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Topographic Correction Curves

TOPOGRAPHIC CORRECTION CURVES

by

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In this report there is presented a set of curves for obtaining topographic corrections under conditions likely to be met in seismic refraction work at sea.

The object of the topographic correction is to eliminate deviations from the travel time curves due to variations of the observed topography on the ocean bottom from the plane surface assumed in the usual methods of reduction. In usual practice these variations are taken with reference to some mean base line, either sloping or horizontal, which best fits the data obtained from fathograms and vertical shot reflection times. The resulting corrections then reduce the travel times to this base line. It is necessary to choose the layer, L_x, which is assumed to cause the topography on the ocean floor. This choice is made according to the type of topography and structure involved; if the corrections are considerable the validity of the choice of L_x may be tested by comparing the reduction of scatter resulting from different assumptions.

The correction for surface topography having been made, there may remain scatter attributable to buried topography, i. e., topography not reflected on the ocean bottom. In this case there would be no scatter caused in arrivals through layers above L_x; this fact enables one to guess the location of L_x, and then to estimate the relief on its surface. It should be noted that this remaining scatter could be due to horizontal changes in velocity or inhomogeneities in layers not observed by the refraction data.

In Figure I:

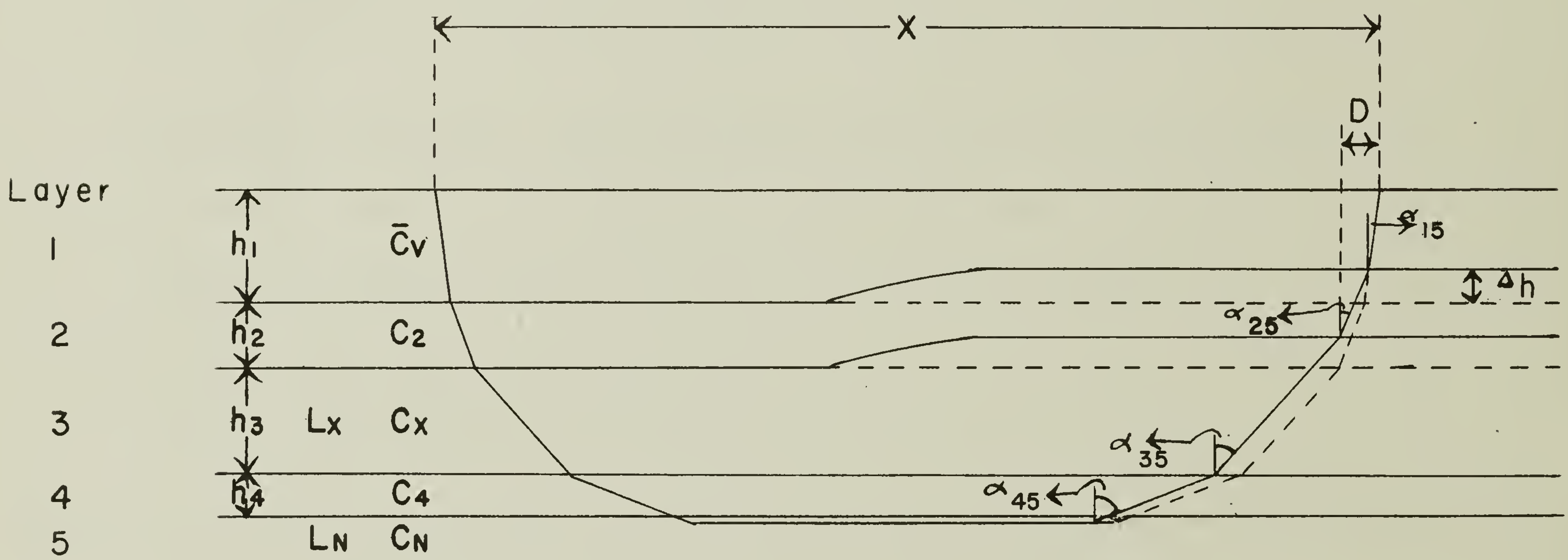
$\bar{C}_v$ is the average vertical sound velocity in water;

C_x is the velocity in L_x, the deepest layer in which the topography is assumed;

C_n is the velocity in L_n, the deepest layer traversed by the arrival in question;

Δh is the depth to assumed base line minus the actual depth.

Figure I.



The travel time in the undeformed case (dashed lines) is given by:

$$T_1 = \frac{X}{C_n} - \frac{2}{C_n}\left[h_1 \tan\alpha_{15} + h_2 \tan\alpha_{25} + h_3 \tan\alpha_{35} + h_4 \tan\alpha_{45}\right]$$

$$+ 2\left[\frac{h_1 \sec\alpha_{15}}{\bar{C}_v} + \frac{h_2 \sec\alpha_{25}}{C_2} + \frac{h_3 \sec\alpha_{35}}{C_x} + \frac{h_4 \sec\alpha_{45}}{C_4}\right]$$

The travel time in the deformed case is given by:

$$T_2 = \frac{x}{c_n} - \frac{2}{c_n}\Big[h_1 \tan\alpha_{15} - \frac{\Delta h}{2}\tan\alpha_{15} + h_2\tan\alpha_{25} + h_3\tan\alpha_{35} + \frac{\Delta h}{2}\tan\alpha_{35} + h_4\tan\alpha_{45}\Big]$$
$$+ 2\Big[\frac{h_1\sec\alpha_{15}}{\bar{c}_v} - \frac{\Delta h\sec\alpha_{15}}{2\bar{c}_v} + \frac{h_2\sec\alpha_{25}}{c_2} + \frac{h_3\sec\alpha_{35}}{c_x} + \frac{\Delta h\sec\alpha_{35}}{2c_x} + \frac{h_4\sec\alpha_{45}}{c_4}\Big]$$

Subtracting:

$$\Delta T = T_1 - T_2 = \Delta h\Big[-\frac{\tan\alpha_{15}}{c_n} + \frac{\tan\alpha_{35}}{c_n} + \frac{\sec\alpha_{15}}{\bar{c}_v} - \frac{\sec\alpha_{35}}{c_x}\Big]$$
$$= \frac{\Delta h}{\bar{c}_v}\Big[\Big(\sec\alpha_{15} - \frac{\bar{c}_v}{c_n}\tan\alpha_{15}\Big) - \frac{\bar{c}_v}{c_x}\Big(\sec\alpha_{35} - \frac{c_x}{c_n}\tan\alpha_{35}\Big)\Big]$$

Since $\sin\alpha_{15} = \bar{c}_v/c_n$ and $\sin\alpha_{35} = c_x/c_n$

the correction in travel time (ΔT) of a refracted arrival due to a change in water depth (Δ h) is given by the equation:

$$\Delta T = \frac{\Delta h}{\bar{c}_v}\Big[\sqrt{1 - \frac{\bar{c}_v^{\,2}}{c_n^{\,2}}} - \frac{\bar{c}_v}{c_x}\sqrt{1 - \frac{c_x^{\,2}}{c_n^{\,2}}}\Big] \tag{1}$$

This equation is unaffected by the number or thickness of layers between the water and L_x or between L_x and L_n. When the arrival is through L_x, i. e., $c_x = c_n$, equation (1) reduces to:

$$\Delta T = \frac{\Delta h}{\bar{c}_v}\sqrt{1 - \frac{\bar{c}_v^{\,2}}{c_x^{\,2}}} \tag{2}$$

The curves give:

(1) topographic corrections (Δ T) for $\frac{\Delta h}{\bar{c}_v}$ = 1.0 sec. as a function of $c_x/\bar{c}_v$ for various values of $c_n/\bar{c}_v$ according to equation (1)

(2) topographic corrections for $\frac{\Delta h}{\bar{c}_v}$ = 1.0 sec. as a function of $\frac{c_x}{\bar{c}_v}$ when $c_x = c_n$ according to equation (2) (note that when

L_n is above L_x this curve for $c_n=c_x$ is still used, but $\frac{c_x}{\bar{c}_v}$ is replaced by $\frac{c_n}{\bar{c}_v}$.);

(3) for comparison, a curve of topographic correction vs. $\frac{c_x}{\bar{c}_v}$ according to the approximate equation

$$\Delta T = \frac{\Delta h}{\bar{c}_v}\left(1 - \frac{\bar{c}_v}{c_x}\right) \tag{3}$$

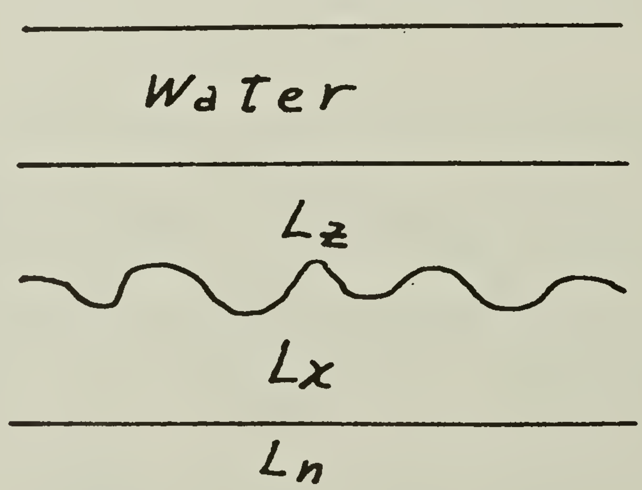
Equation (3), which may be obtained from Equation (1) by letting $\frac{c_n}{\bar{c}_v} \to \infty$ was used in plotting the series of topographic correction curves given by Officer and Wuenschel (1951). An examination of the curves indicates that in some cases the use of this approximation will lead to considerable error.

For the case of buried topography we replace $\bar{c}_v$ by c_z, the velocity in L_z, defined as the layer which does not reflect in its upper surface the topography in its lower surface (see Fig. 2); then:

$$\Delta T = \frac{\Delta h}{c_z}\left[\sqrt{1 - \frac{c_z^2}{c_n^2}} - \frac{c_z}{c_x}\sqrt{1 - \frac{c_x^2}{c_n^2}}\right] \quad *$$

Note that in this case the graph gives the correction for $\frac{\Delta h}{c_z} = 1$ sec.

Figure II



When computing corrections it is necessary to know the point at which the sound ray passes through the surface of relief. The horizontal

* A simplified form of this equation similar to equation (2), found in standard exploration geophysics texts, is used to interpret buried faulting from refraction data.

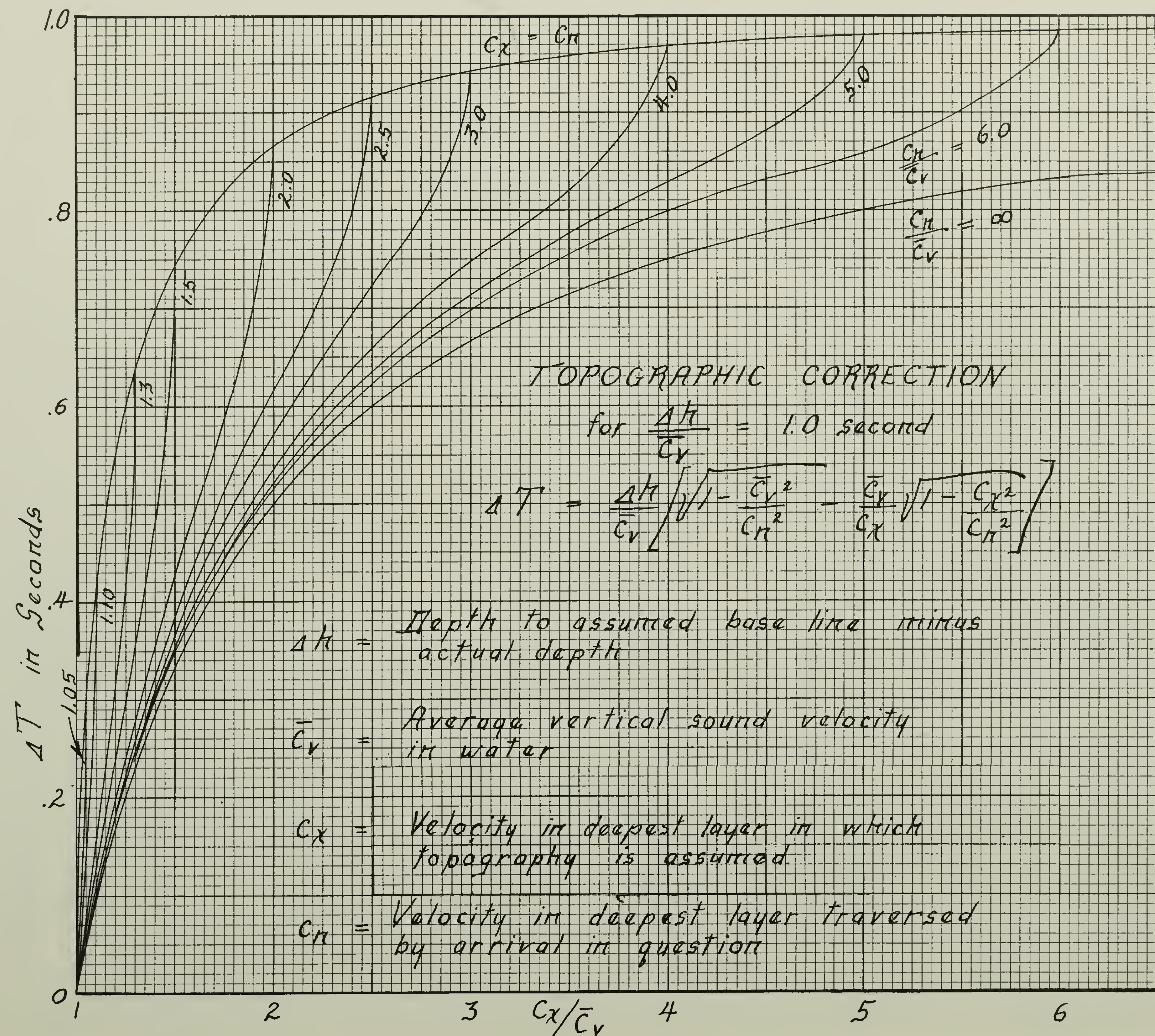
distance of the point from that directly below the ship (the offset distance) is given by:

$$D = h_1 \tan \alpha_{1n} + h_2 \tan \alpha_{2n} + \cdots\cdots + h_{(x-1)} \tan \alpha_{(x-1)n}$$

(see Figure 1). The first term is usually large compared to the succeeding terms and is thus normally the only one used.

The above derivation has been made on the assumption of flat horizontal surfaces. The error introduced by application of the resulting formula to sloping layers is negligible for angles normally encountered.

Reference: C. B. Officer, Jr. and P. C. Wuenschel, Reduction of Deep Sea Refraction Data, Technical Report No. 1, Contract NObsr 43355, Lamont Geological Observatory, August 1951, Figure 19.



TOPOGRAPHIC CORRECTION
for $\frac{\Delta h}{\bar{C}_v} = 1.0$ second
$\Delta T = \frac{\Delta h}{\bar{C}_v}\left[\sqrt{1-\frac{\bar{C}_v^2}{C_n^2}} - \frac{\bar{C}_v}{C_x}\sqrt{1-\frac{C_x^2}{C_n^2}}\right]$
Δh = Depth to assumed base line minus actual depth
$\bar{C}_v$ = Average vertical sound velocity in water
C_x = Velocity in deepest layer in which topography is assumed
C_n = Velocity in deepest layer traversed by arrival in question
$C_x = C_n$
$\frac{C_n}{\bar{C}_v} = 6.0$
$\frac{C_n}{\bar{C}_v} = \infty$
1.05
1.10
1.3
1.5
2.0
2.5
3.0
4.0
5.0
ΔT in Seconds
$C_x/\bar{C}_v$
0
.2
.4
.6
.8
1.0
1
2
3
4
5
6