Oak Ridge Health Studies Document Summary Form

DOCUMENT TITLE: Maximum Ground Concentrations from the 7500 Stack

DOCUMENT NUMBER OR IDENTIFIER: ___

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PUBLICATION DATE: 12/9/53

DATA TIME PERIOD: Start 1953 Stop

CLASSIFICATION CATEGORY: UNK (UNC) OUO UCNI CL* *Category & Level: FRD or RD or NSI; CONF or S or TS

SITE(S) DOCUMENT ADDRESSES: K (X) Y S ORR MELT CLIN WOC WOL POPL EFPC PCE BEAR WATT

SOURCE/LOCATION OF DOCUMENT: X-10 ~~DOC~~ DF : Reactor - Homogeneous (1953)

DOCUMENT CATEGORY

AI [DL dr dc da] [ED (ea) ew es ef] EP [HO hp hr hs hw] IN IP [ST (sa) sw ss] TM WP

Primary category - circle once; Secondary category (optional) - circle twice. Circle only one in a bracketed group.

DATE ENTERED INTO DATABASE: BY: InMagic No.

KEYWORDS: air release stack meteorology

ABSTRACT:

Update of a previous evaluation of the limitations on fuel leakage from the HRE by Burnett (CF-52-3-208), which made an assumption that the minimum dilution of the stack effluent at a distance of 500 meters (from building 7503) was about 2000. New data evaluated by the meteorological group indicates that the minimum dilution may be higher. The paper gives the maximum ground concentration for a unit emission rate of 1 curie/second and the distance from the stack at which this concentration is expected to occur.

COPY AT: ACA

REVIEWER: GM Bruce DATE REVIEWED: 3/28/96

ChemRisk Document No. 2669

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UNITED STATES
ATOMIC ENERGY COMMISSION

In Reply
Refer To: ORB:RFM

Oak Ridge, Tennessee
December 9, 1953

Carbide and Carbon Chemicals Company
Post Office Box P
Oak Ridge, Tennessee

Attention: Dr. C. E. Larson, Director, Oak Ridge National Laboratory

Subject: MAXIMUM GROUND CONCENTRATIONS FROM THE 7500 STACK

Gentlemen:

As a result of conversation between D. C. Davis, R. F. Myers and S. E. Beall on November 24, the enclosed special study was prepared by the Weather Bureau Office.

Sincerely yours,

C. S. Shoup
for Herman M. Roth
Acting Director
Research and Medicine Division

Enclosure:
Report W/Graphs (3)

CC: C. E. Center
N. H. Woodruff

Myers:ec

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3 M E Ramsey
w/encl.
J. A. Swartout
S. E. Beall
K. Z. Morgan
A. M. Weinberg

Maximum Ground Concentrations from the 7500 Stack

R. F. Myers
Weather Bureau
Oak Ridge, Tenn.

A previous evaluation of the limitations on fuel leakage from the HRE from a Health Physics viewpoint has been made by Burnett of ORNL (CF-52-3-208). The assumption was made in that paper that the minimum dilution of the stack effluent at a distance of 500 meters (building 7503) was about 2000.

Since that time a considerable amount of data has been evaluated by the meteorological group which has indicated that the minimum dilution at the ground may be higher than the figure of 2000 which was used in the Burnett estimate.

The velocity of the stack stream is now fixed at about 1900 feet/min. and during low wind speeds, the effective stack height is much larger than the actual height above ground due to the momentum of the jet.

In order to assist the operation personnel and the health-physicist to more accurately estimate the maximum ground concentrations which would result from an accidental release of activity, a set of graphs and a nomogram have been prepared which give the maximum ground concentration for a unit emission rate of 1 curie/second and the distance from the stack at which this concentration is expected to occur.

The graphs and nomogram are based on the work of O. G. Sutton on the diffusion of matter over level terrain. The formulae which he developed are more fully discussed in part 4 of ORO-99, "A Meteorological Survey of Oak Rige." The system for the determination of the diffusion parameter using an empirical relation between the range of direction and the standard deviation of direction was developed by Holland and Myers and tested for the instrumentation used at Oak Ridge.

The accuracy of the estimated concentration will vary from a factor of 2 on a windy day or night to an order of magnitude on calm nights. The concentrations given represent what might be measured in a 3-15 minute sampling period. The distances at which the maximum counts/minute have been found in several case studies of increased emission rate for short periods in the continuous stream from the 3039 stack have confirmed this type of estimate within 15-20%.

The equation used for computing the maximum ground concentration is:

$$\frac{X_m}{Q} = \frac{2}{\pi e u \left(h + 1.5 \frac{V_s d_s}{U}\right)^2} \quad \frac{C_z}{C_y}$$

Encl 1

where X_m is the concentration in curies/meter^3
Q is the emission rate in curies/sec.
U is the average hourly wind speed in meters/sec.
h is the height of the stack (30 meters)
V_s is the velocity of the stack effluent (9.7 meters/sec.)
d_s is the stack diameter in meters (0.3m)
$C_z = C_y$ (isotopic turbulence assumed at this height above ground. The ratio of C_z/C_y has been found to be 1 for average and night time conditions and 0.6 for calm sunny days at a height of 18 feet)

The factor 1.5 $V_s d_s/U$ which is added to the height of the stack takes into account the plume rise due to its momentum. This expression developed by Rupp, Beall, Bornwasser and Johnson (CE 1398) was found to best represent the lowest 10% of the observations made on the smoke emitted from the 3018 stack, the ORNL steam plant stack and several TVA steam plant stacks. This conservative estimate of the rise of the plume, particularly at wind speeds under 4 mph, introduces a safety factor into the calculations.

The distance of the maximum ground concentration is given by:

$$X_m = \left[(h + 1.5\ V_s d_s/U)^2/C^2\right]^{1/(2-n)}$$

where X_m is the distance of maximum concentration in meters
h is the stack height (30 meters)
V_s is the velocity of the stack effluent (9.7 meters/sec.)
d_s is the stack diameter (0.3 meters)
U is the average hourly wind speed in meters/sec.
C^2 is a parameter depending on the gustiness of the wind
n is a stability parameter depending on the vertical temperature gradient.
The stability parameter may be found from the following table when the average temperature gradient between 5 and 65 feet is known. This measurement is continuously recorded at building 7503.

Typical values for a bright sunny day are 0.17 to 0.20, for a windy cloudy day or night 0.25 and for a clear calm night 0.35 to 0.50.

Stability parameter n

Temperature gradient $(T_{65} - T_5)$	n
<-2.0	.17
-1.0, -2.0	.20
-0.5, -0.3	.23
-0.25	.25
0	.27
0.5	.30
1,2	.35
3	.37
4	.40
>4	.50

C^2, the gustinews parameter can be calculated from meteorological data. The assumption is made that the values of the vertical gustiness C_z are equal to the values of crosswind gustiness C_y. This has been shown to not introduce much error when the height of the stack is more than 25 meters. One form of Sutton's semiempirical equation for C_y^2 is:

$$C_y^2 = \frac{4\, V^n}{(1-n)(2-n)U^n} (\tan \sigma_\theta)^{2 - 2n}$$

where V is the kinemetic vicosity of air 1.4 - 1.8 x 10^{-5} gm/m/sec.
n is the stability parameter
U is the wind speed in meters/sec.
σ_θ is the standard deviation of the wind direction

The standard deviation of the wind vane σ_θ has usually been computed rather laboriously by making high speed recordings of the wind direction and reading off values at 10 second intervals. A new approach was tried using the ratio of extreme range of a value to its standard deviation. Comparisons were made between the extreme range of wind direction in a 15 minute period and the standard deviation of the sample. It was found that the range was about 6.8 times the standard deviation.

A nomogram was constructed which performs the C^2 calculation if the stability parameter, wind speed and direction range are known. As an example suppose the 60 foot temperature gradient is $+6^\circ$F, the wind speed is 10 mph and the direction range for a 15 minute period is 135°. For values of temperature gradient in excess of +4F, n is taken as 0.50 (previous table). A straight edge is used to connect a wind speed of 10 mph on scale I and an n of 0.5 on scale II. The intersection of the straight edge and reference line R_1 is marked. The intersection of a straight edge connecting the n value of 0.5 on scale II and the 135° direction range on scale III with reference line R_2 is marked. When the points on R_1 and R_2 are connected, the C^2 value is found from the intersection with scale IV.

The graphs which have been drawn for the 7500 installation give the distance of ground maximum when the C^2 value, the n value and the wind speed are known. Since wind speed is the least sensitive parameter individual graphs were prepared for 1, 2, 5, 10, 15 and 30 mph.

Three examples which are typical of day, night and average conditions will be given.

A. A leak occurs at 3:45 p when a wind is blowing from 180°(S) with an average speed of 2 mph. The temperature gradient (60 feet) is -2.5°F. The extreme range of the wind vane in the period 3:45 p was 220° (320° to 100°).

From the table n = 0.17
From the nomogram C^2 = 0.2
From the graphs, the maximum ground concentration will be 210 microcuries/meter^3 per curie/sec. emitted occurring at a distance of 300 meters from the stack to the North.

B. A release occurs on a windy, cloudy night with a temperature gradient of -0.23°F, the wind is from 40° (NE) with a speed of 10 mph. The 15 minute direction range is 140° (340° to 120°).

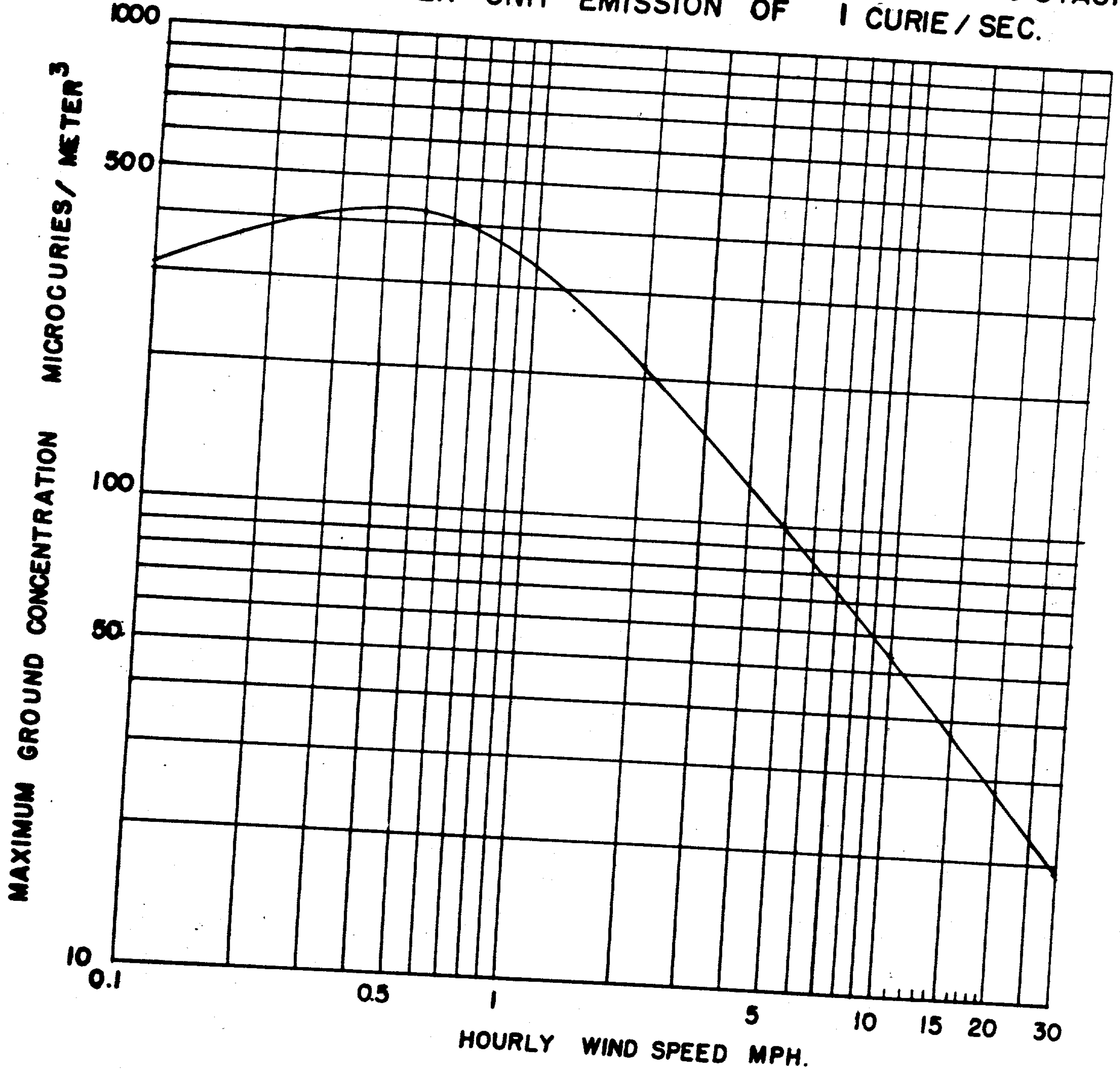
From the table n = .25
From the nomogram C^2 = 0.03
From the graphs, the maximum ground concentration will be 54 microcuries/meter^3 per curie/sec emitted and will be found at a distance of 2700 meters to the SW.

C. A release occurs on a clear calm night with a temperature gradient of +6°F. The wind is from 065° (ENE) with an average speed of 1 mph. The 15 minute direction trace varied from 40° to 80° giving a range of 40°.

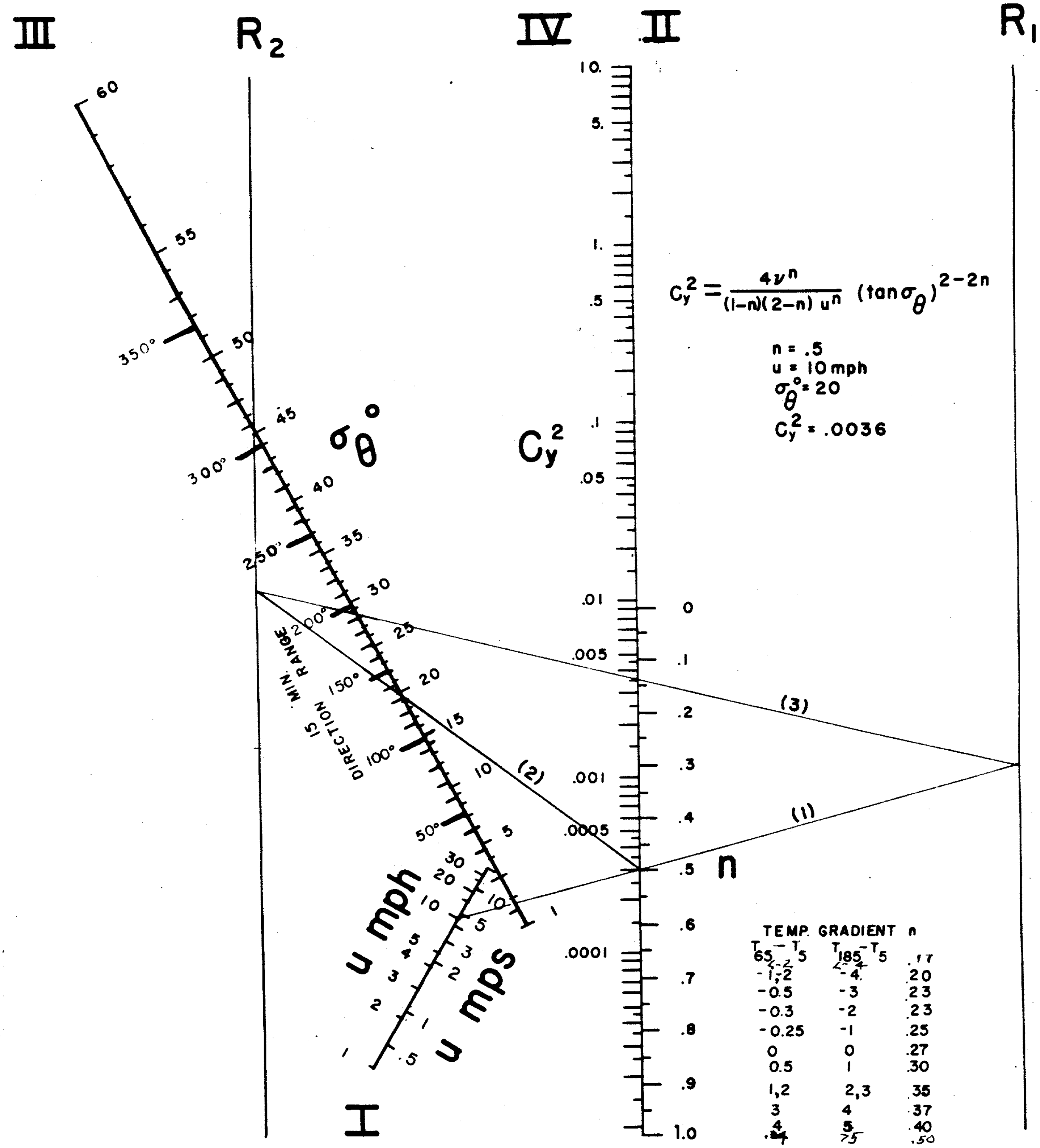
From the table n = .50
From the nomogram C^2 = .0035
From the graphs the maximum ground concentration will be 330 microcuries/meter^3 per curie/sec. emitted occurring at more than 50 km - WSW of the stack.

The last example points out that some care must be used in predicting the maximum ground concentration since the cloud would take over 100 hours to reach a distance of 50 km. and hence when the sun rises and destroys the stable layer of air near the ground by heating, the thin ribbon of effluent which has remained aloft during the night would be brought to the ground shortly after sunrise and then the daytime diffusion condition will become established.

MAXIMUM GROUND CONCENTRATION FROM 7500 STACK PER UNIT EMISSION OF 1 CURIE / SEC.



NOMOGRAM FOR SOLVING SUTTON'S C_y^2 EQUATION

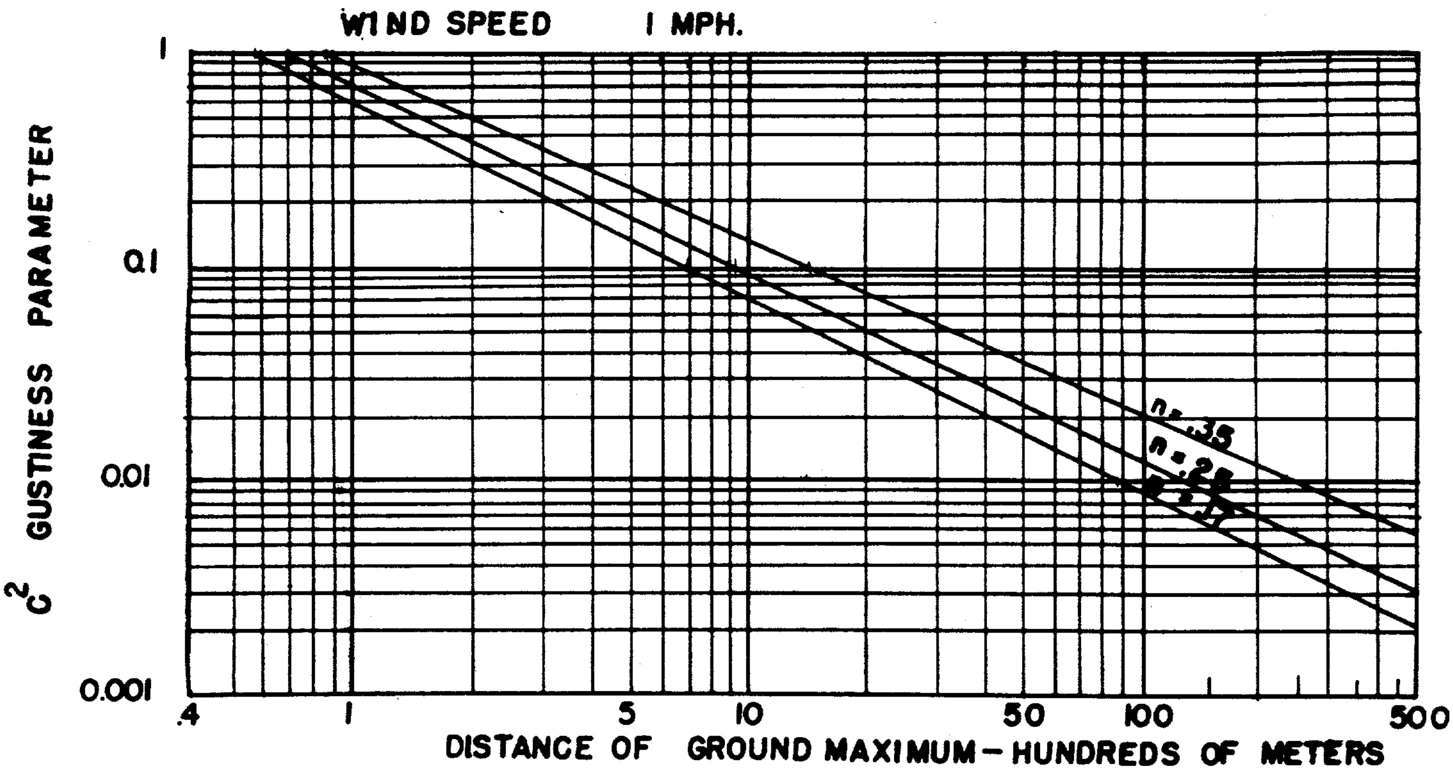


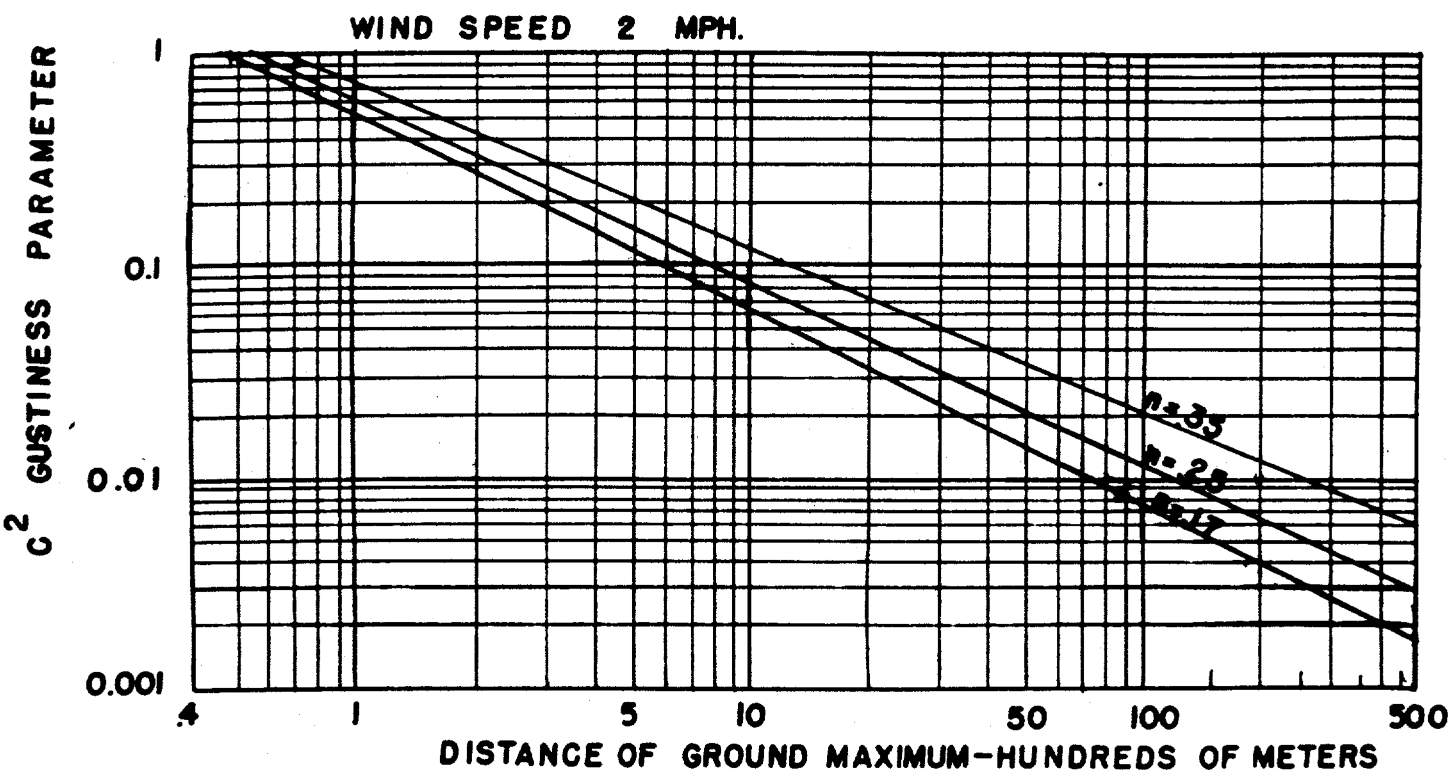
$$C_y^2 = \frac{4\nu^n}{(1-n)(2-n)\,u^n}\,(\tan\sigma_\theta)^{2-2n}$$

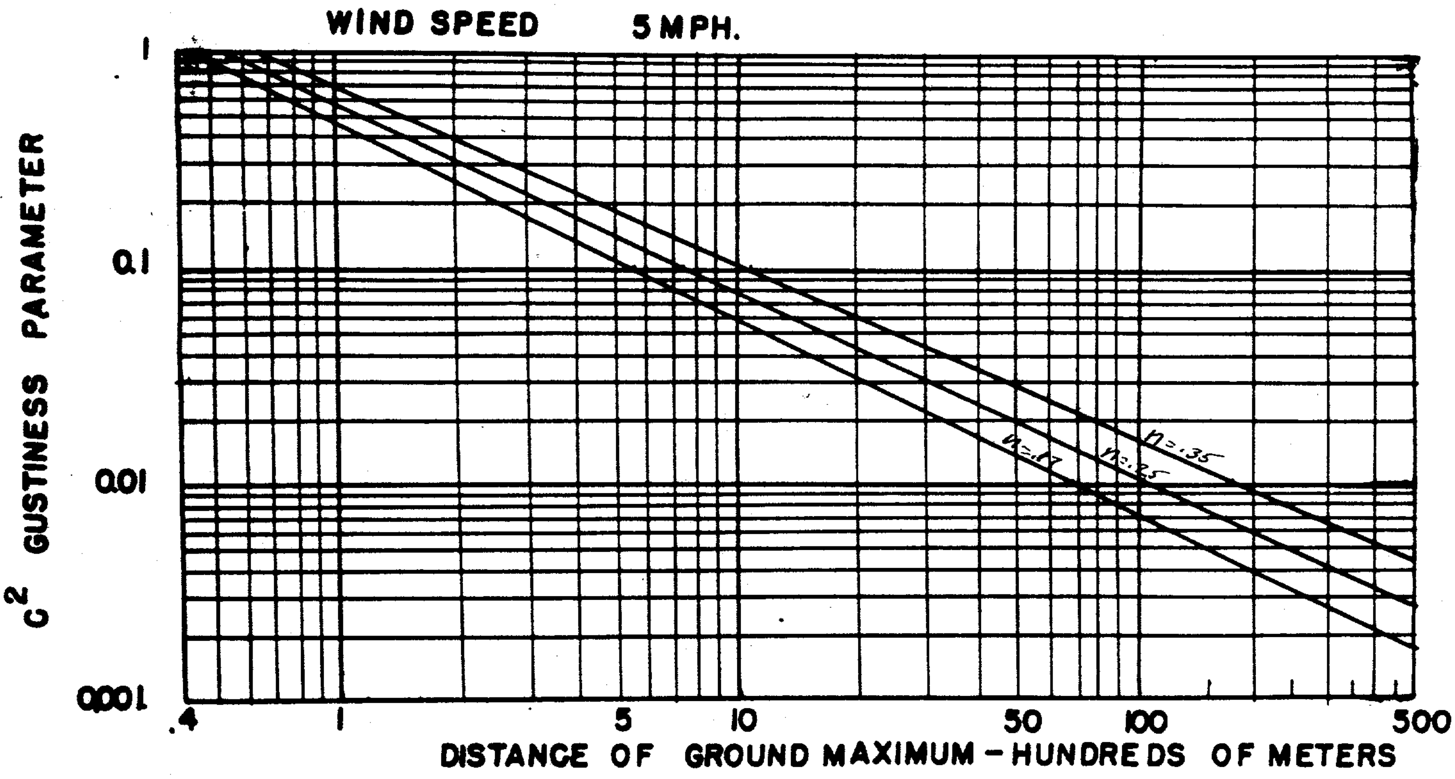
$n = .5$
$u = 10$ mph
$\sigma_\theta^\circ = 20$
$C_y^2 = .0036$

TEMP. GRADIENT $T_{65}-T_5$	$T_{185}-T_5$	n
<-2	<-4	.17
-1,-2	-4	.20
-0.5	-3	.23
-0.3	-2	.23
-0.25	-1	.25
0	0	.27
0.5	1	.30
1,2	2,3	.35
3	4	.37
4	5	.40
>4	>5	.50

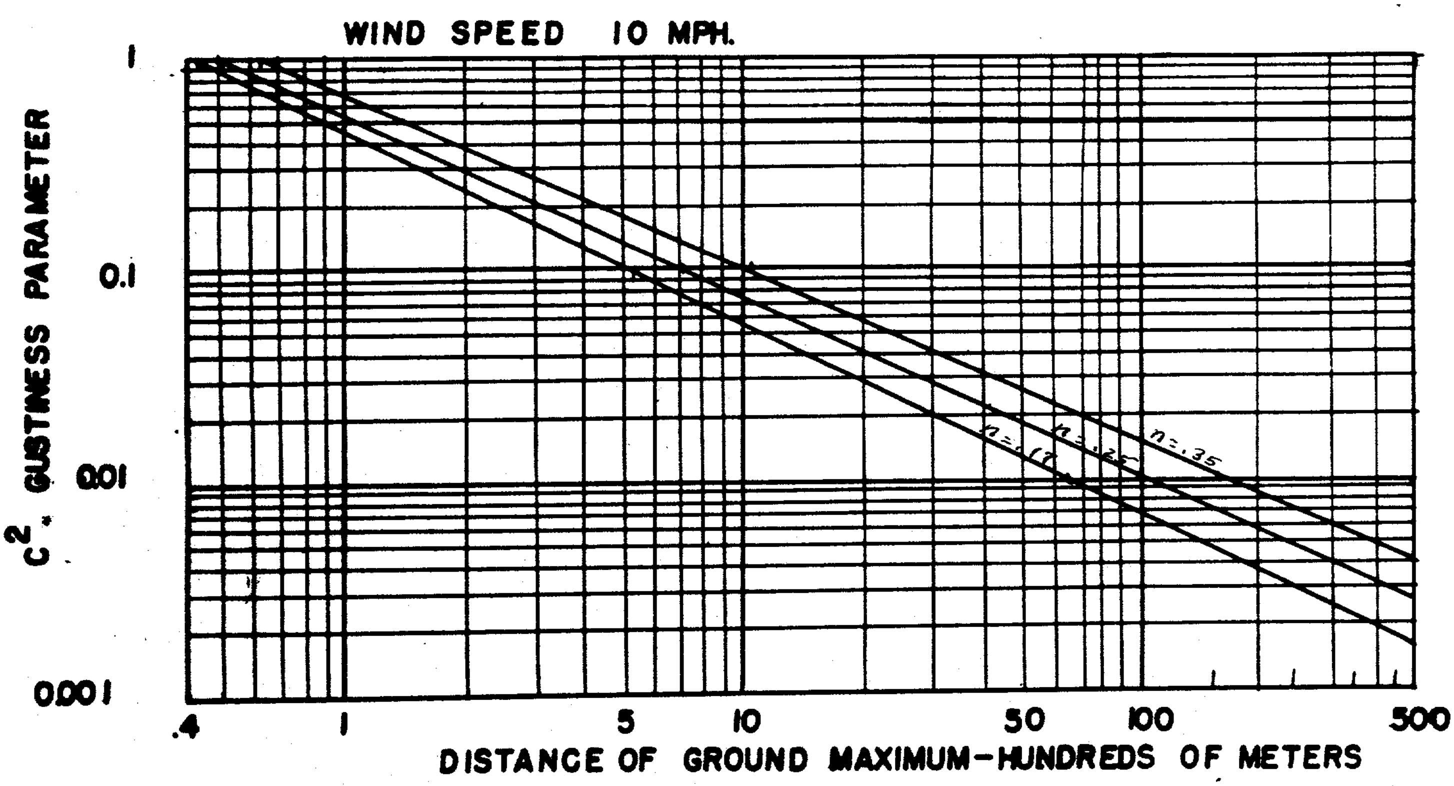
U.S.W.B. Oak Ridge, Tenn.


WIND SPEED 1 MPH.
C^2 GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM – HUNDREDS OF METERS
n=.35
n=.25
n=.17

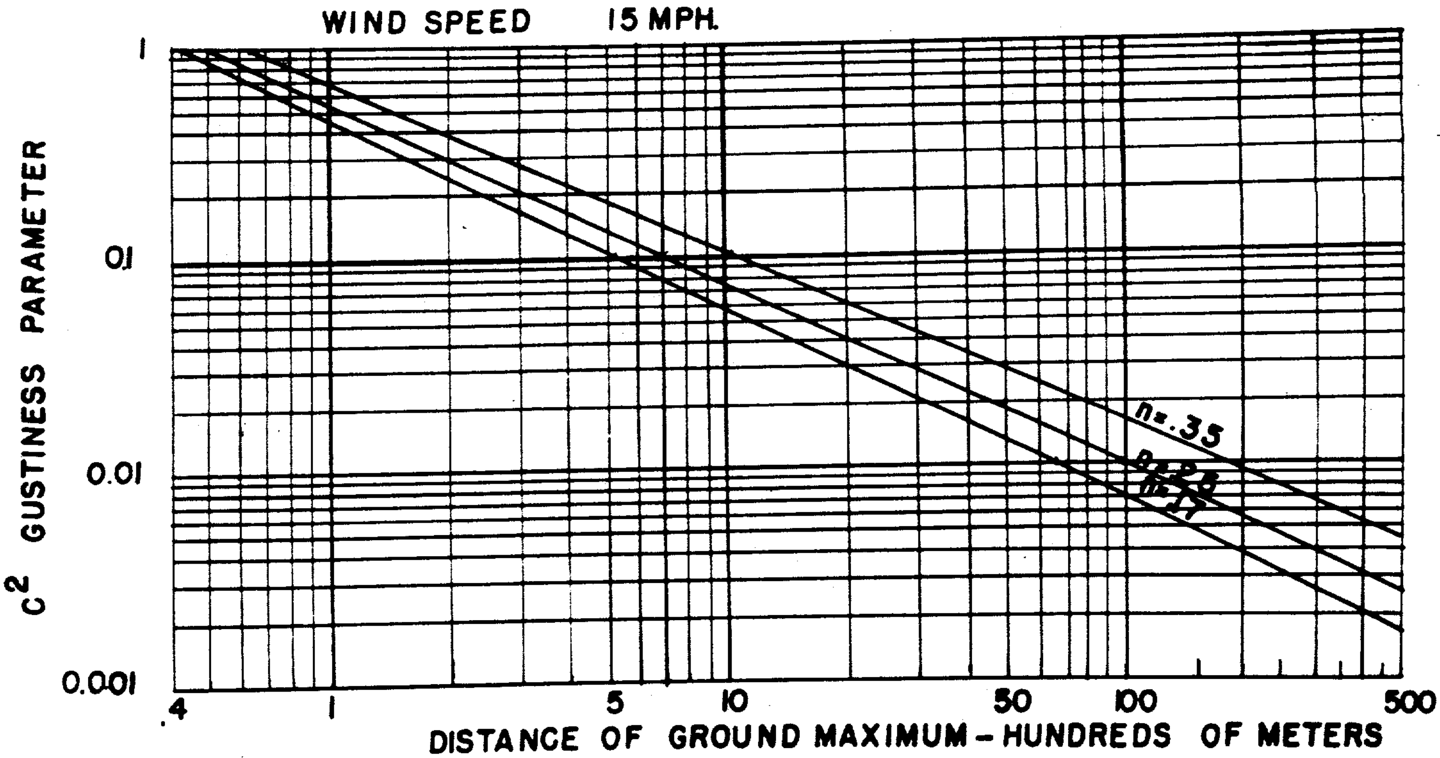

WIND SPEED 2 MPH.
C^2 GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM – HUNDREDS OF METERS
n=.35
n=.25
n=.17

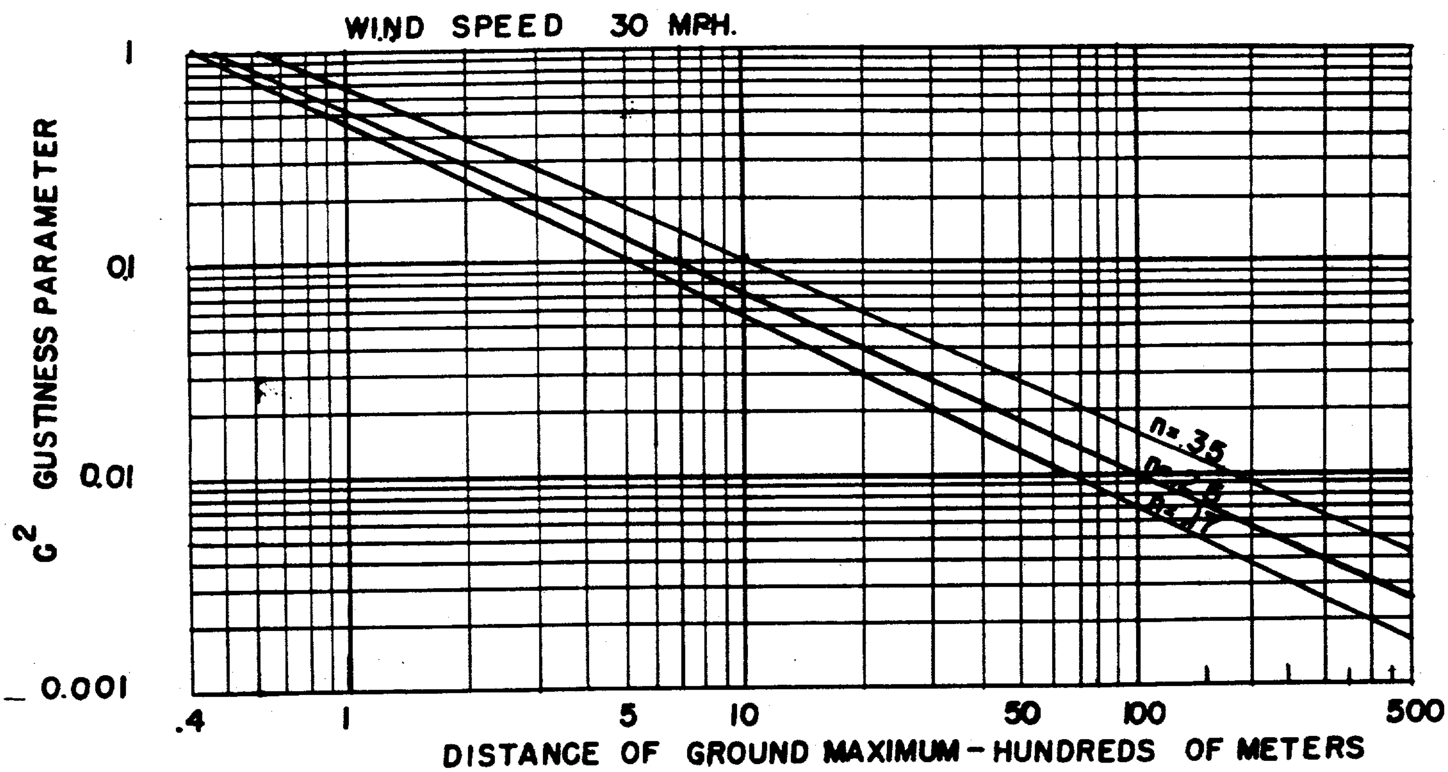


WIND SPEED 5 MPH.
C^2 GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM - HUNDREDS OF METERS
n=.17
n=.25
n=.35



WIND SPEED 10 MPH.
C^2 GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM-HUNDREDS OF METERS
n=.17
n=.25
n=.35


WIND SPEED 15 MPH.
C² GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM - HUNDREDS OF METERS
n=.35
n=.25
n=.17


WIND SPEED 30 MPH.
C² GUSTINESS PARAMETER
1
0.1
0.01
0.001
.4
1
5
10
50
100
500
DISTANCE OF GROUND MAXIMUM - HUNDREDS OF METERS
n=.35
n=.25
n=.17