders, it is assumed operations are uniformly distributed over the daytime and nighttime periods. Active retarders, including master, group intermediate, and track retarders, are grouped at a single location at the geometric center of the retarders. For these, it is assumed that each car classified passes two retarders on average, and that retarder squeal occurs about 50 percent of the time. For non-releasable inert retarders, grouped at a single point, it is assumed that each car classified passes through one retarder, and that retarder squeal occurs about 85 percent of the time. Thus:

$$N_d = 15/24[(F)(\# \text{ of cars classified/day})]$$
$$N_n = 9/24 [(F)(\# \text{ of cars classified/day})]$$

Where: $F = 1.0$ for active retarders
$F = 0.85$ for non-releasable inert retarders

For Equation (10), the following inputs were used:

SEL = 100 dBA (active), 90 dBA (non-releasable)
N_d = to be determined at a later time
N_n = to be determined at a later time
n = to be determined at a later time
D = to be determined at a later time
k = 0.001 dBA/ft

F.3.8 Rail Car Impacts

To determine rail car impacts, Equation (10) was used. It is assumed that the total number of rail car impacts is equal to about half the number of rail cars classified per day, and that the impacts are distributed uniformly over the day and nighttime periods. Thus:

$N_d = 15/24[(0.5)(\text{\# of cars classified/day})]$
$N_n = 9/24\ [(0.5)(\text{\# of cars classified/day})]$

For Equation (10), the following inputs were used:

SEL = 89 dBA
N_d = to be determined at a later time
N_n = to be determined at a later time
n = 2
D = to be determined at a later time
k = 0.005 dBA/ft

F.3.9 Idling Locomotives

Idling locomotives were modeled using the following equation (Equation 11):

$$L_{dn} = L_{max} + 10 \log (NH_d + 10NH_n) - 13.8 - 20 \log (D/100) - k(D-100) + 8 \log(1.33N_1) + 10 \log (NR) \quad \text{(Equation 12)}$$

Where: L_{max} = Average maximum source noise level, dBA (67 for idling locomotives)
Nh_d = Number of source operating hours during day (7am to 10 pm)
Nh_n = Number of source operating hours during night (10 pm to 7 am)
D = distance from noise source, feet
k = combined air/ground sound absorption coefficient, dBA/ft (0.0025)
N_1 = number of noise sources per row (2)
NR = number of rows of noise sources (3)

F.3.10 Locomotive Engine Load Tests

Load test cells are modeled according to the following equation (Equation 12):

$$L_{dn} = L_{max} + 10 \log (NH_d + 10NH_n) - 13.8 - 20 \log (D/100) - k(D-100) \qquad \textbf{(Equation 12)}$$

Where: L_{max} = Average maximum source noise level, dBA (78 for idling locomotives, 40 CFR Part 201)
NH_d = Number of source operating hours during day (7am to 10 pm) (4 hrs)
NH_n = Number of source operating hours during night (10 pm to 7 am) (2 hrs)
D = distance from noise source, feet
k = combined air/ground sound absorption coefficient, dBA/ft (0.002)

Where specific information is unavailable, EPA suggests an assumption of 6 hours of testing per day, with NH_d = 4 hours and NH_n = 2 hours.

F.3.11 Noise Results for Wayside Trains

The existing and future number of trains for each segment and alternative are shown in Table F-5 below.

Table F-5
Number of Trains of Each Alternative

Rail Line Segment	Existing Number of Trains	Future Number of Trains		
		20 million tons	50 million tons	100 million tons
Wasta to Midland	2	11	21	37
Midland to Wolsey	4	11	21	37
Wolsey to Huron	6	11	21	37
Huron to Arlington	6	11	21	37
Arlington to Brookings	8	11	21	37
Brookings to Tracy	10	11	21	37
Tracy to Walnut Grove	8	11	21	37
Walnut Grove to Waseca	10	11	21	37
Waseca to Owatonna	14	11	21	37
Owatonna to Lewiston	12	11	21	37
Lewiston to Winona	10	11	21	37
Mankato	10	28	44	--
Winona	10	28	34	42/54

Based on the number of trains for each segment, Table F-6 shows the distances to the 65 and 70 dBA L_{dn} contour for both wayside noise areas and rail crossings.

Table F-6
Distances to 65 and 70 dBA L_{dn} Contours*

Number of Trains	Distance to 65 L_{dn} Wayside	Contour (feet) Crossing	Distance to 70 L_{dn} Wayside	Contour (feet) Crossing
2**	45	320	20	160
4**	85	500	40	260
6**	110	660	60	330
8	150	800	75	400
10**	150	930	80	465
11	200	1000	95	500
12**	160	1050	80	525
14**	180	1160	90	590
18	255	1375	130	690
21	300	1600	145	770
28	365	1850	175	930
34	390	2100	200	1050
37	420	2230	210	1120
42	450	2415	225	1210
44	490	2500	235	1250
54	535	2855	270	1435

* Contour distances were rounded to the nearest five feet.
** Existing Trains

Additional attached tables (FA-1 to FA-7) show detailed information used to develop Table F-6.

F.4 NOISE MITIGATION ANALYSIS

F.4.1 Mitigation Strategies Considered

On the rail line segments meeting the STB's threshold for noise analysis, SEA considered the impacts of wayside noise to warrant mitigation if the noise level at sensitive receptor sites were to increase by at least 5 dBA L_{dn} and reach 70 dBA L_{dn} as a result of the proposed DM&E construction and operation. Noise-sensitive receptors include residences, schools, churches, and hospitals. Some regulatory agencies require mitigation at a lower noise level or at smaller increases in noise level. Before deciding to use the 70/5 dBA L_{dn} noise mitigation criteria, SEA considered the criteria used in past railroad transactions, as well as the following criteria of several Federal transportation agencies:

The Federal Highway Administration (FHWA) in 23 CFR Part 772 specifies that noise levels approach or exceed 67 dBA $L_{eq(h)}$ (hourly energy-averaged noise level) and/or increase substantially over existing conditions before considering mitigation; and it specifies that required noise mitigation must be warranted, feasible, and reasonable. The noise level is in terms of maximum hourly equivalent noise level, denoted as $L_{eq(h)}$. State transportation departments define a substantial increase as generally between 10 and 15 dBA $L_{eq(h)}$.

The Federal Transit Administration (FTA) has noise and vibration criteria that apply to new transit projects; however, these criteria do not apply to the proposed construction. The FTA noise criteria specify a sliding scale of allowed increases in noise level based on existing ambient noise levels. FTA further defines the severity of noise impact based on the land use and whether the associated activities are daytime or nighttime activities (FTA, *Transit Noise and Vibration Impact Assessment*, April 1995).

The Federal Aviation Administration (FAA) considers L_{dn} values above 65 dBA (annual average) unacceptable for residences, schools, churches, and hospitals and considers an increase of 1.5 dBA L_{dn} to be an impact (Federal Interagency Committee on Aircraft Noise, *Federal Agency Review of Selected Airport Noise Analysis Issues*, August, 1992).

In the evaluation of DM&E's rail system, it was assumed that all three projected load levels (20 MNT, 50 MNT, and 100 MNT) meet the SEA noise evaluation criteria (65 dBA L_{dn} and a 3 dBA increase in noise levels) and have to be considered for mitigation. For the 20 MNT load, the increase in noise may not meet the criteria, but was included due to the unknown effect of local traffic changes after the new rail line is operational. Clearly, the 50 MNT and 100 MNT levels will meet the SEA noise evaluation criteria.

SEA's preliminary conclusion is that it should not recommend mitigation to train horns being sounded at highway/rail at-grade crossings until FRA develops and adopts its new regulations. Communities will have the opportunity to qualify for quiet zones once the final FRA regulations are in place.

F.4.2 Feasibility and Reasonableness of Mitigation

SEA acknowledges that noise impacts between 65 and 70 dBA L_{dn} may pose concern to some parties. However, the 70/5 dBA L_{dn} criteria is based on feasibility and reasonableness of mitigation. Feasibility considerations include technical practicality, site topography, the existing noise environment, right-of-way and easement requirements, and public safety. Reasonableness considerations are the vast area of the proposed rail operations, cost effectiveness, and the desires of local residents.

F.4.3 Mitigation Strategies for Noise

The SEA has considered various noise mitigation strategies for the proposed construction. SEA assessed whether there are any ways to reduce horn noise in the vicinity of grade crossings without significantly affecting railroad safety. SEA also examined different ways to mitigate wayside noise (locomotive and wheel/rail noise) along the length of affected rail line segments.

Near grade crossings, warning horns on locomotives constitute the overwhelming majority of noise generated by rail operation. Unlike other potentially adverse environmental impacts, rail horn noise is a deliberately created annoyance imposed to enhance safety. The STB has consistently declined to mitigate noise caused by horns on grounds, stating that any attempt to significantly reduce [train horn] noise levels at grade crossings would jeopardize safety, which we consider to be of paramount importance[1]. A study by the Federal Railroad Administration (FRA) evaluating the impacts of whistle free crossings in Florida on rail safety provides support for SEA's position. In its study, FRA determined vehicle/train accidents increased between 195 and 500 percent, depending on considerations such as how many accidents would not have prevented if whistles were sounded and what constituted an accident, at crossings where whistle soundings were banned[2]. Additionally, in a joint study between FRA and the Association of American Railroads (AAR), it was determined that crossings with whistle bans averaged 84

[1] Federal Transportation Board, Section of Environmental Analysis. *Union Pacific Railroad-control-Southern Pacific Railroad*, Decision No. 4, Finance Docket No. 32760, August 12, 1996.

[2] Federal Railroad Administration, 1999. Cited in *Use of Locomotive Horns at Highway-Rail Grade Crossings; Proposed Rule*. Docket No. FRA-1999-6439, Notice No. 1. Issued December 16, 1999.

percent more collisions than comparable crossings where whistles were sounded[3]. Reducing loudness below certain levels could increase train-vehicle accidents. As the STB has found, reducing the duration of the horn could result in similar negative impacts on safety.

Recently passed Federal legislation, namely, the Swift Act (49 USC 20153) directs the Secretary of the DOT to develop regulations relating to noise and rail safety measures. FRA is the Federal agency within DOT that has the primary responsibility for establishing train horn requirements and alternatives. On January 13, 2000, FRA published a Notice of Proposed Rulemaking in the Federal Register that proposes requirements for locomotive horn sounding at grade crossings and a procedure for the establishment of quiet zones for train horns. FRA defines a quiet zone as a segment of rail line within which is situated one or a number of consecutive highway-rail crossings at which locomotive horns are not routinely sounded. FRA's proposal includes establishing an application process for communities to obtain FRA approval to establish quiet zones. Approval would require the community to implement supplemental safety measures, such as four-quadrant gates, directional horns, median barriers, temporary road closures, or other measures determined by FRA to be effective at enhancing grade crossing safety. FRA has prepared a Draft EIS as part of its proposed rulemaking. Following completion of the EIS process, FRA will publish the final rule. The final rule will take affect one year after publication of the final rule. FRA is continuing the rulemaking process, however, no dates for publication of the final rule have been proposed. SEA believes that FRA's final regulations will provide a safe, effective means to address horn noise concerns.

SEA's preliminary conclusion is that it should not recommend alternatives to train horns being sounded at highway/rail at-grade crossings until FRA develops and adopts its new regulations. Communities will have the opportunity to qualify for quiet zones once the final FRA regulations are in place.

SEA does consider noise impacts to sensitive receptors which meet or exceed the mitigation criteria, stated above, for wayside noise alone to warrant potential mitigation. Table F-7 identifies a number of possible noise mitigation options, the associated advantages and disadvantages, costs, and the circumstances where mitigation might be applied based on the information available to date. Site-specific considerations, for both horn and wayside noise, would dictate the appropriateness of an option for a particular site.

---

[3] Ibid

Table F-7
Potential Noise Mitigation Summary

Mitigation Option	Advantages	Disadvantages	Cost per Unit	Typical Application
Grade Crossing Separations	Eliminates horn sounding	Very expensive	$5 million to $10 million per separation	When also used to address traffic and safety
Grade Crossing Warning Device	Greatly reduced noise impact	Unproven technology	$12,000 to 15,000 per crossing	Medium residential density, high rail traffic crossing
Crossing Closures	Could eliminate horn sounding; inexpensive	Worsens vehicular traffic; limits access	Less than $10,000 per crossing	Low vehicular traffic crossing
Four Quad Gates	Could eliminate horn sounding; considered safe	Not yet FRA authorized	$100,000 to $300,000 per crossing	High residential density, high rail and vehicular traffic crossing
Median Barriers	Could eliminate horn sounding	Some safety concerns; not yet FRA authorized	Varies: $20,000 to $200,000[a] per crossing	Moderate residential density, medium/high rail and vehicular traffic crossing
One Way Street Pairings	Could eliminate horn sounding	Worsens vehicular traffic; limits access; Not yet FRA authorized	Less than $10,000 per crossing	Low vehicular traffic crossing
Building Sound Insulation	Inexpensive noise reduction for nearby buildings, expensive when implemented over larger areas	Noise reduction ineffective outside of building	$10,000 to $20,000 per building	Low residential density crossing (horn or wayside)

Table F-7
Potential Noise Mitigation Summary

Continuous Welded Rail	Provides system-wide noise reduction	Already being done (No new noise improvement)	Varies depending on existing track	System-wide wayside noise
Wheel/Rail Maintenance	Provides system-wide noise reduction	Usually already done (No new noise improvement)	Varies depending on current procedures	System-wide wayside noise
Noise Barriers	Reduces wayside[c] noise in high density residential areas	Can be expensive, restricts access, maintenance, safety concerns	$200 or more per linear foot	High density wayside noise
Land Use Provisions	Can prevent future impacts, reduce severe impacts	Potentially expensive to acquire affected properties	Varies depending on property values	Undeveloped or highly affected areas

a Costs include construction and installation; costs vary with the length of the barrier which is dictated by queue lengths.

b With one-way street, the cross bar can cover the entire street width and eliminate the need for horns

c Wayside noise refers to wheel/rail noise and locomotive noise.

* * * * *

[THIS PAGE INTENTIONALLY LEFT BLANK]

ATTACHMENTS

Tables of Noise Projections for Proposed Train Levels

Ground Vibration Impacts Associated with Unit Coal Trains on the DM&E Railroad

(28 January 2000)

[THIS PAGE INTENTIONALLY LEFT BLANK]

Table FA-1
DME Existing Noise Projections

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft) w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Rapid City to Midland	98.3	10	6400	435.2	93.1	99.4	112.5	2	1.25	0.75	59.5	72.5	43	317	21	159
Midland to Wolsey	98.3	30	6400	145.1	97.0	100.7	112.5	4	2.5	1.5	63.7	75.5	82	504	41	252
Wolsey to Huron	98.3	34	6400	128	97.4	100.9	112.5	6	3.75	2.25	65.7	77.3	111	660	56	331
Huron to Arlington	98.3	21	6400	207.2	95.7	100.2	112.5	6	3.75	2.25	65.0	77.3	100	660	50	331
Arlington to Brookings	98.3	20	6400	217.6	95.6	100.2	112.5	8	5	3	66.2	78.5	120	799	60	401
Brookings to Tracy	98.3	28	6400	155.4	96.8	100.6	112.5	10	6.25	3.75	67.6	79.5	149	928	75	465
Tracy to Wal. Grove	98.3	24	6400	181.3	96.2	100.4	112.5	8	5	3	66.4	78.5	125	799	62	401
Wal. Grove to Waseca	98.3	23	6400	189.2	96.1	100.3	112.5	10	6.25	3.75	67.3	79.5	143	928	72	465
Waseca to Owatonna	98.3	23	6400	189.2	96.1	100.3	112.5	14	8.75	5.25	68.8	81.0	179	1161	90	582
Owatonna to Lewiston	98.3	20	6400	217.6	95.6	100.2	112.5	12	7.5	4.5	68.0	80.3	157	1047	79	525
Lewiston to Winona	98.3	24	6400	181.3	96.2	100.4	112.5	10	6.25	3.75	67.4	79.5	144	928	72	465

Table FA-2
Projected Future Noise Levels for 11 trains/day and 6400 feet length train

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft) w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Midland to Wolsey	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Wolsey to Huron	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Huron to Arlington	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Arlington to Brookings	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Brookings to Tracy	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Tracy to Wal. Grove	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Wal. Grove to Waseca	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Waseca to Owatonna	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Owatonna to Lewiston	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495
Lewiston to Winona	98.3	49	6400	88.8	98.7	101.5	112.5	11	6.875	4.125	69.0	79.9	184	988	92	495

Table FA-3
Projected Future Noise Levels for 11 trains/day and 7400 feet length train

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft) w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Midland to Wolsey	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Wolsey to Huron	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Huron to Arlington	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Arlington to Brookings	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Brookings to Tracy	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Tracy to Wal. Grove	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Wal. Grove to Waseca	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Waseca to Owatonna	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Owatonna to Lewiston	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495
Lewiston to Winona	98.3	49	7400	102.7	99.4	101.9	112.5	11	6.875	4.125	69.3	79.9	194	988	97	495

Table FA-4
Projected Future Noise Levels for 21 trains per day and 6400 feet length

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Midland to Wolsey	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Wolsey to Huron	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Huron to Arlington	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Arlington to Brookings	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Brookings to Tracy	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Tracy to Wal. Grove	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Wal. Grove to Waseca	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Waseca to Owatonna	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Owatonna to Lewiston	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762
Lewiston to Winona	98.3	49	6400	88.8	98.7	101.5	112.5	21	13.125	7.875	71.8	82.7	283	1521	142	762

Table FA-5
Projected Future Noise Levels for 21 trains per day and 7400 feet length

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Midland to Wolsey	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Wolsey to Huron	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Huron to Arlington	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Arlington to Brookings	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Brookings to Tracy	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Tracy to Wal. Grove	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Wal. Grove to Waseca	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Waseca to Owatonna	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Owatonna to Lewiston	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762
Lewiston to Winona	98.3	49	7400	102.7	99.4	101.9	112.5	21	13.125	7.875	72.1	82.7	298	1521	149	762

Table FA-6
Projected Future Noise Levels for 37 trains/day and 6400 feet length train

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft) w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Midland to Wolsey	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Wolsey to Huron	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Huron to Arlington	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Arlington to Brookings	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Brookings to Tracy	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Tracy to Wal. Grove	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Wal. Grove to Waseca	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Waseca to Owatonna	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Owatonna to Lewiston	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112
Lewiston to Winona	98.3	49	6400	88.8	98.7	101.5	112.5	37	23.125	13.875	74.2	85.2	412	2219	207	1112

Table FA-7
Projected Future Noise Levels for 37 trains/day and 7400 feet length train

Line Segment	SEL (loc) locomotive	Velocity mph	Train Length feet	Passby time seconds	SEL (cars)	SEL (total) w/o horns	SEL (total) w horns	Total trains per day	# of day Trains	# of night Trains	Ldn(100 ft) w/o horn	Ldn (100 ft) w horn	Dist. To 65 dBA Ldn(ft) w/o horn	Dist. To 65 dBA Ldn(ft) w horn	Dist. To 70 dBA Ldn(ft) w/o horn	Dist. To 70 dBA Ldn(ft) w horn
Wasta to Midland	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Midland to Wolsey	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Wolsey to Huron	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Huron to Arlington	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Arlington to Brookings	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Brookings to Tracy	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Tracy to Wal. Grove	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Wal. Grove to Waseca	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Waseca to Owatonna	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Owatonna to Lewiston	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112
Lewiston to Winona	98.3	49	7400	102.7	99.4	101.9	112.5	37	23.125	13.875	74.6	85.2	435	2219	218	1112

Ground Vibration Impacts Associated with Unit Coal Trains on the DM&E Railroad

(28 January 2000)

[THIS PAGE INTENTIONALLY LEFT BLANK]

WILSON, IHRIG & ASSOCIATES, INC.
ACOUSTICAL CONSULTANTS

5776 BROADWAY
OAKLAND, CA
U.S.A. 94618-1531
Tel: (510) 658-6719
Fax: (510) 652-4441
E-mail:info@wiai.com
Web: www.wiai.com

GROUND VIBRATION IMPACTS ASSOCIATED WITH UNIT COAL TRAINS ON THE DM&E RAILROAD

28 January 2000

Submitted to:

Mr. Stephen G. Thornhill, P.E.
Burns & McDonnell
9400 Ward Parkway
Kansas City, MO 64114

Prepared by:

James T. Nelson, Ph.D., P.E.
Vice President

[THIS PAGE INTENTIONALLY LEFT BLANK]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

[THIS PAGE INTENTIONALLY LEFT BLANK]

1. INTRODUCTION

This report discusses the potential for ground vibration impacts on wayside structures and land uses caused by the expansion and upgrade of the DM&E Railroad and introduction of unit coal trains in Minnesota and South Dakota The report is based on discussions at the office of Burns & McDonnell, topographical maps showing the alignment, and in-house data for ground vibration produced by railroads elsewhere. The report begins with a review of applicable criteria for ground vibration impacts on people and structures, a discussion of representative test data that WIA has acquired over the years, prediction of ground vibration versus distance from the DM&E Railroad, and a review of vibration mitigation options. The report is limited to a general evaluation of the potential impacts that may occur, rather than a site specific analysis, because of a lack of detailed information concerning soils, propagation characteristics, and structure type. No sites were visited as part of this vibration study.

2. CRITERIA

There are three major types of impacts of concern: 1) building damage, 2) human response, and 3) industrial, commercial, and institutional impacts. Of these, building damage has been identified as a major source of concern by residents along the alignment. There exist desirable limits on vibration to avoid disruption of sleep, discomfort, etc., and much of the reaction to ground vibration by building owners may be related to concern over building damage. Industrial, commercial, and institutional vibration impacts include impacts on sensitive semiconductor manufacturers, laboratory research facilities, and medical equipment.

Building Damage Criteria

Documented cases of damage to structures by vibration produced by rail operations are rare. However, ground vibration produced by railroads can be of a magnitude sufficient to exceed damage criteria under certain circumstances and, therefore, should be of some concern.

The principal unit of measurement used for assessing damage potential is the vibration velocity amplitude, initially proposed as an indicator of damage by Langefors[1] and by Edward and Northwood[2] about 1960. These workers indicate that building damage appears to be most directly related by the velocity amplitude over a broad frequency range, as opposed to the acceleration or

---

[1]Langefors, U., Kihlstrom, C.H., and W.I. Duvall, "Ground Vibrations in Blasting," **Water Power, V10,** February 1958, pp. 335-424

[2]Edwards, A.T. and T.D. Northwood, "Experimental Studies on the Effects of Blasting on Structures," **The Engineer, V210,** September 30, 1960, pp. 538-546.

displacement amplitude. The use of the particle velocity was further supported in research by the U.S. Bureau of Mines.[3]

Two types of velocity amplitudes are in use. The first of these is the peak particle velocity (PPV), or peak amplitude of velocity, occurring during a transient event. The PPV is most common, because it is easily measured with an inexpensive geophone and seismograph. Self-contained unattended portable monitoring units are available for measuring ground vibration, making the measurement process inexpensive and easily accomplished. There exist extensive measurement data correlating the PPV with damage to structures. However, the PPV is sensitive to phase relationships between various frequency components that make up the velocity spectrum, and varying readings may be obtained between two monitors placed within several feet of one-another.

The second type of velocity amplitude is the root-mean-square (rms) velocity occurring during the train passage. The rms velocity is easily measured with a vibration meter, and has an advantage over the PPV of being insensitive to phase relations of various frequency components. Unfortunately, the rms velocity is not used extensively for assessing building damage potential. The building damage criteria referred to here are, thus, primarily given in terms of PPV. For most purposes, the PPV is approximately 3 to 7 times greater than the rms velocity. For convenience, one may assume that the peak particle velocity is 5 times (14 dB) greater than the rms velocity for typical train induced ground vibration.

Historical limits on ground vibration are usually of the order of 2 in/sec to 2.8 in/sec PPV. Many of these are based on intermittent vibration from pile driving or blasting. The US Bureau of Mines established a safe threshold of 2 in/sec for blasting criteria in 1971. However, that criterion has been reduced with time to as low as 0.4 in/sec.[4]

Building damage criteria for transportation sources of vibration are lower than construction or blasting vibration, because of the repetitive nature of transportation vibration. The Federal Transit Administration implies a limit of 0.2 in/sec and 0.12 in/sec PPV for fragile buildings and extremely

---

[3]Nichols, H.R., Johnson, C.H., and W.I. Duvall, **Blasting Vibrations and Their Effects on Structures**, Denver Mining Research Center, Denver CO, Report No. PB-231971, prepared for U.S. Department of the Interior Bureau of Mines (BuMines B656), Washington, D.C., 1971.

[4]Siskind, D. E., Stagg, M. S., Kopp, J. W., and C. H. Dowding, 1980, **Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting,** RI 8507, Bureau of Mines Report of Investigations, U.S. Department of the Interior Bureau of Mines, Washington, D.C., 74 pp.

fragile historical buildings, respectively,[5] exposed to construction vibration. Paolillo recommended a limit of 0.2 in/sec PPV for vibration produced by rail transit systems.[6]

The Federal Highway Administration recommends a limit of 0.1 in/sec PPV for highway traffic generated vibration.[7] This is, perhaps, the most relevant building damage criterion adopted by a federal agency that could be applied to railroad induced ground vibration. The limit evidently applies to all types of structures.

AASHTO recommends damage criteria of 1.0 to 1.5 PPV for engineered structures, 0.4 to 0.5 in/sec PPV for residential structures with gypsum board walls, 0.2 to 0.3 in/sec PPV for residential structures with plastered walls, and 0.1 in/sec PPV for historical or critical structures.[8] These criteria are intended to apply to architectural damage; structural damage criteria would be higher.

The most restrictive criterion that we have encountered is 0.08 in/sec PPV for ancient ruins and historic structures.[9]

There are numerous other studies concerning damage criteria for structures, but the above are representative of criteria applied at United States transit systems and highways. Based on the above, Table 1 summarizes recommended criteria for assessing the potential for damage to buildings by vibration caused by the DM&E Railroad.

---

[5]**Transit Noise and Vibration Impact Assessment,** 1995, Final Report by Harris, Miller, Miller, and Hanson for the US Department of Transportation, Federal Transit Administration, DOT-T-95-16, pg. 12-9.

[6]A. Paolillo, 1980, "Suitability of Existing Vibration Criteria for Rapid Transit Systems," paper presented at the Annual Meeting of the Acoustical Society of America, GA.

[7]**Engineering Guidelines for the Analysis of Traffic-Induced Vibration,** 1978, Final Report, Report No. FHWA-RD-78-166, for U.S. Federal Highway Administration, Offices of Research and Development, Washington, D.C.

[8]**Standard Recommended Practice for Evaluation of Transportation Related Earthborne Vibrations,** 1990, American Association of State Highway & Transportation Officials (AASHTO) Designation: R 8-81.

[9]**DIN 4150: Parts 1-3:** 1986, Structural Vibration in Buildings, Effects on Structures

TABLE 1 CRITERIA FOR BUILDING DAMAGE THRESHOLDS[2]

Category	Description	Peak Particle Velocity[1] - in/sec PPV -
I	Reinforced Concrete Structures	0.5
II	Wood Frame and Unreinforced Masonry	0.2
III	Historical Structures	0.1

Notes: 1 Applies to a bandwidth limited signal between 1 Hz and 80 Hz.

2 Vibration instrumentation and measurement procedures shall conform to ANSI S2.47.

Damage versus vibration magnitude must be considered in a statistical sense. Thus, even if vibration magnitudes are less than the criterion, there is no guarantee that damage will not occur, and there is no certainty that vibration in excess of the criterion will result in damage to a building. The above limits are representative of criteria and standards that have been developed and applied at a number of transportation systems.

The above vibration criteria would apply to vibration measured at the foundation of a building affected by railroad induced vibration. The criteria would specifically apply to the vector sum of vibration amplitude, which may be constructed from the PPV in each orthogonal axes as:

$$PPV_{sum} = (PPV_x^2 + PPV_x^2 + PPV_x^2)^{1/2}$$

For many situations, the vertical component of vibration is reasonably representative of the vector sum of vibration. The horizontal components of ground vibration from trains are usually less than the vertical components, though this is not always the case. Measuring the vertical component is often adequate for characterizing vibration for building damage evaluation.

The vibration velocity should be measured with instrumentation capable of measuring vibration over a frequency range extending from 1 Hz to 100 Hz, a range easily met by many commercial instrumentation manufacturers. The transducer should be rigidly attached to the foundation, or to an aluminum spike driven into the ground within one meter of the setback line of buildings along the alignment. The provisions of ISO 4866 and ANSI S2.47 should be followed in mounting transducers and selecting instrumentation.

Human Response

Recommended limits for human exposure to building vibration are provided in American National Standards Institute S3.29.[10] This standard recommends a limit of 4,000 micro-in/second rms for 1/3 octave vibration velocities at residential structures, equivalent to 72 dBV relative to 1 micro-in/sec. The criterion curve is illustrated in Figure 1. The standard further provides for characterizing vibration in terms of a weighted vibration velocity or acceleration magnitude that includes all frequency components. The limit for the weighted vibration velocity is again 4,000 micro-in/sec. The weighting network approximates the shape of the criterion curve given in Figure 1.

The Federal Transit Administration also recommends an rms vibration velocity limit of 4,000 micro-in/sec, or 72 dBV, for frequent events occurring more than 70 times per day.[11] For less frequent events, the FTA recommended criterion is raised to 10,000 micro-in/sec, or 80 dBV. However, the less frequent events covered by the FTA are short commuter trains or rail transit trains, rather than long freight or unit trains.

The FTA recommends limits of 75 dBV (5,600 micro-in/sec rms) and 83 dBV (14,000 micro-in/sec rms) for frequent and infrequent events, respectively, for institutional land use, which would include quiet offices, schools, churches, and other areas involving cognitive activity. This would not apply to offices in industrial spaces. ANSI S3.29 suggests a limit of 16,000 micro-in/sec (84dBV) for all offices.

Occupants of commercial structures are less susceptible to ground vibration, due primarily to daytime activities. Examples of commercial structures include shops, shopping centers, hallways, or other areas involving primarily day use with people standing or moving about. The ANSI Standard S3.29 recommendation for institutions would be a limit of 16,000 micro-in/sec (84 dBV).

Recommended criteria for human occupancy are summarized in Table 2. Meeting these limits would not guarantee that complaints concerning ground vibration will not occur, but would result in ground vibration levels that are reasonable and acceptable.

---

[10]American National Standard Institute S3.29-1983, **Guide to the Evaluation of Human Exposure to Vibration in Buildings,** Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, New York 10017

[11]**Transit Noise and Vibration Impact Assessment,** 1995, Final Report by Harris, Miller, Miller, and Hanson for the US Department of Transportation, Federal Transit Administration, DOT-T-95-16, pg. 8-3.

TABLE 2 VIBRATION IMPACT CRITERIA FOR HUMAN OCCUPANCY[1]

Category	Description	in/sec-rms[2]	dBV[2,3]
I	Residential	0.004	72
II	Offices, waiting rooms, schools, churches	0.008	78
III	Commercial	0.016	84
IV	Workshops, industrial	0.032	90

Notes:

1) The vibration impact criterion should not be less than existing vibration produced by trains.

2) The rms vibration amplitude or level should be determined during the duration of passage of the train

3) The level in decibels is relative to 1 micro-in/sec

Vibration Sensitive Industrial, Research, and Medical Facilities

There exist numerous environmental vibration specifications for vibration sensitive equipment used by industry, education, and medical institutions. These specifications should be consulted if there is a concern over vibration at a specific site for a specific piece of equipment.

Generic criteria are published for various types of industrial or research activities that might be affected by ground and building vibration. These criteria provide a means of assessing possible vibration impacts without precise knowledge of specific pieces of equipment.

Industrial Facilities

Vibration sensitive industries include semiconductor manufacturing, lens grinding, milling operations, or other types of activities where precision tool alignment and inspection are of prime importance. The FTA recommends an rms vibration velocity level limit of 65 dBV (relative to 1,800 micro-in/sec) for both frequent and infrequent events for these types of facilities. However, the state-of-the-art in semiconductor manufacturing demands that overall floor vibration be limited to 1,000 micro-in/sec (60 dBV), and that 1/3 octave band vibration be limited to as low as 250 micro-in/sec (48 dBV). The latter low limits are appropriate for sub-micron photo-lithography steppers, wafer inspection machines, and scanning electron micro-scopes. Vibration below these limits would not be expected to affect high power micro-scopes, precision balances, and other common laboratory equipment. Many pieces of properly isolated semiconductor manufacturing equipment may operate satisfactorily at floor vibration magnitudes as high as 2,000 micro-in/sec rms.

The Institute of Environmental Sciences has established limits for 1/3 octave band floor vibration for various types of vibration sensitive equipment found in "clean rooms," such as those employed in the semiconductor industry.[12] These equipment are representative of equipment used in other high precision manufacturing or industries or educational institutions. The limits apply to 1/3 octave band root-mean-square vibration velocity magnitudes. They could also be applied to overall vibration velocity magnitudes, with an amplitude multiplying factor of 1.4 (+3 dB).

Sensitive manufacturing facilities located close to the DM&E alignment may already be experiencing vibration in excess of limits for sensitive equipment. Therefore, for existing receivers, the vibration impact criteria for sensitive manufacturing should not be less than the vibration produced by existing rail traffic and other sources. If a semi-conductor manufacturer is located within 1,000 feet of the track, the facility should be inspected, vibration measurements conducted to ascertain existing vibration with and without trains, and equipment specifications should be reviewed, before determining the potential impact of train vibration.

Research Institutions

Research institutions may have unique vibration sensitive equipment with unknown characteristics. Examples include laser interferometers, magnetometers, and so-forth. A site inspection should be conducted to identify any sensitive pieces of equipment that might be subjected to train vibration. As with sensitive manufacturing facilities, research institutions located close to the DM&E alignment may already be experiencing vibration in excess of limits for vibration sensitive instruments. Therefore, for existing receivers, the vibration impact criteria for sensitive research institutions should not be less than the vibration produced by existing rail traffic and other sources. If a research facility is located within 1,000 feet of the track, the facility should be inspected, vibration measurements conducted to ascertain existing vibration with and without trains, and equipment specifications should be reviewed, before determining the impact of train vibration. For certain types of equipment such as high resolution metrology systems of resolution 0.1 micron or better, the impact range might be extended to 5,000 ft, depending on geology.

Medical Facilities

Medical facilities may have sensitive equipment that could be affected by train vibration. Examples include scanning electron micro-scopes, magnetic resonance imaging systems, bench micro-scopes, micro-balances, and similar laboratory equipment. The FTA recommends a limit of 65 dBV (1,800 micro-in/sec) for buildings where low ambient vibration is essential for interior operations, and this would presumably apply to vibration sensitive areas in hospitals. However, there may exist other equipment that are particularly sensitive to vibration. Micro-balances and high-power micro-scopes may be affected by floor vibration exceeding 1,000 micro-in/sec (60 dBV). One of the most sensitive pieces of equipment often found at hospitals is the electron micro-scope, which may be

---

[12]**Recommended Practice IES-RP-CC012.1, Considerations in Cleanroom Design,** Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, Illinois 60056

affected by 1/3 octave band vibration velocities exceeding 250 micro-in/sec. Modern, well designed electron microscopes with pneumatic vibration isolators can withstand higher levels of vibration. Certain cell counting and other analytical instrumentation may be similarly affected.

Magnetic resonance imaging systems (MRI) are very common at large hospitals and at smaller radiography clinics. Many MRI's are capable of withstanding significant vibration without adverse impact on operation. However, the state-of-the-art in magnetic resonance imaging has advanced considerably over the last ten years, with the result that systems are appearing with very restrictive specification limits on floor vibration. For example, the most recent (1998) GE Medical Systems specification for MRI's limits ground vibration measured with a narrowband analyzer with effective noise bandwidth of 0.75 Hz and resolution of 0.5 Hz to less than 10 micro-g from 0 to 10 Hz, 50 micro-g from 10 to 30 Hz, 10 micro-g from 30 to 38 Hz, and 2,000 micro-g from 38 to 45 Hz. The limits are ambiguous, because they are also given for an analysis with effective noise bandwidth of 0.2 Hz and resolution of 0.125 Hz. (The effective noise bandwidth is the bandwidth of each analysis bin in the frequency spectrum, and the amount of random vibration energy measured within each bin increases linearly with increasing frequency bandwidth.) The specification further indicates that transient vibration amplitude should be limited to 500 micro-g zero-to-peak, which is easily exceeded by footfall and mechanical equipment induced vibration where these MRI's are installed on composite metal deck and concrete floors.

Ground vibration produced by freight trains passing at roughly 600 feet at 50 mph can exceed the spectral limits on floor vibration discussed above for MRI's. If a medical facility with vibration sensitive equipment is located within 1,000 feet of the track, the facility should be inspected, vibration measurements be conducted to ascertain existing vibration with and without trains, and equipment specifications should be reviewed, before determining the impact of train vibration. Vibration impact criteria should not be more restrictive than existing vibration produced by trains and other sources.

ANSI Standard S3.29 recommends a limit of 2,800 micro-in/sec (69 dBV) for operating rooms during times when surgical activities are occurring. However, ceiling mounted microscopes often require less than 500 to 1000 micro-in/sec (54 to 60 dBV) for satisfactory performance. The ceiling mounted microscopes are susceptible to vibration because of the cantilevered adjustable arms supporting the microscopes.

Table 3 summarizes recommended vibration criteria for various types of vibration sensitive equipment that might be affected by ground vibration. Meeting these limits should result in little or no vibration impact, and there is a significant probability that ground vibration magnitudes moderately in excess of these limits by a factor of 2 (equivalent to 6 dB) would not result in impact on operations. There is also a significant probability that existing vibration magnitudes due to trains and internal building sources are in excess of these limits. Therefore, a survey of existing vibration should be conducted at potentially impacted receivers to determine existing vibration levels both with and without existing trains, and equipment specifications should be reviewed, before determining impact on a specific site.

TABLE 3 VIBRATION IMPACT CRITERIA FOR SENSITIVE FACILITIES

Category	Description	1/3 Octave Vibration[1]	
		1/3 Octave Velocity micro-in/sec-rms[2]	dBV[2,3]
	Surgical Theaters	2800[4]	69
	Magnetic Resonance Imaging Systems	500[5]	54
VC-A	Optical micro-scopes to 400x, micro-balances, optical balances, proximity and projection aligners	2,000[6]	66
VC-B	Optical micro-scopes to 1000x, inspection and photo-lithography equipment to 3micron line width	1,000[6]	60
VC-C	Photo-lithography and wafer inspection systems at 1 micron line width	500[6]	54
VC-D	Electron micro-scopes, E-beam systems, operating to the limits of their capability (100,000x)	250[6]	48

Notes:

1) The vibration impact criterion should not be less than existing vibration produced by trains.

2) The rms vibration amplitude or level should be determined during the duration of passage of the train

3) The level in decibels is relative to 1 micro-in/sec

4) Source: ANSI S3.29

5) Estimated from specifications and data

6) Source: Institute of Environmental Sciences

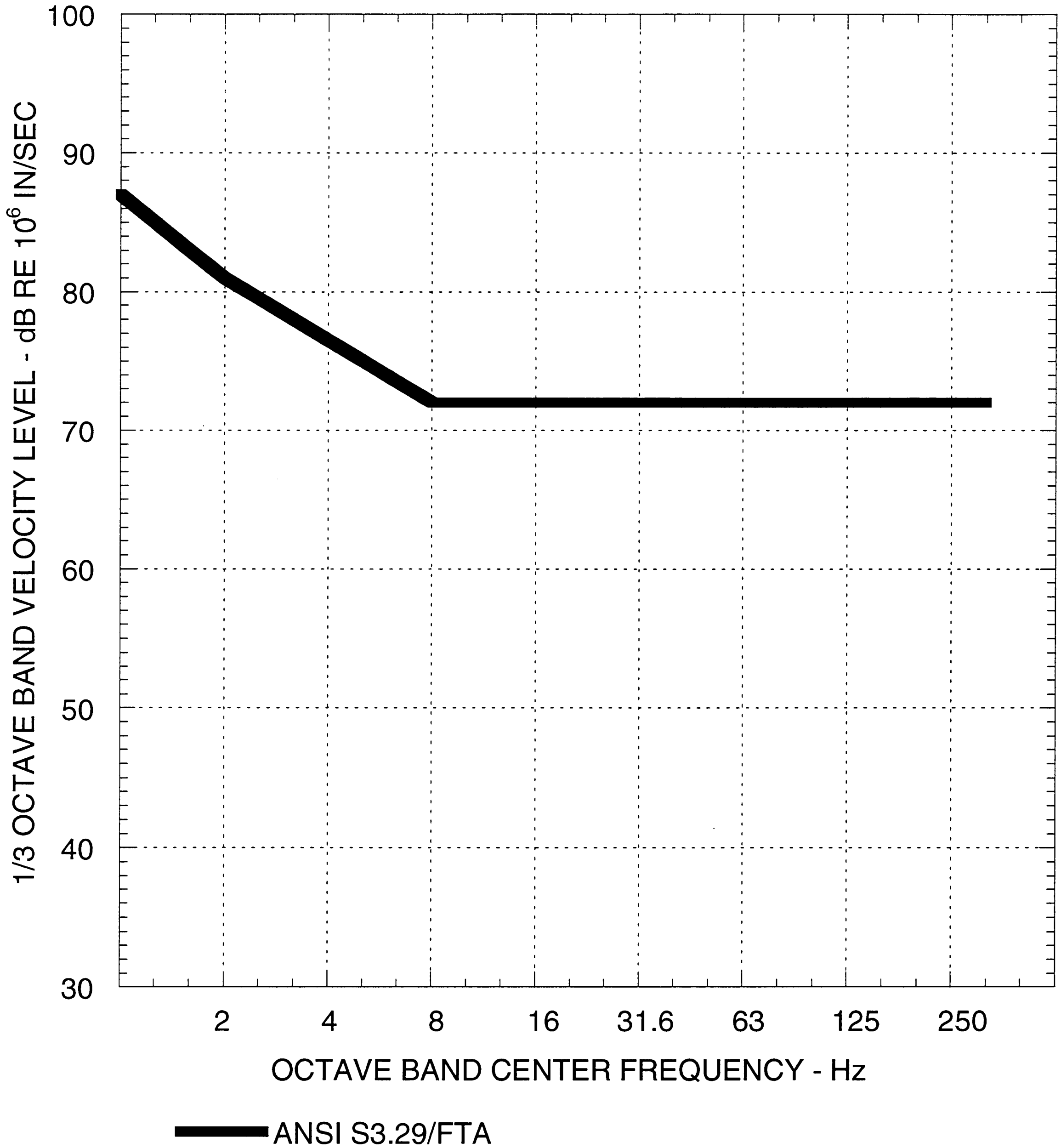

FIGURE 1 RESIDENTIAL FLOOR VIBRATION CRITERION

3. EXAMPLES OF GROUND VIBRATION FROM TRAINS

This section concerns representative vibration data that provide a basis for estimating ground vibration from unit coal trains operating along the up-graded portions of the DM&E track. The data were collected from a variety of sources, and are by no means exhaustive. Further, they are not substitutes for data collected at specific sites that might be affected by the DM&E upgrade and introduction of unit coal trains.

The data are presented in terms of 1/3 octave band root-mean-square (rms) vibration velocity levels in decibels relative to 1 micro-in/sec. The magnitude of vibration velocity can be obtained from the level in decibels according to the following formula:

$$v \text{ (micro-in/sec)} = 1 \text{ micro-in/sec} \times 10^{(L \text{ (dBV)}/20)}$$

Here, the unit for vibration level is dBV. The vibration level is analogous to sound level in decibels, and the letter "V" is appended to distinguish vibration velocity levels from the sound levels, such as the A-weighted sound level, dBA. The level is referenced to one micro-in/sec.

Conversely, the level in decibels is given by:

$$L(\text{dBV}) = 20 \text{ Log}_{10}\, v_{rms}(\text{micro-in/sec})$$

Kamloops, BC

Significant vibration occurred in Kamloops, BC, after worn gag-pressed rail was replaced with new roller-straightened continuous welded rail over one of two parallel tracks. Introduction of unit trains consisting of coal hopper cars was met with vigorous community reaction and concern over building damage. The vibration due to trains operating on the new track was significantly higher than due to trains operating on older adjacent track.

One-third octave ground vibration spectra for various train speeds are plotted in Figures 2 and 3 for distances of about 100 and 200 feet (30 and 60 meter) from the track. In these examples, the frequencies of the peaks in the 1/3 octave band spectra increase from 4 Hz to 10 Hz as the train speed increases from 20 to 40 mph. A narrowband analysis of recorded analog data (not shown here) indicated that the spectral peak was related to the roller pitch diameter of the straightening machine used by the steel mill. An extenuating factor, however, was the soil, which responded readily to vibration forces.

The levels of vibration recorded at both 100 and 200 feet from the track were very much in excess of the criteria discussed above for residential use and greatly in excess of criteria for a variety of industrial processes. While these levels can be considered extreme, they could occur at any railroad passing over soft alluvial soils, such as might be encountered in river bottom-land, with undulating rail and unit trains.

A number of claims were made for building damage resulting from the ground vibration produced by these trains. However, the peak particle velocities were of the order of 0.1 in/sec, comparable with the most restrictive criterion for building damage. No information has been obtained concerning resolution of these claims.

The roller straightened rail was replaced again with new roller straightened rail that was straightened to a straightness specification of about plus or minus 0.015 inch over any 6 foot long section of the rail. (The actual specification was not obtained for this report.) The ground vibration obtained at 30 and 60 meters from the retrofitted track are illustrated in Figures 4 and 5. Although not shown here, the levels obtained for the roller straightened rail were comparable with levels obtained for unit trains operating on gag-pressed rail. Figure 6 compares 1/3 octave band spectra measured at 30 meters from the rail before and after replacement. Replacement of the undulating rail with rail straightened to specifications produced a substantial reduction of ground vibration. The post replacement vibration levels at 8 Hz were only moderately higher than the human exposure criterion curve of Figure 1, but were substantially reduced from previous levels, and comparable with or less than before the track up-grade

The principal conclusion to be drawn from these data is that wayside ground vibration is directly related to rail straightness. Wheel roughness and radial run-out also have a similar effect on wayside ground vibration. Unfortunately, rail manufactured in the United States is not normally subject to a straightness specification except for upturn at the ends of rail sections. Thus, one may not guarantee that new rail supplied for upgrade of the DM&E railroad will not have an undulation due to manufacturing processes. Once laid, there is no evidence that the rail will straighten with time. In fact, the literature suggests that the rail will assume the profile established during manufacture. Thus, care must be exercised in selecting new rail for installation in vibration sensitive areas, and a specification for maximum undulation can be considered as part of the procurement process.

Gag pressed rail is not necessarily less significant than roller straightened rail. In fact, there is no quantitative specification employed for undulation when straightening with a gag-press. The rail is simply specified to be "straight". However, gag-pressed rail would not contain coherent undulation such as that produced by the rollers of a roller straightener. The economics of rail manufacturing are probably such that gag-pressed rail is not readily available, and roller straightened rail manufactured to tight tolerances for vertical and lateral undulation would appear to be acceptable for controlling vibration.

Reno, Nevada

An example of ground vibration at 10 and 50 feet from the Union Pacific tracks in in downtown Reno, Nevada, are presented in Figure 7. Trains speeds were of the order of 15 to 20 mph. The track condition was unknown, though the data were collected in 1978 when the road was owned by Southern Pacific, and are representative of main line track of a major transcontinental railroad. Soil data were not obtained, but the area is within about ½ mile from a river, and the terrain is reasonably flat, indicative of uniform soil conditions. This is a high desert, located at the foot of the Sierra Nevada mountains. The soil would be expected to be relatively stiff.

The 1/3 octave spectra obtained at this location differ considerably from those obtained at Kamloops, probably because of differences in soil, consist type, train speed, and rail. These data are probably representative of ground vibration from low-speed trains on reasonably stiff soil. For example, the low frequency vibration is much lower than vibration at higher frequencies, with the maximum centered about the 31.5 Hz 1/3 octave band.

Goleta, California

Vibration data for freight trains running on continuous welded rail in Goleta, California, are presented in Figure 8 for distances of 110 and 190 feet from the track. The topography is locally flat, but the coastal mountains are located north of the community, within a mile of the track, and the Pacific Ocean is located within a mile or so of the track.

The data collected in Goleta differ from that collected at Reno, Nevada. The peaks in the vibration spectra occur at low frequencies, in contrast to the data shown for Reno. Again, soil layering and stiffness, train speed, vehicle type, and rail condition are major factors. The data are actually comparable with vibration levels discussed above for unit trains running on straightened rail in Kamloops, British Columbia. One would expect that unit trains operating on these rails would produce higher vibration levels than those measured, due to differences in weight. The vibration levels are within criteria for residential floor vibration, but could be in excess of criteria for sensitive manufacturing operations.

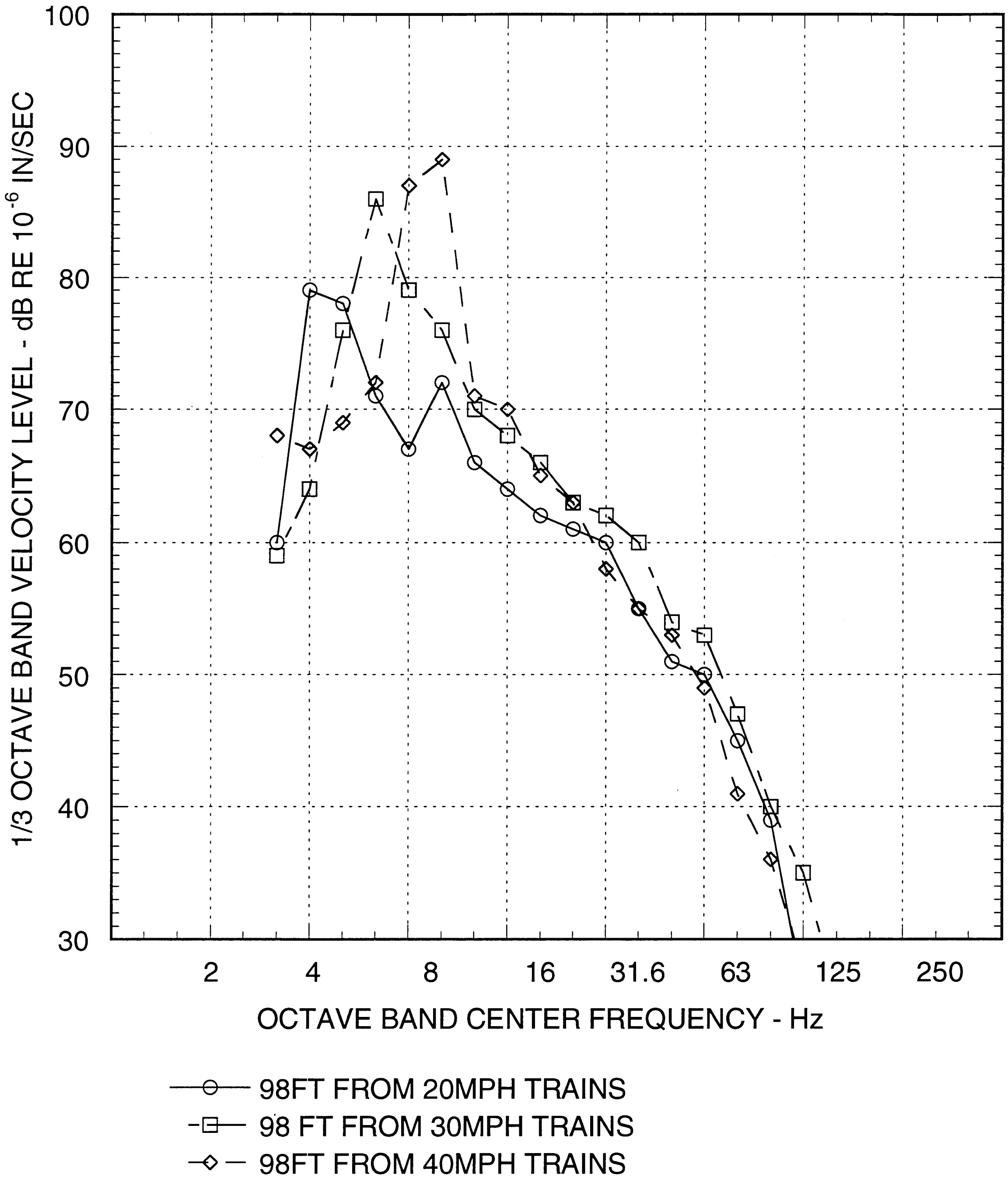

FIGURE 2 GROUND VIBRATION PRODUCED BY LOADED HOPPER CARS ON ROLLER STRAIGHTENED CONTINUOUS WELDED RAIL

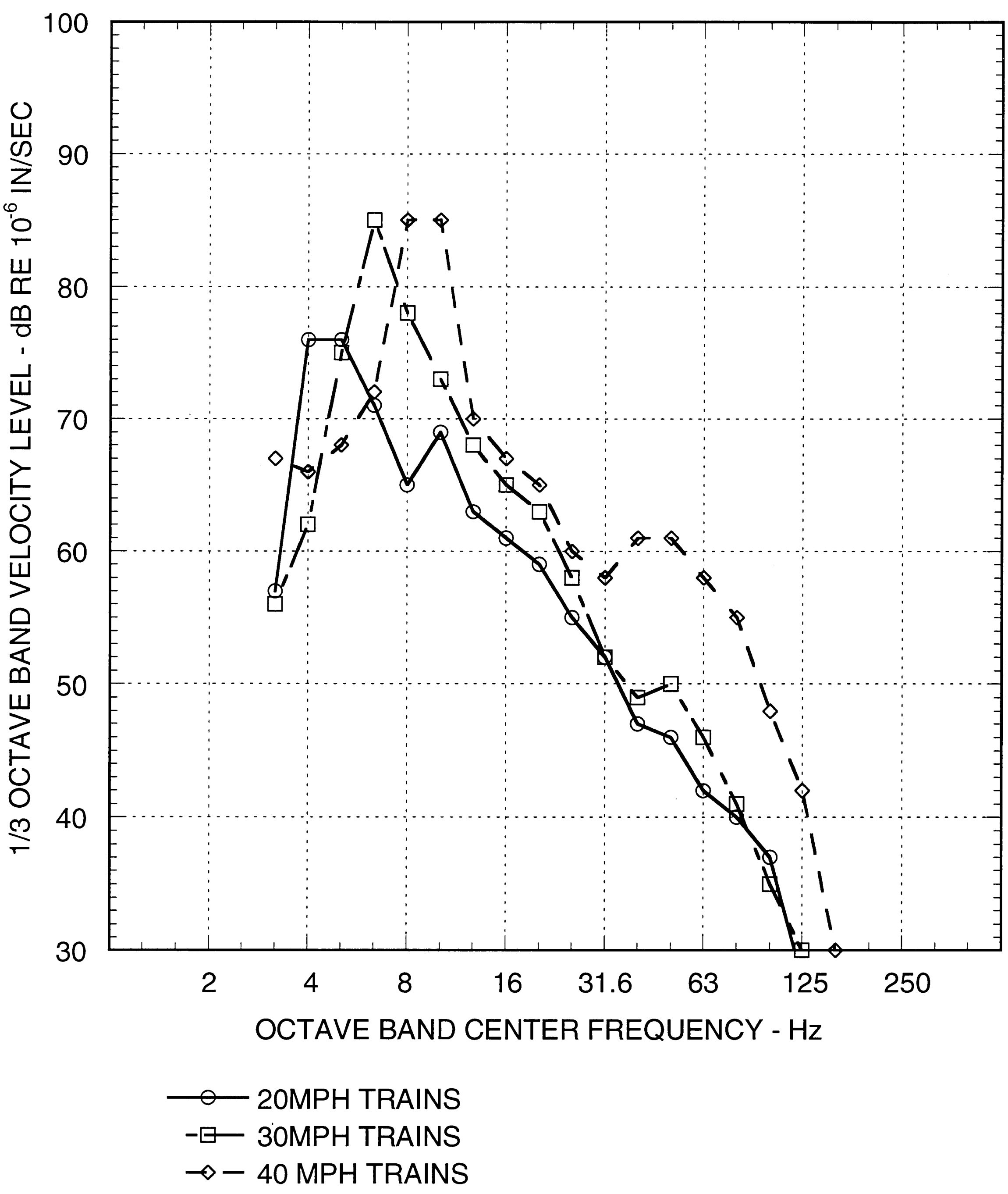

FIGURE 3 GROUND VIBRATION AT 200 FEET FROM PASSING UNIT TRAINS

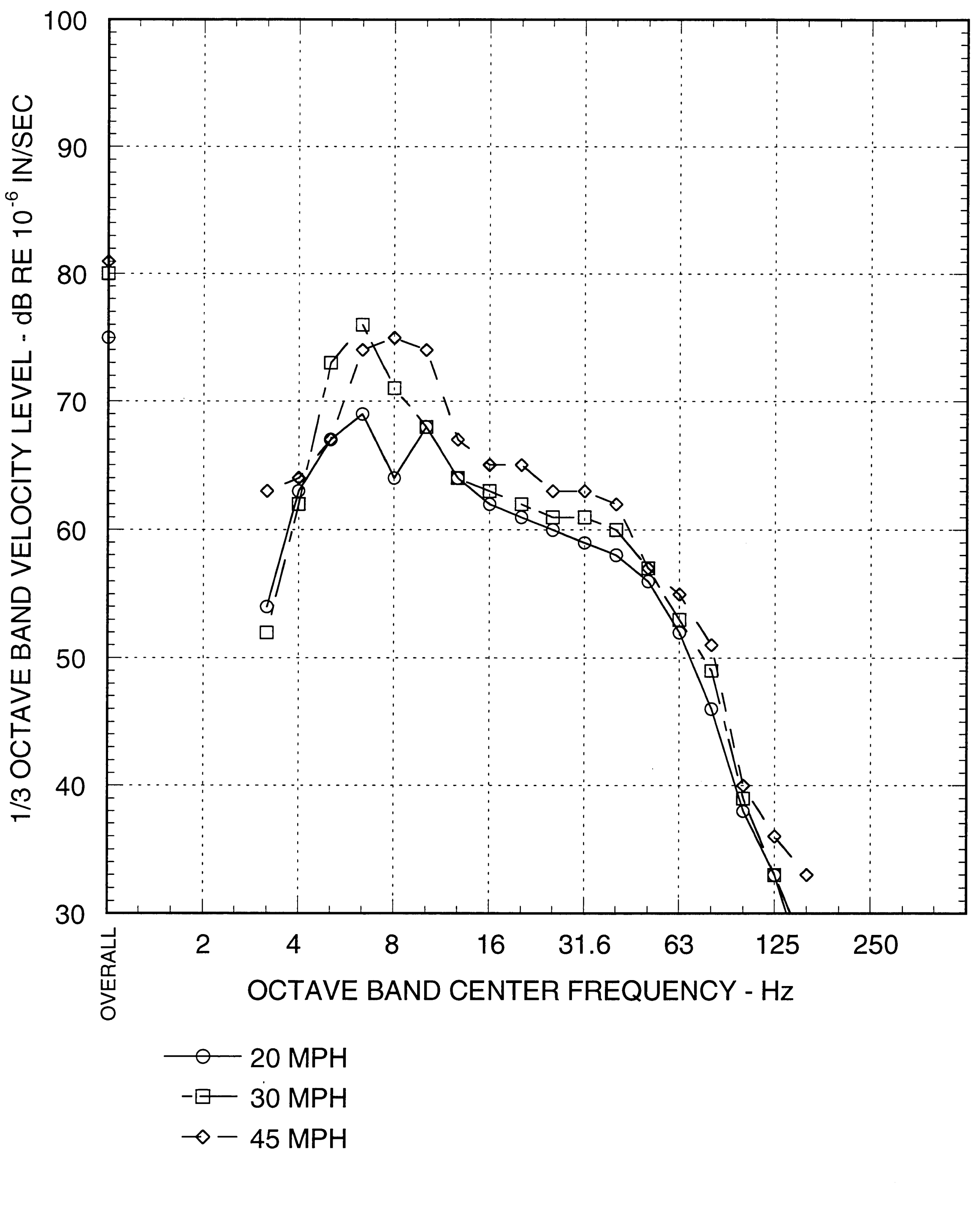

FIGURE 4 GROUND VIBRATION AT 30 M FROM UNIT TRAIN ON ROLLER STRAIGHTENED RAIL WITHOUT UNDULATION

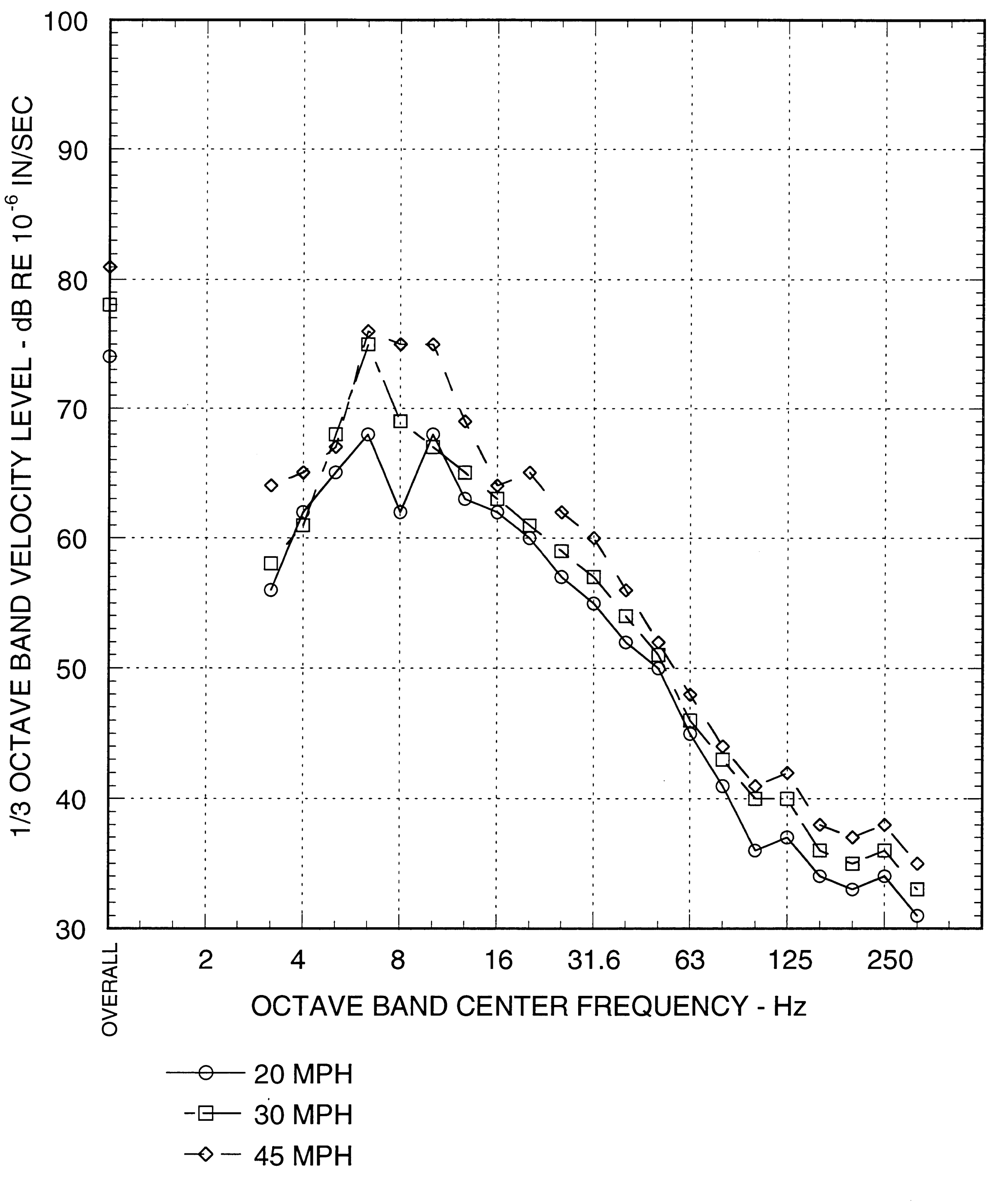

FIGURE 5 GROUND VIBRATION AT 60 M FROM UNIT TRAINS ON ROLLER STRAIGHTENED RAIL WITHOUT UNDULATION

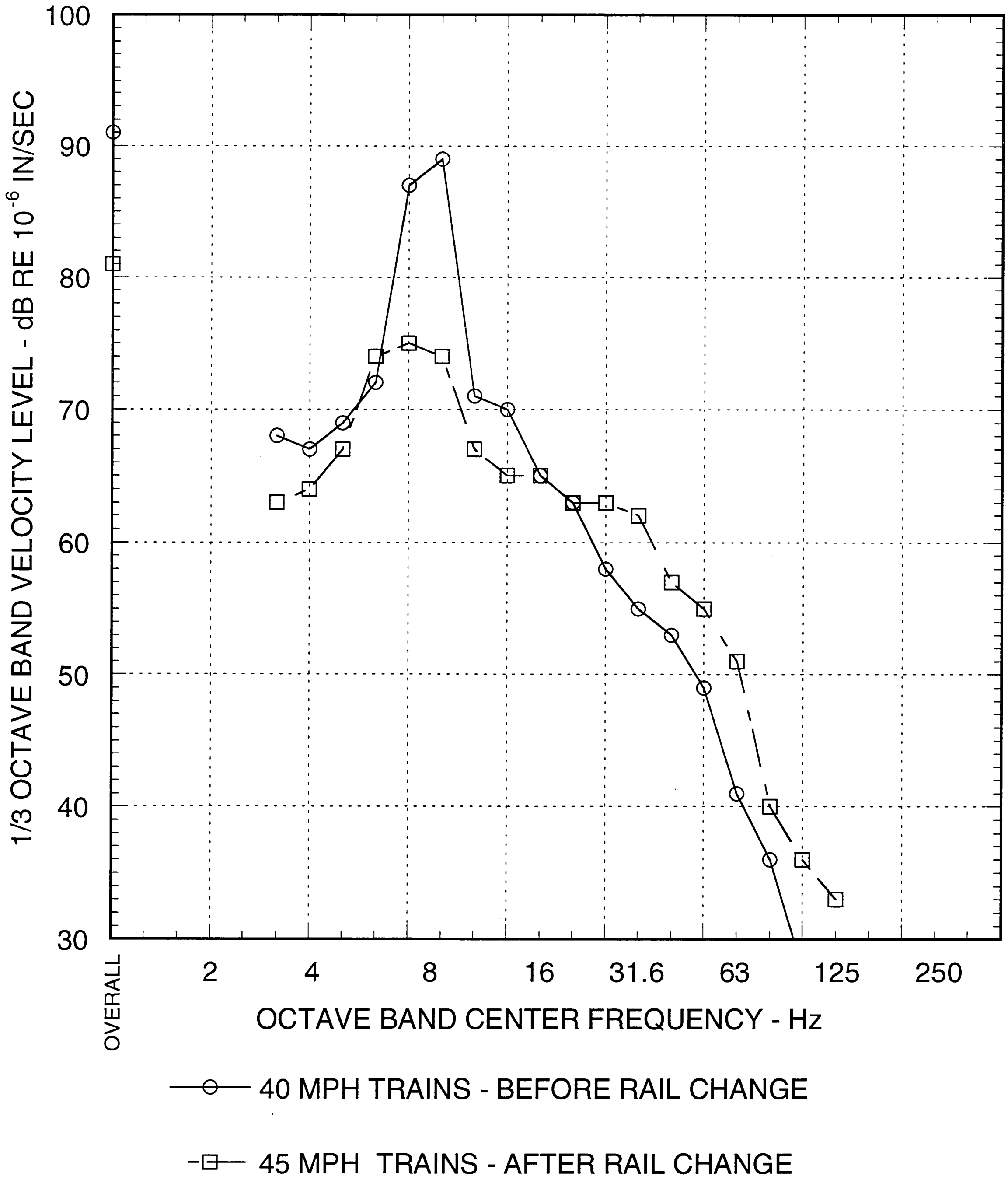

FIGURE 6 COMPARISON OF GROUND VIBRATION BEFORE AND AFTER CHANGE OF ROLLER STRAIGHTENED RAIL

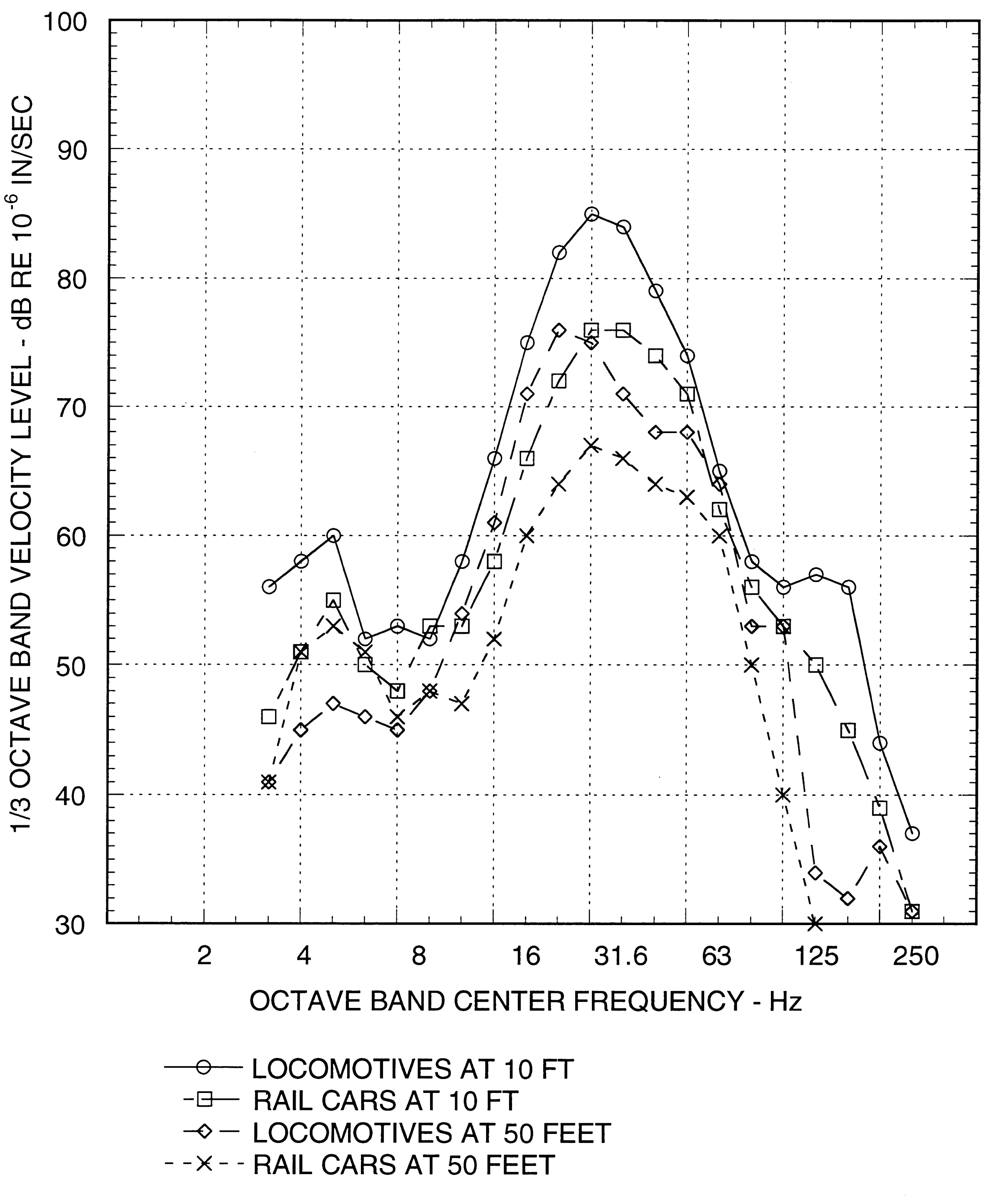

FIGURE 7 GROUND VIBRATION FROM PASSING LOW-SPEED FREIGHT TRAINS IN DOWNTOWN RENO, NEVADA

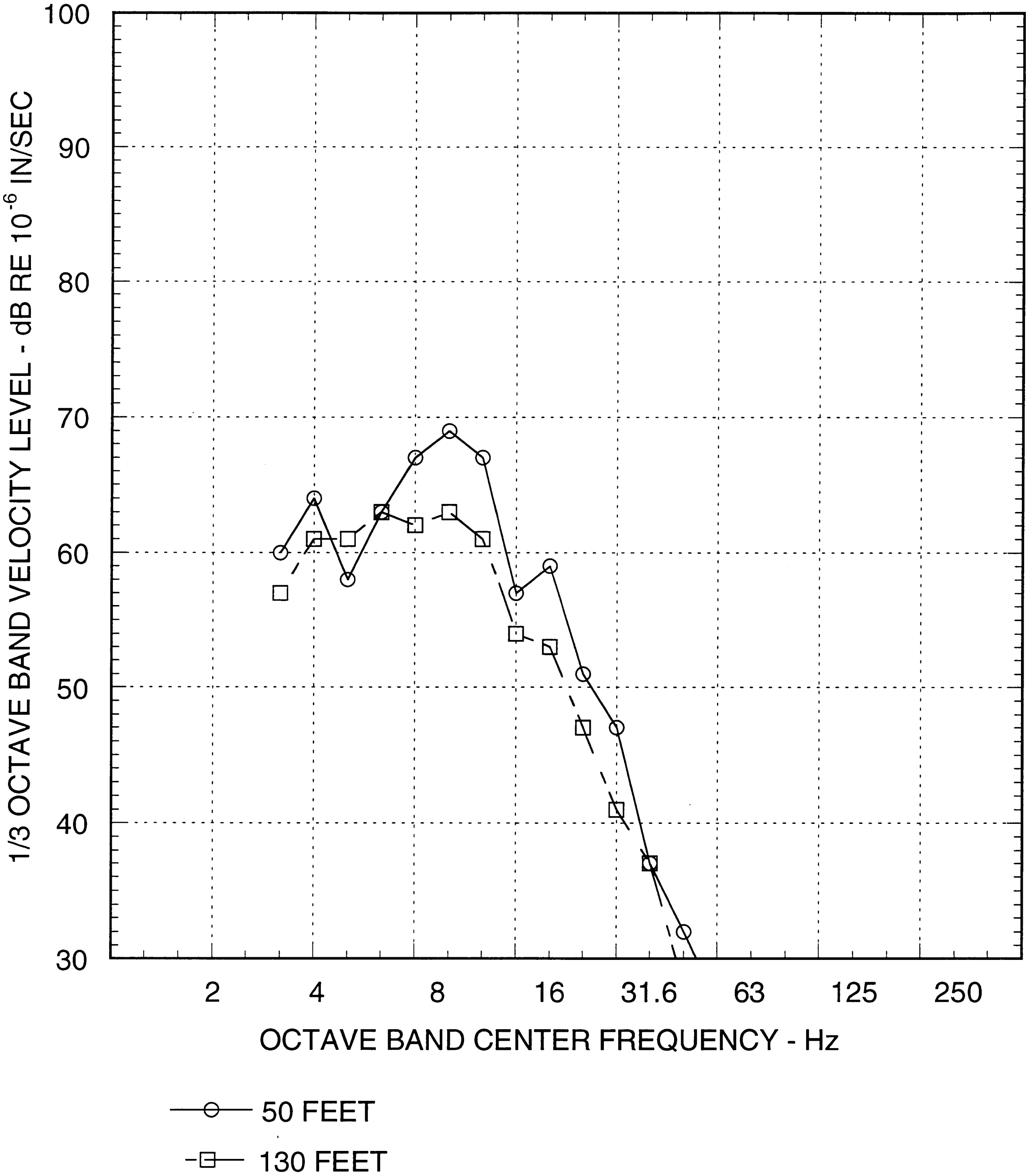

FIGURE 8 GROUND VIBRATION FOR 60 MPH FREIGHT TRAIN IN GOLETA, CALIFORNIA