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STUDY OF SHELL SUPPORTED RING FRAMES WITH OUT-OF-PLANE LOADING

FINAL REPORT

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FOREWORD

Presented herwith is the final report for Contract No. NAS8-20097, "Study of Shell Supported Ring Frames with Out-of-Plane Loadings". This document, including Appendices 1 and 2, together with References (a), (b), (c), (d), and (e), constitutes the fulfillment of this contract.

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LIST OF ILLUSTRATIONS

LIST OF REFERENCES

a. Monthly Report of 8 August 1965.

b. Monthly Report of 10 September 1965.

c. Monthly Report of 12 October 1965.

d. Monthly Report of 15 November 1965.

e. Monthly Report of 10 December 1965.

f. Transmittal of Ring Frame Cases Letter of 28 October 1965 from Contracting Officer's Representative to Mr. A. L. Kolom, Chief, Structures Research, Los Angeles Division of North American Aviation, Inc.

ABSTRACT

The goal of this study was to provide an analytical tool for the solution of the deflections and internal loading distribution of ring frames in cylindrical shells when the rings are directly loaded by out-of-plane loadings and are supported by the shell. In order to keep this study within manageable bounds, certain ground rules were laid down: only circular cylindrical shells were considered, the frames were uniform around their periphery, the analysis was limited to the elastic range of behavior and to a room temperature environment, and the frame sections were considered to remain locally undistorted under load. Four loading cases were investigated: a concentrated force normal to the plane of the ring, a concentrated moment in a radial plane of the cylinder, a distributed force normal to the plane of the ring and acting over a portion of the ring circumference, and a distributed moment in radial planes of the cylinder and acting over a portion of the ring circumference. By using the principles of superposition, any more complex loading case can be derived from these four basic conditions. Early in the investigation, it was proven that if the angle between the frame section principal axes and the plane of the ring could be assumed negligible, the principles of the superposition would also permit the out-of-plane loading conditions to be treated completely independently of in-plane loading influences. It was demonstrated by reasonably extreme cases that the effect of assuming the principal axes unrotated was indeed negligible in the ring solution (not calculation of stresses) and, therefore, this assumption was adopted for the remainder of the analysis. In the solution, only those internal loads and moments, and only those deflections and rotations are solved for which are directly influenced by out-of-plane loading. Unit loading cases and unit elastic/

geometric parameters are used wherever possible to make the solution as general as possible without undue increase in bulk. Frame response is given entirely in terms of section elastic properties, rather than by dimensional description, so that there is general applicability of the program without restriction on frame section shapes.

In Part I of this report, the theoretical solution of the problem is developed, using finite difference principles, in which the structure is divided into small beam elements. A mathematical solution is developed for the general case of integrating a structure from such elements by treating the interrelationship between elements in a rigorous manner. In Part II, the general solution was adapted to the specific case at hand, the uniform circular ring supported by a shell and loaded out of plane, and translated into a specific matrix algebra readily programmable for a digital computer.

The digital computer program developed in conjunction with Part II was used to produce the unit frame response curves compiled in Appendix 1. By appropriate combination and unitizing of parameters, the solution has been condensed into only two variable parameters GJ/EI and C/R, which are elastic/geometric properties of the structure and are defined in the text. For a suitable range of each of these parameters, for each of the four unit loading cases, frame internal loadings and deflections responsive to out-of-plane loadings are presented for each station around the ring circumference. Appendix 2 contains two sample problems illustrating the analytical technique developed in this program.

INTRODUCTION

Strength/weight efficiency in the structural design of aerospace vehicles is essential to meet desired performance goals. Ring frames supported by shell structure and loaded out of the plane of the ring elastic axis are quite common in aerospace structures. Up to now, frames were analyzed for loads in their elastic axis plane. Since this is only a planar (2 dimensions) problem and, as such, is very simple, it leads to graphical solutions, used almost exclusively for over a century. The out-of-plane loading involves the 3 dimensions of space and, as such, not only precludes the use of graphical methods but also complicates unrealistically the corresponding tabular methods.

A fresh start may consist of setting up the solution of a curved beam of variable properties and with a skew-curved (non-planar) elastic line with vector representation and matrix algebra. This is relatively simple but its generality conceals some general characteristics of the problem which are of great value in the overall solution. In other words, this first draft matrix algebra should be searched for these characteristics and later the solution be tailored to their use.

The resulting theoretical method, which is presented in this report, is of an even more general application than the skew beam case. It will be shown that it applies to the case of such a beam supported elastically along its length, provided the new factors are properly identified. By generality it is meant that the solution of the elastic support part is just another step of the same mathematical form and technical formulation as the solution of the curved beam itself. As a result, the problem of this program can be solved either in two steps, solving the ring first and the ring-shell tie second or in only one step where the individual ring-shell ties are only additional elements of the structure.

It is the purpose of this report to present this theoretical method with its applications for optimization of the solution, to give the formulated analytical procedure readily adaptable for use with digital computer programs and to include optimization curves, covering a wide range of independent parameters, with the method for using them.

PART I

THEORETICAL SOLUTION

SECTION A

UNIT SOLUTION OF THE RING

FOREWORD

The analytical formulation of the ring solution presented in this section, applies to any complete loop beam in 3 dimensions. Very little change would be necessary, and then only in the part called "Determination of the Ring Indeterminates", when it is not a complete loop.

As soon as we concern ourselves with "Practicable Optimization" the mathematical model of the curved beam becomes the model of a circular ring with constant properties. This model is presented now and will be used hereafter, although most of the basic relations are completely general.

THE MATHEMATICAL MODEL OF THE CIRCULAR RING

GEOMETRY

Figure 1A shows the plane ZX of the ring elastic line, which is a circle of radius R. The center of the ring is taken as the origin of the basic system of coordinates XYZ (clockwise system). The elastic line circle is oriented like the trigonometric circle, starting from point ($Z = R, X = 0, Y = 0$). Any point i on this oriented circle is identified by the trigonometric angle φ_i and its coordinates are $X_i = R \sin \varphi_i$, $Y = 0$, $Z_i = R \cos \varphi_i$.

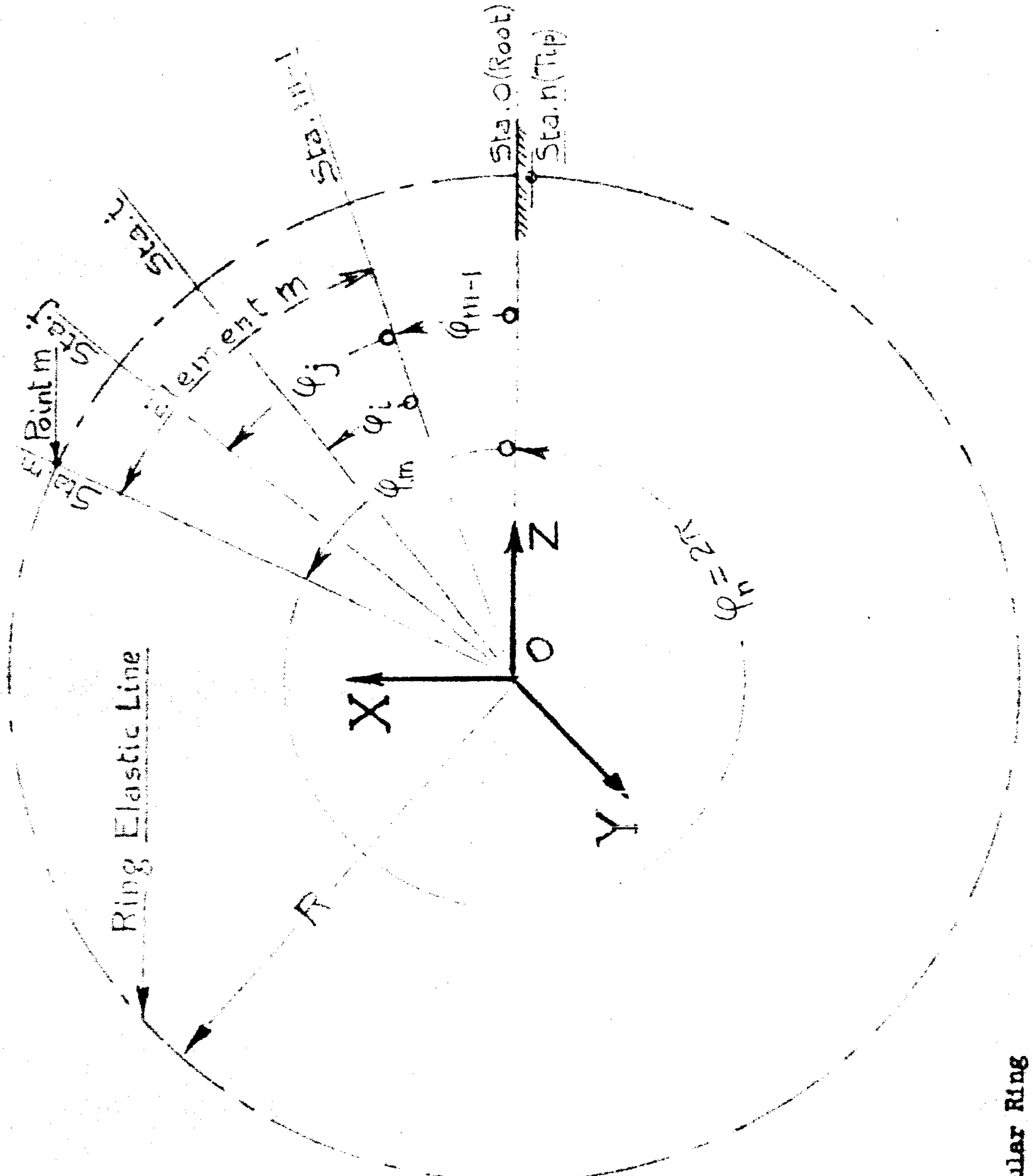


Figure 1A. Circular Ring

Running stations m are numbered from 0 ($\varphi = 0$) to n ($\varphi = 2\pi$). We can imagine the ring supported at Station 0 and cut from the support at Station n (free end) and acting for the moment as a cantilever beam.

For the problem ahead, four types of running stations, such as m, are identified.

1. Station m (φ_m) at which a concentrated external load is, or may be, applied.
2. Station m-1 ($\varphi_{m-1} < \varphi_m$), such that the element of the ring between them is called element m, and may be subjected to a distributed external load, still unspecified.
3. Station i of element m, $\varphi_m > \varphi_i \geq \varphi_{m-1}$ at which an elemental deformation will be computed.
4. Station j of element m, $\varphi_m > \varphi_j > \varphi_{m-1}$, at which the final internal loading and deflections may be required.

STATION IDENTIFICATION

Figure 1B shows the stations related to Station m, located between elements m and m + 1. Station$\Big|_{m}^{m-1}$ is cut inboard of Station m and Station$\Big|_{m}^{m+1}$ is cut outboard. The concentrated load applied at Station m is between them.

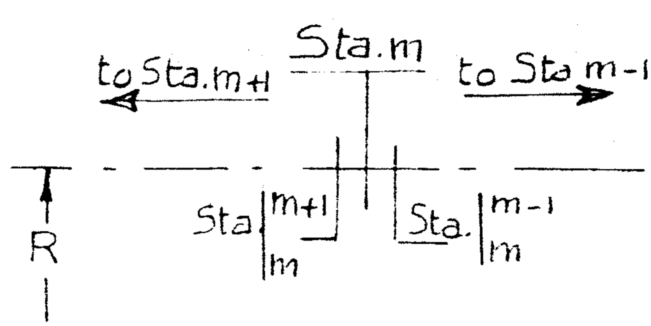


Figure 1B. Station Identification

THE EXTERNAL AND INTERNAL LOADING

EXTERNAL APPLIED LOADING

Loading is either concentrated at the typical Station m or distributed on element m.

We identify concentrated loading with the letter Δ, measuring increment of, so that $\Delta\Phi_m$ is the increase of internal loading at Station m, thus an external load.

We identify the distributed load by the (small) φ, such that φ_m is the distributed loading on element m, for one inch of elastic line ds_m (= $Rd\varphi_m$). Load φ_m is a vector while angle φ_m is a scalar quantity so no confusion is possible.

When there is no superscript the vector $\Delta\Phi_m$ (=$\Delta\Phi_m^{(o)}$) is in the general system. In the element system there is a superscript between parenthesis, usually (m). The vector φ_m is always in the system m of the cross section of the element m where the increment of distributed loading $\varphi_m \, ds_m$ is applied, therefore vector φ_m needs no superscript.

INTERNAL LOADING

If we cut the ring at Station m, the load applied by the outboard part of the ring to the inboard part on the face of the cut is called the Internal Loading. In the reference system it is identified as Φ_m (= $\Phi_m^{(o)}$), in the system m of the cut as $\Phi_m^{(m)}$ and at stations $\Big|_m^{m-1}$ and $\Big|_m^{m+1}$ as $\Phi_m^{(m),\ m-1}$ and $\Phi_m^{(m),\ (m+1)}$ respectively.

DETAILED LOAD VECTORS

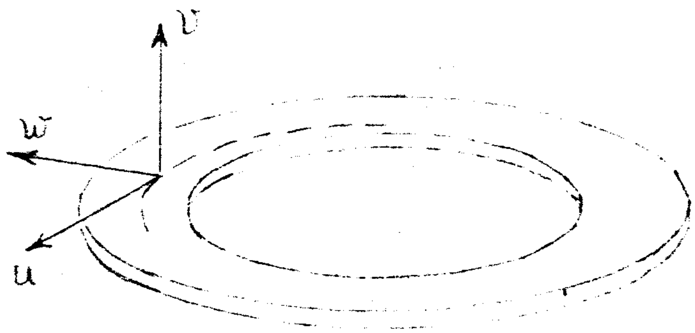
The load vectors $\Delta\Phi$, φ, Φ are vectors of order six; the three components of the force and the three components of the moment.

$$\Delta\Phi_m = \begin{vmatrix} \Delta F_m \\ \Delta M_m \end{vmatrix} \text{ with } \Delta F_m = \begin{vmatrix} \Delta F_m^X \\ \Delta F_m^Y \\ \Delta F_m^Z \end{vmatrix} \ \& \ \Delta M_m = \begin{vmatrix} \Delta M_m^X \\ \Delta M_m^Y \\ \Delta M_m^Z \end{vmatrix}$$

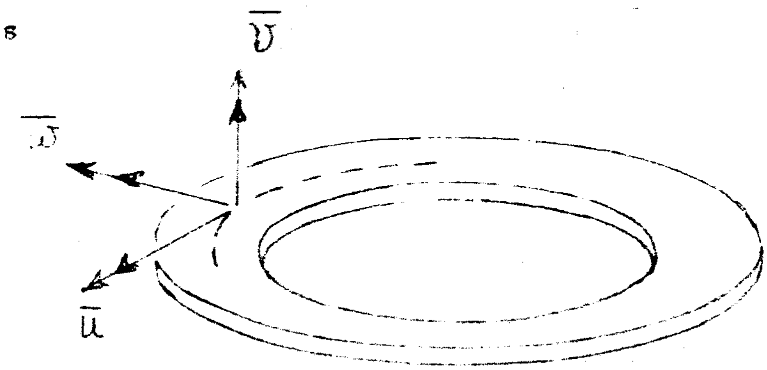
$$\varphi_m = \begin{vmatrix} f_m \\ m_m \end{vmatrix} \text{ with } f_m = \begin{vmatrix} f_m^X \\ f_m^Y \\ f_m^Z \end{vmatrix} \ \& \ m_m = \begin{vmatrix} m_m^X \\ m_m^Y \\ m_m^Z \end{vmatrix}$$

$$\Phi_m = \begin{vmatrix} F_m \\ M_m \end{vmatrix} \text{ with } F_m = \begin{vmatrix} F_m^X \\ F_m^Y \\ F_m^Z \end{vmatrix} \ \& \ M_m = \begin{vmatrix} M_m^X \\ M_m^Y \\ M_m^Z \end{vmatrix}$$

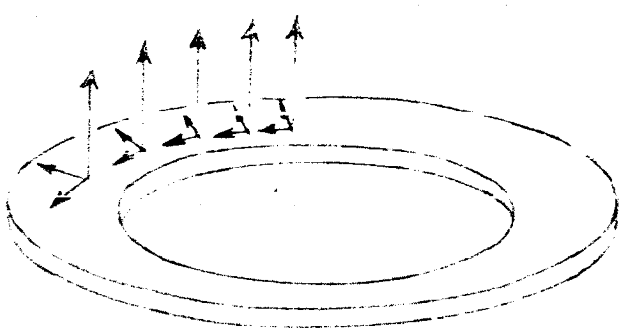
Figures 2A, 2B, 2C, and 2D show the type of external loading.



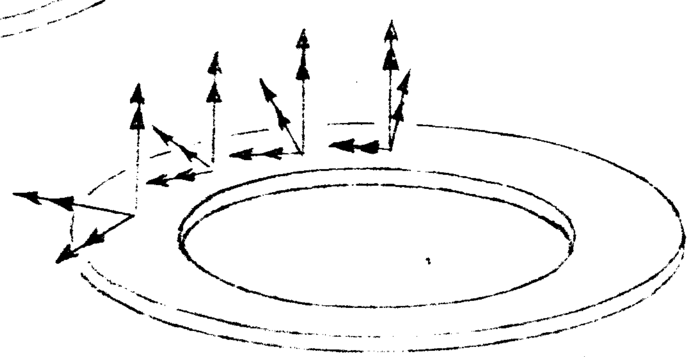
a. Concentrated Forces



b. Concentrated Moments



c. Distributed Forces over Segment of Ring



d. Distributed Moments over Segment of Ring

Figure 2. Types of Ring Loading

EQUIVALENCE OF LOAD VECTOR

SELECTION OF BASIC SYSTEM

It is often convenient to select a basic system for this equivalence. In this problem, the system of reference of figure 1A is selected. The problem is to determine at Station p the load vector Φ_p which is equivalent to load vector Φ_m located at Station m. This is done with the matrix π.

$$\Phi_p = \begin{vmatrix} F_p \\ M_p \end{vmatrix} = \pi_p^m \Phi_m = \begin{vmatrix} I & O \\ \sigma_p^m & I \end{vmatrix} \cdot \begin{vmatrix} F_m \\ M_m \end{vmatrix}$$

with $I = \begin{vmatrix} 1,0,0 \\ 0,1,0 \\ 0,0,1 \end{vmatrix}$ and $O = \begin{vmatrix} 0,0,0 \\ 0,0,0 \\ 0,0,0 \end{vmatrix}$

and $\sigma_p^m = \sigma_m - \sigma_p$ and generally $\sigma_i = \begin{vmatrix} 0, -Z_i, Y_i \\ Z_i, 0, -X_i \\ -Y_i, X_i, 0 \end{vmatrix}$

We note that $\sigma_p^m = -\sigma_m^p ; \sigma_p^m + \sigma_n^p = \sigma_n^m$

Also $\pi_p^m \pi_n^p = \pi_n^m$

Proof: $\begin{vmatrix} I & O \\ \sigma_p^m & I \end{vmatrix} \begin{vmatrix} I & O \\ \sigma_n^p & I \end{vmatrix} = \begin{vmatrix} I & O \\ \sigma_p^m + \sigma_n^p & I \end{vmatrix} = \begin{vmatrix} I & O \\ \sigma_n^m & I \end{vmatrix}$

THE DISPLACEMENTS AND DEFLECTIONS

DEFLECTION

Deflection is always associated with deformation. If a solid S is deformed between the origin and Point A, an element of the solid at A has moved relative to an element at the origin and this relative displacement could be called Δ_A^O, O for origin.

DISPLACEMENT

Although a deflection is a relative displacement, displacement is also associated with solid body motion. It is always relative, never absolute. If, in the solid S, the origin O is used for the reference system, and the origin is subjected to a displacement Δ_O arbitrary and relative to a fixed system, we can find the displacement Δ_A at Point A of an element of solid S resulting from Δ_O, provided Δ_O, Δ_A and the coordinates of Points O and A use the same coordinate system.

TOTAL DISPLACEMENT

The two previous cases can take place simultaneously. As the result of the deformation between O and A and the arbitrary motion Δ_O of the solid at O, an element of S at A has been displaced $\Delta_A^O + \Delta_A$ relative to the fixed system.

Finally, assuming no deformation between Points A and B of solid S, the displacement Δ_B of B, relative to the fixed system can be found from $\Delta_A^O + \Delta_A$ at A in the same manner as Δ_A was found from Δ_O.

VECTOR DISPLACEMENT

At Station m of the ring elastic axis, the displacement relative to the fixed system is called Δ_m ($\Delta_m^{(0)}$) in the system of the origin.

If at Station m, curvilinear coordinate s_m, we take a small arc ds_m = 1 inch and the slice between Station s_m and $s_m + ds_m = s_m + 1$ is deformed, Station m + dm, at $s_m + ds_m$, is displaced relative to Station m. This displacement is an elemental deflection. It is usually computed in (m) system. It will be called $\delta_m^{(m)} ds_m = \delta_m^{(m)}$ since ds_m = 1 inch.

Vectors Δ_m and $\delta_m^{(m)}$ are of order six; the three components of the linear displacement and the three components of the rotational displacement.

$$\Delta_m = \begin{vmatrix} D_m \\ R_m \end{vmatrix} \text{ with } D_m = \begin{vmatrix} D_m^X \\ D_m^Y \\ D_m^Z \end{vmatrix} \text{ and } R_m = \begin{vmatrix} R_m^X \\ R_m^Y \\ R_m^Z \end{vmatrix}$$

and since $\delta_m^{(m)}$ is in the system of Section m, u_m, V_m, W_m (defined later)

$$\delta_m^{(m)} = \begin{vmatrix} d_m^{(m)} \\ r_m^{(m)} \end{vmatrix} \text{ with } d_m^{(m)} = \begin{vmatrix} d_m^u \\ d_m^v \\ d_m^w \end{vmatrix} \text{ and } r_m^{(m)} = \begin{vmatrix} r_m^u \\ r_m^v \\ r_m^w \end{vmatrix}$$

EQUIVALENCE OF DISPLACEMENT VECTOR

SELECTION OF BASIC SYSTEM

As for the load vector it is convenient to select a basic system. In general, the system used for the load vector is used for the displacement. Our problem is to determine at Station p the displacement vector Δ_p resulting from the solid body displacement Δ_m taking place at Station m. The same rule applies to $\delta_m^{(o)}$ equivalent to $\delta_m^{(m)}$. This is done with the matrix P.

$$\Delta_p = \begin{vmatrix} D_p \\ R_p \end{vmatrix} = P_p^m \Delta_m = \begin{vmatrix} I & \sigma_p^m \\ O & I \end{vmatrix} \cdot \begin{vmatrix} D_m \\ R_m \end{vmatrix}$$

$$\text{with } I = \begin{vmatrix} 1, 0, 0 \\ 0, 1, 0 \\ 0, 0, 1 \end{vmatrix} \text{ and } O = \begin{vmatrix} 0, 0, 0 \\ 0, 0, 0 \\ 0, 0, 0 \end{vmatrix}$$

and $\sigma_p^m = \sigma_m - \sigma_p$ and generally $\sigma_i = \begin{vmatrix} 0, -Z_i, Y_i \\ Z_i, 0, -X_i \\ -Y_i, X_i, 0 \end{vmatrix}$

Similarly with matrix π_p^m, $\sigma_p^m = -\sigma_m^p$; $\sigma_p^m + \sigma_n^p = \sigma_n^m$

also $P_p^m P_n^p = P_n^m$. The proof of this, which is given below, is similar to the one for matrix

$$P_n^m = \begin{vmatrix} I & \sigma_p^m \\ O & I \end{vmatrix} \cdot \begin{vmatrix} I & \sigma_n^p \\ O & I \end{vmatrix} = \begin{vmatrix} I & \sigma_n^p + \sigma_p^m \\ O & I \end{vmatrix} \equiv \begin{vmatrix} I & \sigma_n^m \\ O & I \end{vmatrix}$$

Note that $P_p^m = (\pi_m^p)^*$

BASIC CROSS-SECTION OF THE RING

STATION m

The cross-section of Station m is shown on figure 3. It shows the three axes u_m, v'_m, w'_m where u_m is the oriented tangent to the elastic axis at point m, w'_m is radial outward in the elastic axis plane and v'_m is normal to this plane and u_m, v'_m, w'_m form a clockwise system. We select the principal axis of the section which makes with v'_m an angle θ_m. It is called v_m. w_m (the other principal axis) makes an angle of $+\pi/2$ with v_m and thus makes an angle of θ_m with w'_m. (Angle θ_m is positive as u_m.)

The three axes u_m, v_m and w_m form the system (m) of the cross-section m, m, i.e., the section properties system at m.

MATRIX TRANSFORMATION λ_o^m

It can be proven, in general, with $b_m = \text{Cos}\,\theta_m$, $c_m = \text{Sin}\,\theta_m$, that

$$\text{with } U_o = \begin{vmatrix} X \\ Y \\ Z \end{vmatrix}, \; U_m = \begin{vmatrix} u_m \\ v_m \\ w_m \end{vmatrix}, \; \lambda_o^m = \begin{vmatrix} \cos(\varphi_m - \varphi_o), & 0, & -\sin(\varphi_m - \varphi_o) \\ c_m \sin(\varphi_m - \varphi_o), & b_m, & c_m \cos(\varphi_m - \varphi_o) \\ b_m \sin(\varphi_m - \varphi_o), & -c_m, & b_m \cos(\varphi_m - \varphi_o) \end{vmatrix}$$

$$(U_o = U^{(o)}) \qquad (U_m = U^{(m)})$$

$$\& \; \Lambda_o^m = \begin{vmatrix} \lambda_o^m & O \\ O & \lambda_o^m \end{vmatrix} \text{ we have } U_m = \lambda_o^m U_o, \; U_o = \lambda_m^o U_m, \; \lambda_m^o = (\lambda_o^m)^*$$

$$\text{and } \Phi_m^{(m)} = \Lambda_o^m \Phi_m, \; \Delta_m^{(m)} = \Lambda_o^m \Delta_m, \; \delta_m^{(m)} = \Lambda_o^m \delta_m$$

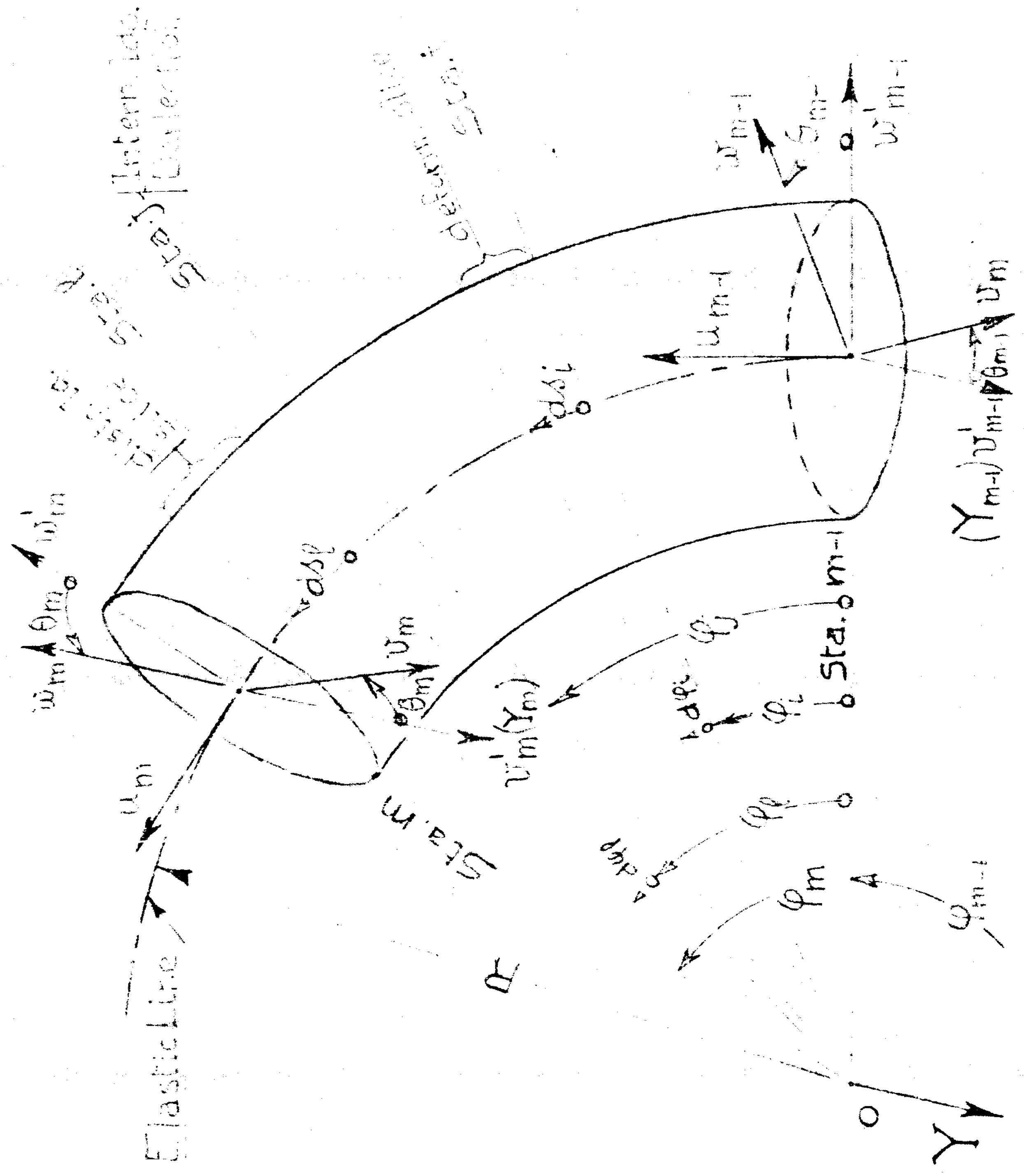


Figure 3. Basic Element m

SECTION PROPERTIES AT STATION m

At this cross-section (in the principal axes system m) the two principal bending properties EI, the two principal shear properties GA_s, the axial property EA and the torsional property GJ can be computed. Three of these properties are related to forces resulting in deflections and the other three are related to moments resulting in rotations. These properties are arranged conveniently in diagonal matrices as follows:

$$K_m = \begin{vmatrix} K_m^D & 0 \\ 0 & K_m^R \end{vmatrix}$$

$$\text{with } K_m^D = \begin{vmatrix} K_m^{D,u}, & 0, & 0 \\ 0, & K_m^{D,v}, & 0 \\ 0, & 0, & K_m^{D,w} \end{vmatrix} = \begin{vmatrix} \frac{1}{N_m}, & 0, & 0 \\ 0, & \frac{1}{S_m^v}, & 0 \\ 0, & 0, & \frac{1}{S_m^w} \end{vmatrix}$$

$$\text{and } K_m^R = \begin{vmatrix} K_m^{R,u}, & 0, & 0 \\ 0, & K_m^{R,v}, & 0 \\ 0, & 0, & K_m^{R,w} \end{vmatrix} = \begin{vmatrix} \frac{1}{D_m}, & 0, & 0 \\ 0, & \frac{1}{B_m^v}, & 0 \\ 0, & 0, & \frac{1}{B_m^w} \end{vmatrix}$$

where superscripts D and R refer to deflection and rotation respectively, superscripts v and w indicate component directions,

$$\text{and at Sta. } m \; (i = v, w) \quad \begin{cases} N_m = (EA)_m \\ S_m^i = (GA_s)_m^i \end{cases} \quad \text{and} \quad \begin{cases} D_m = (GJ)_m \\ B_m^i = (EI)_m^i \end{cases}$$

These section-properties are identified at Station m, as they may be variable.

BASIC ELEMENT OF THE RING

ELEMENT m

This element is shown on figure 3 and is the portion of the ring located between Stations m-1 and m. It will be analyzed as a cantilever beam, fixed at Station m-1 and free at Station m.

At Station $\Big|_{m}^{m-1}$, the internal load is Φ_{m}^{m-1}. We want to find at any Station j ($\varphi_{m-1} < \varphi_j \leqslant \varphi_m$) the deflection, relative to Station m-1, resulting from the load Φ_{m}^{m-1} applied at Station m.

At any Station ℓ (φ_ℓ), there is a unit distributed load applied on the elemental ring slice $ds_\ell = R d\varphi_\ell$. This distributed load is $\varphi_m(\ell)$, distributed on the element m, expressed in the m section system $\{(u_\ell, v_\ell, w_\ell)\}$. We want to find at any Station j ($\varphi_{m-1} < \varphi_j \leqslant \varphi_m$), the deflection, relative to Station m-1, resulting from this distributed load $\varphi_m(\ell)$. This distributed load can vary with Station ℓ.

At any Station i ($\varphi_{m-1} \leqslant \varphi_i \leqslant \varphi_j$), we take an elemental ring slice $ds_i = R d\varphi_i$, at which we will compute the internal loading, resulting from the external loads above, and the deformation, or the displacement of Station $s_i + ds_i$ relative to Station s_i.

INTERNAL LOADING AT ANY STATION j ($\varphi_{m-1} \leqslant \varphi_j \leqslant \varphi_m$)

$$\Phi_j^{(o)} = {}^{m}\pi_j \, \Phi_m^{m-1} = L_j^m \, \Phi_m^{m-1} \quad \text{with} \quad L_j^m = \pi_j^m$$

for distributed load between φ_j and φ_m ($\varphi_j \leqslant \varphi_\ell \leqslant \varphi_m$)

$$\Phi_j^{(o)} = \ell_j^m \, \varphi_m^{(m)} = \int_{\varphi_\ell = \varphi_j}^{\varphi_m} d\Phi_j^{(o)}, \quad d\Phi_j^{(o)} = \pi_j^\ell \Lambda_\ell^o \, \varphi_\ell^{(\ell)} ds_\ell .$$

L_j^m and l_j^m are internal load matrices. For concentrated load at Station m, $L_j^m = \pi_j^m$. For distributed load $\varphi_\ell^{(\ell)}$ on cantilever ring arc m,

with $\ell = m$ and $\varphi_\ell^{(\ell)} = \varphi_m^{(m)} =$ constant, with $ds_\ell = R\,d\varphi_\ell$,

$$l_j^m = R\int_{\varphi_\ell=\varphi_j}^{\varphi_\ell=\varphi_m} \pi_j^\ell \Lambda_\ell^o \, d\varphi_\ell$$

DEFLECTION AT ANY STATION J

In general, the deflection of the cantilever beam m at Station j is the sum, at Station j, of the effects of the deformation of the slice ds_i between the root (Station m-1) and Station j. In turn, the deformation of slice ds_i results from the internal loading Φ_i at Station i, which results from the external loading between Station i and Station m. For the concentrated load Φ_m^{m-1}, $\Phi_i = \pi_i^m \Phi_m^{m-1} = L_i^m \Phi_m^{m-1}$. For the distributed load $\varphi_\ell^{(\ell)}$, $\Phi_i = l_i^m \varphi_m^{(m)}$

On the other hand, the internal loading at Station i in the System i is $\Phi_i^{(i)} = \Lambda_o^i \Phi_i$ since $\Phi_i = \Phi_i^{(o)}$.

THE CONCENTRATED LOAD Φ_m^{m-1}

The deflection at j is $\Delta_j = H_j^m \Phi_m^{m-1} = \int_{\varphi_i=\varphi_{m-1}}^{\varphi_j} d\Delta_i$

$$\text{with } d\Delta_i = P_j^i \Lambda_i^o K_i \Lambda_o^i \pi_i^m \Phi_m^{m-1} ds_i$$

$$\text{therefore } H_j^m = R\int_{\varphi_i=\varphi_{m-1}}^{\varphi_i=\varphi_j} P_j^i \Lambda_i^o K_i \Lambda_o^i \pi_i^m \, d\varphi_i$$

H_j^m is the stiffness matrix of the element m, cantilevered from Station m-1, loaded at Station m with Φ_m^{m-1}, when deflection at Station j is required. Obviously, Station j can be varied from Station m-1, where $H_{m-1}^m = 0$ (Station m-1 is the root), to Station m, where H_m^m is maximum. H_m^m is of general use.

If we use the matrix H_m^m for the case where Station m-1 is Station 0, the integral limits are from $\varphi_j = \varphi_o$ to $\varphi_i = \varphi_m$ and H_m^m will be called K_m^m. In particular, when m = 1, $K_1^1 = H_1^1$.

FOR THE DISTRIBUTED LOADING $\varphi_m^{(m)}$

The deflection at Station j, Δ_j, is due to $\varphi_\ell^{(\ell)} = \varphi_m^{(m)}$ applied from Station m-1 to Station m. At Station i, where the deformation is computed, the internal loading is

$$\Phi_i^{(o)} = \ell_i^m \varphi_m^{(m)} \quad \text{with} \quad \ell_i^m = R \int_{\varphi_\ell = \varphi_i}^{\varphi_\ell = \varphi_m} \pi_i^\ell \Lambda_\ell^o \, d\varphi_\ell$$

$$\text{but} \quad \Delta_j = h_j^m \varphi_m^{(m)} = \int_{\varphi_i = \varphi_{m-1}}^{\varphi_j} d\Delta_i$$

$$\text{with} \quad d\Delta_i = P_j^i \Lambda_i^o K_i \Lambda_o^i \ell_i^m \varphi_m^{(m)} ds_i$$

$$\text{therefore} \quad h_j^m = R \int_{\varphi_i = \varphi_{m-1}}^{\varphi_i = \varphi_j} P_j^i \Lambda_i^o K_i \Lambda_o^i \ell_i^m \, d\varphi_i$$

The difference between h_j^m and H_j^m is that matrix π_i^m ($= L_i^m$) is replaced by integral loading matrix ℓ_i^m.

As Station j varies from Station m-1 to Station m, the stiffness matrix h_j^m varies between $h_{m-1}^m = 0$ (Station m-1 is the root) and h_m^m.

REMARK ON ρ_j^m, H_j^m AND h_j^m

For a circular arc of any angle and constant properties, these integral matrices can be computed algebraically and programmed. The program of H_j^m is used for K_m^m.

SEPARATING THE 3-DIMENSION SOLUTION INTO THE IN-PLANE AND THE OUT-OF-PLANE SOLUTIONS

This case occurs when one of the principal axes is in the elastic line plane of the ring. On page 13, $\theta = 0$ and $b = \cos\theta = 1$, $c = \sin\theta = 0$. With $C_m = \cos\varphi_m$, $S_m = \sin\varphi_m$ matrix λ_0^m is simplified. We have

$$\begin{vmatrix} u_m \\ v_m \\ w_m \end{vmatrix} = \begin{vmatrix} C_m, & 0, & -S_m \\ 0, & 1, & 0 \\ S_m, & 0, & C_m \end{vmatrix} \cdot \begin{vmatrix} X_m \\ Y_m \\ Z_m \end{vmatrix} \therefore \begin{vmatrix} X_m \\ Y_m \\ Z_m \end{vmatrix} = \begin{vmatrix} C_m, & 0, & S_m \\ 0, & 1, & 0 \\ -S_m, & 0, & C_m \end{vmatrix} \cdot \begin{vmatrix} u_m \\ v_m \\ w_m \end{vmatrix}$$

IN-PLANE

In the in-plane we have rotational scalars $\bar{v}_m$, $\bar{Y}_m$ and lineal scalars u_m, X_m, w_m, Z_m, thus

$\bar{v}_m = \bar{Y}_m$, $u_m = C_m X_m - S_m Z_m$, $w_m = S_m X_m + C_m Z_m$

$\bar{Y}_m = \bar{v}_m$, $X_m = C_m u_m + S_m w_m$, $Z_m = -S_m u_m + C_m w_m$

$$\text{or} \begin{vmatrix} u_m \\ w_m \end{vmatrix} = \begin{vmatrix} C_m, & -S_m \\ S_m, & C_m \end{vmatrix} \cdot \begin{vmatrix} X_m \\ Z_m \end{vmatrix} \therefore \begin{vmatrix} X_m \\ Z_m \end{vmatrix} = \begin{vmatrix} C_m, & S_m \\ -S_m, & C_m \end{vmatrix} \cdot \begin{vmatrix} u_m \\ v_m \end{vmatrix}$$

OUT-OF-PLANE

In the out-of-plane we have linear scalars v_m, Y_m and rotational scelars $\bar{u}_m$, $\bar{X}_m$, $\bar{w}_m$, $\bar{Z}_m$, thus

$$v_m = Y_m, \; \bar{u}_m = C_m \bar{X}_m - S_m \bar{Z}_m, \; \bar{w}_m = S_m \bar{X}_m + C_m \bar{Z}_m$$

$$Y_m = v_m, \; \bar{X}_m = C_m u_m + S_m w_m, \; \bar{Z}_m = -S_m \bar{u}_m + C_m \bar{w}_m$$

The matrices Λ_0^m, $\left.\begin{matrix}\Pi \\ P\end{matrix}\right|_i^m$ are separated for the in-plane and out-of-plane cases. Λ_0^m is made more general, leaving in Station 0.

$$C_0^m = \cos(\varphi_m - \varphi_0), \; S_0^m = \sin(\varphi_m - \varphi_0)$$

$$\left[\Lambda_0^m\right]^{-1} = \left[\Lambda_0^m\right]^* = \Lambda_n^o; \; \left[\Pi_i^m\right]^{-1} = \Pi_m^i \neq \left[\Pi_i^m\right]^*; \; \left[P_i^m\right]^{-1} = P_m^i \neq \left[P_i^m\right]^*$$

Matrices K_j^m, K_m^m, H_j^m, H_m^m, ℓ_j^m, ℓ_m^m, h_j^m, h_m^m are separated later on.

$$X_i^m = X_m - X_i$$

NOTE: In planar ring $Y_m = Y_i = Y_i^m = 0$

TABLE SHOWING THE SEPARATION OF 3-DIMENSIONAL BASIC MATRICES FOR THE IN-PLANE AND OUT-OF-PLANE CASES.

Matrix	3-Dim. $\theta = 0$	In-plane	Out-of-plane
Λ_o^m	$\begin{bmatrix} \begin{matrix} C_o^m & 0 & -S_o^m \\ 0 & 1 & 0 \\ S_o^m & 0 & C_o^m \end{matrix} & O \\ O & \begin{matrix} C_o^m & 0 & -S_o^m \\ 0 & 1 & 0 \\ S_o^m & 0 & C_o^m \end{matrix} \end{bmatrix}$	$\begin{bmatrix} C_o^m & -S_o^m & 0 \\ S_o^m & C_o^m & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & C_o^m & -S_o^m \\ 0 & S_o^m & C_o^m \end{bmatrix}$
λ_i^m	$\begin{bmatrix} I & O \\ \begin{matrix} 0 & -Z_i^m & Y_i^m \\ Z_i^m & 0 & -X_i^m \\ -Y_i^m & X_i^m & 0 \end{matrix} & I \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ Z_i^m & -X_i^m & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & 0 \\ -Z_i^m & 1 & 0 \\ X_i^m & 0 & 1 \end{bmatrix}$
P_i^m	$\begin{bmatrix} I & \begin{matrix} 0 & -Z_i^m & Y_i^m \\ Z_i^m & 0 & -X_i^m \\ -Y_i^m & X_i^m & 0 \end{matrix} \\ O & I \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & -Z_i^m \\ 0 & 1 & X_i^m \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & Z_i^m & -X_i^m \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Note.

$$X_i^m = X_m - X_i \qquad C_o^m = \cos(\varphi_m - \varphi_o)$$

$$Y_i^m = Y_m - Y_i \equiv 0 \qquad S_o^m = \sin(\varphi_m - \varphi_o)$$

$$Z_i^m = Z_m - Z_i$$

ACTUAL SOLUTION OF THE RING

PRELIMINARY REMARKS

The ring is a curved beam supported at Station 0 until the load $\Delta\phi_n$ ($= \phi_n^{n-1}$) applied at the tip Station n is determined. This load is the "indeterminate" of the problem and is obtained as the solution of the boundary condition. This condition stipulates that $\Delta\phi_n$ is the load which must be applied at Station n, in order to bring Station n back to its original position before the cutting. $\Delta\phi_n$ is = 0 if no external load is applied to the ring except at Station 0, where the ring support resists it without imposing deformation to the ring.

Therefore, the indeterminate $\Delta\phi_n$ must be known before the ring solution can be completed. Actually, $\Delta\phi_n$ must be assumed to be known before the deflection at Station n, Δ_n can be formulated for writing the boundary equations.

The following solution will then present the solution for the internal loading at any Station m ($1 \leq m \leq n-1$), the deflection at any Station m ($1 \leq m \leq n$) resulting from the application to the cantilever beam of the external loading $\Delta\phi_m$ ($1 \leq m \leq n$) and $\varphi_m^{(m)}$ ($1 \leq m \leq n$), all given except the indeterminate $\Delta\phi_n$. The boundary equations then become specific and the "indeterminate" $\Delta\phi_n$ is their solution.

In the case where the curved beam is not a complete loop, which under balanced loading needs no support, but an arc between two end supports, the same procedure can be used, selecting the right hand support for the root and the left one as the tip of our cantilever beam.

The complete solution covers these consecutive steps:

Step One: Determination of Internal Loading ϕ_m^{m-1} at Station $\Big|_m^{m-1}$.

Step Two: Determination of Deflection Δ_m at Station m.

Step Three: Solution of the Boundary Conditions for "Indeterminate".

Step Four: Determination of Final ϕ_m^{m-1} from Station n-1 to Station 0.

Step Five: Determination of Final Δ_m from Station 1 to Station n. Δ_n here should be used as a check.

Step Six: Determination of Final $\phi_j^{(m)}$ and $\Delta_j^{(m)}$, where (m) means That Station j is Between Station m-1 and Station m on Element m, when Such Results are Requested at a Specific Station.

STEP ONE: DETERMINATION OF INTERNAL LOADING ϕ_m^{m-1} IN TERMS OF THE APPLIED LOADING

The recurrence formulae at Station m are

$$\Phi_m^{m-1} = \Phi_m^{m+1} + \Delta\Phi_m, \quad \Phi_m^{m+1} = \Pi_m^{m+1}\Phi_{m+1}^{m} + \ell_m^{m+1}\varphi_{m+1}^{(m+1)}$$

Thus the final recurrence equation at Station m is

$$\Phi_m^{m-1} = \Pi_m^{m+1}\Phi_{m+1}^{m} + \ell_m^{m+1}\varphi_{m+1}^{(m+1)} + \Delta\Phi_m$$

If we want $\phi_j^{(m)}$, internal loading at Station j of element m

$$\Phi_j^{(m)} = \Pi_j^{m}\Phi_m^{m-1} + \ell_j^{m}\varphi_m^{(m)}$$

By using this relation, starting at element n and building up, down and including element m + 1, we obtain $\phi_j^{(m+1)}$ in terms of the external loading, setting $\Delta\phi_n$ separately; then

$$\Phi_j^{(m+1)} = \Pi_j^{n}\Delta\Phi_n + \sum_{i=n-1}^{m+1}\Pi_j^{i}\left[\Delta\Phi_i + \ell_i^{i+1}\varphi_{i+1}^{(i+1)}\right] + \ell_j^{m+1}\varphi_{m+1}^{(m+1)}$$

Now for j = m, $\phi_j^{(m+1)} = \phi_m^{m+1}$ and since $\phi_m^{m+1} + \Delta\phi_m$ ϕ_m^{m-1} we have obtained ϕ_m^{m-1} in terms of applied loading and $\Delta\phi_n$, since $\pi_m^m = I$

$$\Phi_m^{m-1} = \pi_m^n \Delta\Phi_n + \sum_{i=n-1}^{m} \pi_m^i \left(\Delta\Phi_i + \ell_i^{i+1}\varphi_{i+1}^{(i+1)}\right)$$

Support Reaction

At this point, an important relation at m = 0, $[(m - 1) = -1]$ can be proved by this algebra.

$$\Phi_0^{-1} = \pi_0^n \Delta\Phi_n + \sum_{i=n-1}^{1} \pi_0^i \left[\Delta\Phi_i + \ell_i^{i+1}\varphi_{i+1}^{(i+1)}\right] + \pi_0^0\left[\Delta\Phi_0 + \ell_0^1\varphi_1^{(1)}\right]$$

Since $\pi_0^n = \pi_0^0 = I$ and ϕ_0^{-1} should equal $\phi_n^{n-1} = \Delta\phi_n$

we find

$$\Delta\Phi_0 = -\sum_{i=n-1}^{1} \pi_0^i \left[\Delta\Phi_i + \ell_i^{i+1}\varphi_{i+1}^{(i+1)}\right] - \ell_0^1\varphi_1^{(1)}$$

$\Delta\phi_0$ is an external load applied to the ring at Station 0 and it should be the support reaction. Its expression shows that it is the balance of all the external loads, concentrated $\Delta\phi_{n-1}$, ,$\Delta\phi_1$, and distributed $\varphi_n^{(n)}$, ,$\varphi_1^{(1)}$ applied to the ring. As the ring loading must be balanced, any Station i with an external loading $\Delta\phi_i$ can be taken as the root of the cantilever, and all the other external loading applied to it. $\Delta\phi_i$ need not be applied since it will be the support reaction.

STEP TWO: DETERMINATION OF DEFLECTION Δ_m IN TERMS OF THE APPLIED LOADING

The recurrence relation at Station m is

$$\Delta_m = P_m^{m-1}\Delta_{m-1} + H_m^m \Phi_m^{m-1} + h_m^m \varphi_m^{(m)}$$

Applying this relation, starting at Station 1 and going to Station m, we have

$$\Delta_m = P_m^o \Delta_o + \sum_{j=1}^{m} P_m^j \left[H_j^j \Phi_j^{j-1} + h_j^j \varphi_j^{(j)} \right]$$

The previous expression of ϕ_m^{m-1} for m = j gives

$$\Phi_j^{j-1} = \pi_j^n \Delta\Phi_n + \sum_{i=n-1}^{j} \pi_j^i \left[\Delta\Phi_i + \ell_i^{i+1} \varphi_{i+1}^{(i+1)} \right]$$

In Δ_m above it gives

$$\Delta_m - P_m^o \Delta_o = \sum_{j=1}^{m} P_m^j H_j^j \pi_j^n \Delta\Phi_n +$$

$$\sum_{j=1}^{m} P_m^j \left\{ H_j^j \sum_{i=n-1}^{j} \pi_j^i \left[\Delta\Phi_i + \ell_i^{i+1} \varphi_{i+1}^{(i+1)} \right] + h_j^j \varphi_j^{(j)} \right\}$$

Now, if we apply only ϕ_m^{m-1} at Station m, $\Delta_m = K_m^m \phi_m^{m-1} + P_m^0 \Delta_0$

but it can also be written, using the π, P and H's.

$$\Delta_m(\phi_m^{m-1}) = H_m^m \Phi_m^{m-1} + P_m^{m-1} H_{m-1}^{m-1} \pi_{m-1}^m \Phi_m^{m-1} + \ldots + P_m^1 H_1^1 \pi_1^m \Phi_m^{m-1} + P_m^o \Delta_o$$

By comparison since $P_m^m = \pi_m^m = I$

$$K_m^m = \sum_{j=1}^{m} P_m^j H_j^j \pi_j^m$$

We can also obtain the H's in terms of the K's

$$K_m^m = H_m^m + P_m^{m-1} K_{m-1}^{m-1} \pi_{m-1}^m$$

therefore,

$$H_m^m = K_m^m - P_m^{m-1} K_{m-1}^{m-1} \pi_{m-1}^m$$

NOTE: This relation is important. It will be seen later that the K's give a simpler boundary equation for the ring. If these integrals are computed and programmed, the more complicated version H need not be computed and programmed for the following steps.

The expression Δ_m above, if m = n, becomes, with $P_r^0 = I$

$$\Delta_n - \Delta_0 = \sum_{j=1}^{n} P_n^j H_j^j \pi_j^n \Delta\Phi_n +$$

$$\sum_{j=1}^{n} P_n^j \left\{ H_j^j \sum_{i=n-1}^{j} \pi_j^i \left[\Delta\Phi_i + \ell_i^{i+1} \varphi_{(i+1)}^{(i+1)} \right] + h_j^j \varphi_j^{(j)} \right\}$$

In the above expression of Δ_n, using the value of K_m^m above

$$\sum_{j=1}^{n} P_n^j H_j^j \pi_j^n = K_n^n,$$

$$\sum_{j=1}^{n} P_n^j H_j^j \pi_j^i = P_n^i \sum_{j=1}^{n} P_i^j H_j^j \pi_j^i = P_n^i K_i^i \quad (1 \leq i \leq n-1)$$

then $\Delta_n - \Delta_0 = K_n^n \Delta\Phi_n +$

$$\sum_{i=n-1}^{1} P_n^i K_i^i \left[\Delta\Phi_i + \ell_i^{i+1} \varphi_{(i+1)}^{(i+1)} \right] + \sum_{i=n}^{1} P_n^i h_i^i \varphi_i^{(i)}$$

Letting i = m

$$\Delta_n - \Delta_0 = K_n^n \Delta\Phi_n + \sum_{m=1}^{n-1} P_n^m K_m^m \left[\Delta\Phi_m + \ell_m^{m+1} \varphi_{m+1}^{(m+1)}\right] + \sum_{m=1}^{n} P_n^m h_m^m \varphi_m^{(m)}$$

STEP THREE: SOLVING THE BOUNDARY EQUATIONS FOR THE INDETERMINATES

In the ring problem the boundary condition is $\Delta_n = \Delta_0$ or $\Delta_n - \Delta_0 = 0$. Therefore, the right hand side of the previous equation must vanish. This right hand side is the sum of the ring deformation. Since the $\Delta\phi_m$ $(1 \leqslant m \leqslant n-1)$ and the $\varphi_m^{(m)}$ $(1 \leqslant m \leqslant n)$ are given, this equation can be solved for the indeterminate $\Delta\phi_n$ (ϕ_n^{n-1}) at the cut Station$\big|_n^{n-1}$. This gives

$$\Delta\Phi_n \left(= \Phi_n^{n-1}\right) = -\left[K_n^n\right]^{-1} \left\{\sum_{m=1}^{n-1} P_n^m K_m^m \left[\Delta\Phi_m + \ell_m^{m+1} \varphi_{m+1}^{(m+1)}\right] + \sum_{m=1}^{n} P_n^m h_m^m \varphi_m^{(m)}\right\}$$

Computing may require a different arrangement of the externally applied loading, separating the concentrated loads $\Delta\phi_m$ from the distributed load $\varphi_m^{(m)}$. It may be convenient to use the following.

For Concentrated Load $\Delta\phi_m$

$$\Delta\Phi_{n(\Delta\Phi_m)} = -\left[K_n^n\right]^{-1} P_n^m K_m^m \Delta\Phi_m$$

For the Sum of the Concentrated Loads $\sum_{m=1}^{n-1} \Delta\phi_m$

$$\Delta\Phi_n = -\left[K_n^n\right]^{-1} \sum_{m=1}^{n-1} P_n^m K_m^m \Delta\Phi_m$$

For Distributed Load $\varphi_n^{(m)}$

$$\Delta\Phi_n(\varphi_m^{(m)}) = -\left[K_n^n\right]^{-1}\left[P_n^{n-1}K_{m-1}^{m-1}\ell_{m-1}^m + P_n^m h_m^m\right]\varphi_m^{(m)}$$

For the Sum of the Distributed Loads $\sum_{m=1}^{n}\varphi_m^{(m)}$. With $K_{m-1}^{m-1} = K_0^0 = 0 \, (m=1)$

$$\Delta\Phi_n = -\left[K_n^n\right]^{-1}\sum_{m=1}^{n}\left(P_n^{m-1}K_{m-1}^{m-1}\ell_{m-1}^m + P_n^m h_m^m\right)\varphi_m^{(m)}$$

This leads to a variation of the total $\Delta\phi_n$, which follows.

$$\Delta\Phi_n = -\left[K_n^n\right]^{-1}\left\{\sum_{m=1}^{n-1}P_n^m K_m^m \Delta\Phi_m + \sum_{m=1}^{n}\left(P_n^{m-1}K_{m-1}^{m-1}\ell_{m-1}^m + P_n^m h_m^m\right)\varphi_m^{(m)}\right\}$$

STEP FOUR: DETERMINATION OF THE FINAL INTERNAL LOADS ϕ_m^{m+1} AND ϕ_m^{m-1}

AT STATION m

Since $\Delta\phi_n = \phi_n^{n-1}$ is known, the internal loading is computed progressively from Station n-1 to Station 0.

Direct Computation of ϕ_m^{m+1}: At Sta. $\Big|_{n-1}^{n}$, $\Phi_{n-1}^{n} = \pi_{n-1}^{n}\Phi_n^{n-1} + \ell_{n-1}^{n}\varphi_n^{(n)}$;

at Sta. $\Big|_{n-2}^{n-1}$, $\Phi_{n-2}^{n-1} = \pi_{n-2}^{n-1}\Phi_{n-1}^{n-2} + \ell_{n-2}^{n-1}\varphi_{n-1}^{(n-1)}$, and finally

with $\Phi_{n-1}^{n-2} = \Phi_{n-1}^{n} + \Delta\Phi_{n-1} \therefore \Phi_{n-2}^{n-1} = \pi_{n-2}^{n-1}\left[\Phi_{n-1}^{n} + \Delta\Phi_{n-1}\right] + \ell_{n-2}^{n-1}\varphi_{n-1}^{(n-1)} =$

$$\pi_{n-2}^{n-1}\Phi_{n-1}^{n} + \pi_{n-2}^{n-1}\Delta\Phi_{n-1} + \ell_{n-2}^{n-1}\varphi_{n-1}^{(n-1)}.$$

In general at $Sta.\Big|_{m}^{m+1}$,

$$\Phi_{m}^{m+1} = \pi_{m}^{m+1}\Phi_{m+1}^{m+2} + \pi_{m}^{m+1}\Delta\Phi_{m+1} + \ell_{m}^{m+1}\varphi_{m+1}^{(m+1)}$$

At the root $Sta.\Big|_{0}^{1}$,

$$\Phi_{0}^{1} = \pi_{0}^{1}\Phi_{1}^{2} + \pi_{0}^{1}\Delta\Phi_{1} + \ell_{0}^{1}\varphi_{1}^{(1)}$$

Direct Computation of ϕ_{m}^{m-1}: At $Sta.\Big|_{n-1}^{n-2}$, $\Phi_{n-1}^{n-2} = \Phi_{n-1}^{n} + \Delta\Phi_{n-1}$;

and with $\Phi_{n-1}^{n} = \pi_{n-1}^{n}\Phi_{n}^{n-1} + \ell_{n-1}^{n}\varphi_{n}^{(n)}$,

$$\Phi_{n-1}^{n-2} = \pi_{n-1}^{n}\Phi_{n}^{n-1} + \ell_{n-1}^{n}\varphi_{n}^{(n)} + \Delta\Phi_{n-1}.$$

In general at $Sta.\Big|_{m}^{m-1}$,

$$\Phi_{m}^{m-1} = \pi_{m}^{m+1}\Phi_{m+1}^{m} + \ell_{m}^{m+1}\varphi_{m+1}^{(m+1)} + \Delta\Phi_{m}.$$

At the root $Sta.\Big|_{0}^{-1} = Sta.\Big|_{n}^{n-1}$,

$$\Phi_{0}^{-1} = \pi_{0}^{1}\Phi_{1}^{0} + \ell_{0}^{1}\varphi_{1}^{(1)} + \Delta\Phi_{0}.$$

Where $\Delta\phi_0$ is the support reaction.

Computing ϕ_{m}^{m+1}, ϕ_{m}^{m-1}, etc.... First $\Phi_{n}^{n-1} = \Delta\Phi_{n}$, the indeterminate,

then $\Phi_{n-1}^{n} = \pi_{n-1}^{n}\Phi_{n}^{n-1} + \ell_{n-1}^{n}\varphi_{n}^{(n)}$, $\Phi_{n-1}^{n-2} = \Phi_{n-1}^{n} + \Delta\Phi_{n-1}$, ...

....

in general $\Phi_{m}^{m+1} = \pi_{m}^{m+1}\Phi_{m+1}^{m} + \ell_{m}^{m+1}\varphi_{m+1}^{(m+1)}$,

then $\Phi_{m}^{m-1} = \Phi_{m}^{m+1} + \Delta\Phi_{m}$. and so on.....

STEP FIVE: DETERMINATION OF THE FINAL DEFLECTION $_m$ AT STATION m

Since $\triangle_0$ is known, $\triangle_m$ is computed progressively from Station 1 to Station n. $\triangle_n$ at Station n provides a check. At Station 1,

$$\triangle_1 = P_1^0 \triangle_0 + H_1^1 \phi_1^0 + h_1^1 \varphi_1^{(1)}$$

In general, at Station m, $\triangle_m = P_m^{m-1} \triangle_{m-1} + H_m^m \phi_m^{m-1} + h_m^m \varphi_m^{(m)}$

At the outboard end Station n, $\triangle_n = P_n^{n-1} \triangle_{n-1} + H_n^n \phi_n^{n-1} + h_n^n \varphi_n^{(n)}$

STEP SIX: DETERMINATION OF FINAL $\phi_j^{(m)}$ AND $\triangle_j^{(m)}$ AT ANY GIVEN STATION j OF ELEMENT m

Since ϕ_{m-1}^n and $\triangle_{m-1}$ are known, $\phi_j^{(m)} = \pi_j^m \phi_m^{m-1} + \ell_j^m \varphi_m^{(m)}$

$$\triangle_j^{(m)} = P_j^{m-1} \triangle_{m-1} + H_j^m \phi_m^{m-1} + h_j^m \varphi_m^{(m)}$$

PARAMETRIC SOLUTION OF THE UNIFORM CIRCULAR RING

REQUIREMENTS OF OPTIMIZATION

The preceding solution is general. However, the matrices l_j^m, h_j^m, H_j^m and K_m^m are only symbolic in the general case. In some particular cases of curved beam they can be computed algebraically and programmed for the computer. In these cases, the study of these matrices may give some clues which may simplify the optimization problem. In the problem of circular shell supported uniform rings with out-of-plane loadings, the previous matrices are at the simplest. For this case, optimization is shown in the following.

PARAMETRIC FORM OF THE BASIC MATRICES

This subsection is still general, as applied to a basic element m of the ring with constant radius R_m and section properties K_m. This means that, unless the optimization of the whole ring or curved beam is undertaken, the parametric form of these matrices is still applicable to cases of curved beams constructed of circular elements m with the above specifications, although of different R_m and K_m.

The following also applies to the case, shown before, where the 3-dimensional case can be split between the in-plane and the out-of-plane cases because the angle θ_m of the principal axes equals zero.

We now proceed to develop the parametric form of the basic matrices in the same order as in this report. The subscript m is omitted and R, K^D and K^R are only shown, with their respective powers, positive or negative.

Matrix π. (1'd. equiv.)

$$\pi_p^m = \left|\begin{array}{c|c} I & O \\ \hline \sigma_p^m & I \end{array}\right| \equiv \left|\begin{array}{c|c} R^0 & O \\ \hline R^1 & R^0 \end{array}\right|$$

Note:
in general the sub-matrix σ_p^m is of the order R^1.

Matrix P. (defl. equiv.)

$$P_p^m = \left|\begin{array}{c|c} I & \sigma_p^m \\ \hline O & I \end{array}\right| \equiv \left|\begin{array}{c|c} R^0 & R^1 \\ \hline O & R^0 \end{array}\right|$$

Matrix Λ. (ch'ge of coord.)

$$\Lambda_o^m = \left|\begin{array}{c|c} \lambda_o^m & O \\ \hline O & \lambda_o^m \end{array}\right| \equiv \left|\begin{array}{c|c} R^0 & O \\ \hline O & R^0 \end{array}\right|$$

Matrix K.
(sect. propert.)

$$K_m = \left|\begin{array}{c|c} K_m^D & O \\ \hline O & K_m^R \end{array}\right| \equiv \left|\begin{array}{c|c} R^\circ K^D & O \\ \hline O & R^\circ K^R \end{array}\right|$$

Matrix L.
(int. ldg. conc. ld.)

$$L_j^m = \pi_j^m = \left|\begin{array}{c|c} I & O \\ \hline \sigma_j^m & I \end{array}\right| \equiv \left|\begin{array}{c|c} R^\circ & O \\ \hline R^1 & R^\circ \end{array}\right|$$

Matrix ℓ.
(int. ldg. dist. ld.)

$$\pi_j^\ell \Lambda_\ell^\circ = \left|\begin{array}{c|c} I & O \\ \hline \sigma_j^\ell & I \end{array}\right| \cdot \left|\begin{array}{c|c} \lambda_\ell^\circ & O \\ \hline O & \lambda_\ell^\circ \end{array}\right| = \left|\begin{array}{c|c} \lambda_\ell^\circ & O \\ \hline \sigma_j^\ell \lambda_\ell^\circ & \lambda_\ell^\circ \end{array}\right|$$

then $\ell_j^m = \displaystyle\int_{\ell=j}^{m} \pi_j^\ell \Lambda_\ell^\circ ds_\ell = R^1 \int \left|\begin{array}{c|c} \lambda_\ell^\circ & O \\ \hline \sigma_j^\ell \lambda_\ell^\circ & \lambda_\ell^\circ \end{array}\right| d\varphi_\ell \equiv \left|\begin{array}{c|c} R^1 & O \\ \hline R^2 & R^1 \end{array}\right|$

Matrices H and K.
(stiffness for conc. ld.)

$$H_j^m = R \int_{\varphi_i = \varphi_{m-1}}^{\varphi_j} P_j^i \Lambda_i^\circ K_i \Lambda_o^i \pi_i^m \, d\varphi_i$$

We have $P_j^i \Lambda_i^\circ K_i \Lambda_o^i \pi_i^m =$

$$\left|\begin{array}{c|c} I & \sigma_j^i \\ \hline O & I \end{array}\right| \cdot \left|\begin{array}{c|c} \lambda_i^\circ & O \\ \hline O & \lambda_i^\circ \end{array}\right| \cdot \left|\begin{array}{c|c} K_i^D & O \\ \hline O & K_i^R \end{array}\right| \cdot \left|\begin{array}{c|c} \lambda_o^i & O \\ \hline O & \lambda_o^i \end{array}\right| \cdot \left|\begin{array}{c|c} I & O \\ \hline \sigma_i^m & I \end{array}\right| =$$

$$\left|\begin{array}{c|c} \lambda_i^o K_i^D \lambda_o^i + \sigma_j^i \lambda_i^o K_i^R \lambda_o^i \sigma_i^m & \sigma_j^i \lambda_i^o K_i^R \lambda_o^i \\ \hline \lambda_i^o K_i^R \lambda_o^i \sigma_i^m & \lambda_i^o K_i^R \lambda_o^i \end{array}\right| \quad \text{Therefore}$$

the parametric form of H_j^m (and K_m^m) is $\left|\begin{array}{c|c} R^1 K^D + R^3 K^R & R^2 K^R \\ \hline R^2 K^R & R^1 K^R \end{array}\right|$

<u>Matrix h.</u>
(stiffness for dist. ld.)

$$h_j^m = R\int_{\varphi_i=\varphi_{m-1}}^{\varphi_j} P_j^i \Lambda_i^o K_i \Lambda_o^i \ell_i^m \, d\varphi_i$$

we write $\ell_i^m = R\int \left|\begin{array}{c|c} \lambda_\ell^o & O \\ \hline \sigma_i^\ell \lambda_\ell^o & \lambda_\ell^o \end{array}\right| d\varphi_\ell = \left|\begin{array}{c|c} R\int \lambda_\ell^o & O \\ \hline R\int \sigma_i^\ell \lambda_\ell^o & R\int \lambda_\ell^o \end{array}\right| = \left|\begin{array}{c|c} RL_i^{m-1} & O \\ \hline R^2\Sigma_i^{m-1} & RL_i^{m-1} \end{array}\right|$

then $P_j^i \Lambda_i^o K_i \Lambda_o^i \ell_i^m = \left|\begin{array}{c|c} I & \sigma_j^i \\ \hline O & I \end{array}\right| \left|\begin{array}{c|c} \lambda_i^o & O \\ \hline O & \lambda_i^o \end{array}\right| \left|\begin{array}{c|c} K_i^D & O \\ \hline O & K_i^R \end{array}\right| \left|\begin{array}{c|c} \lambda_o^i & O \\ \hline O & \lambda_o^i \end{array}\right| \left|\begin{array}{c|c} RL_i^{m-1} & O \\ \hline R^2\Sigma_i^{m-1} & RL_i^{m-1} \end{array}\right| =$

$$R\left|\begin{array}{c|c} \lambda_i^o K_i^D \lambda_o^i L_i^{m-1} + R\sigma_j^i \lambda_i^o K_i^R \lambda_o^i \Sigma_i^{m-1} & \sigma_j^i \lambda_i^o K_i^R \lambda_o^i L_i^{m-1} \\ \hline R\lambda_i^o K_i^R \lambda_o^i \Sigma_i^{m-1} & \lambda_i^o K_i^R \lambda_o^i L_i^{m-1} \end{array}\right| \quad \text{Therefore}$$

the parametric form of h_j^m is $\left|\begin{array}{c|c} R^2 K^D + R^4 K^R & R^3 K^R \\ \hline R^3 K^R & R^2 K^R \end{array}\right|$

PARAMETRIC FORM OF THE BASIC VECTORS

The given vectors are $\Delta\phi_m$ $(1 \leqslant m \leqslant n-1)$, $\varphi_m^{(m)}$ $(1 \leqslant m \leqslant n)$ and Δ_0. The basic vectors are ϕ_m and Δ_m. With the parametric form of the basic matrices, it is easy to obtain the parametric form of the basic vectors and to check that these forms run true through the whole situation.

Vector ϕ_p (Internal Ld.)

$$\Phi_p = \pi_p^m \Delta\Phi_m \therefore \begin{vmatrix} F_p \\ M_p \end{vmatrix} = \begin{vmatrix} R^0 & 0 \\ R^1 & R^0 \end{vmatrix} \cdot \begin{vmatrix} \Delta F_m \\ \Delta M_m \end{vmatrix}$$

For distr. ld. $\varphi_m^{(m)}$

$$\Phi_p = \ell_p^m \varphi_m^{(m)} \therefore \begin{vmatrix} F_p \\ M_p \end{vmatrix} = \begin{vmatrix} R^1 & 0 \\ R^2 & R^1 \end{vmatrix} \cdot \begin{vmatrix} f_m \\ m_m \end{vmatrix}$$

Equivalence of ϕ_p at Station s

$\phi_s = \pi_s^p \phi_p$, but $\pi_s^p \pi_p^m = \pi_s^m$, therefore $\phi_s = \pi_s^m \Delta\phi_m$

Vector Δ_p (Deflection)

$$\Delta_p = P_p^0 \Delta_0 \therefore \begin{vmatrix} D_p \\ R_p \end{vmatrix} = \begin{vmatrix} R^0 & R^1 \\ 0 & R^0 \end{vmatrix} \cdot \begin{vmatrix} D_0 \\ R_0 \end{vmatrix}$$

Equivalence of Δ_p at Station s

$\Delta_s = P_s^p \Delta_p$, but $P_s^p P_p^0 = P_s^0$, therefore $\Delta_s = P_s^0 \Delta_0$.

It is obvious that pre-or postmultiplication of the vectors ϕ_s and Δ_s by the matrix Λ of change of coordinates does not change their R parametric form since its form is I, the unit matrix.

DEFLECTION OF A BASIC ELEMENT m OF THE RING

For conc. ld. $\Delta_j = H_j^m \phi_m^{m-1}$, for dist. ld. $\Delta_j = h_j^m \varphi_m^{(m)}$. These are the most general relations. We already have the parametric form of H_j^m and h_j^m, but we must prove that the equivalence obtained by premultiplying then by matrix P does not change their form. We rewrite them.

$$H_j^m = R^1 \overline{H}, \quad h_j^m = R^2 \overline{H} \quad \text{with} \quad \overline{H} = \left| \begin{array}{c|c} R^0K^D + R^2K^R & R^1K^R \\ \hline R^1K^R & R^0K^R \end{array} \right|$$

For The Concentrated Ld. ϕ_m^{m-1}

If ϕ_m^{m-1} results from $\Delta\phi_r$ at Station r then

$$\Delta_j = H_j^m \phi_m^{m-1} = R^1 \overline{H} \pi_m^r \Delta\phi_r$$

but $\overline{H} \pi_m^r =$

$$\left| \begin{array}{c|c} R^0K^D + R^2K^R & R^1K^R \\ \hline R^1K^R & R^0K^R \end{array} \right| \cdot \left| \begin{array}{c|c} R^0 & 0 \\ \hline R^1 & R^0 \end{array} \right| = \left| \begin{array}{c|c} R^0K^D + R^2K^R & R^1K^R \\ \hline R^1K^R & R^0K^R \end{array} \right|$$

Therefore the parametric form of Δ_j is the same in terms of internal and external loads.

Equivalence of Δ_j at Station s: $\Delta_s = P_s^j \Delta_j = P_s^j R^1 \overline{H} \pi_m^r \Delta\phi_r$

But $P_s^j \overline{H} \pi_m^r =$

$$\left| \begin{array}{c|c} R^0 & R^1 \\ \hline 0 & R^0 \end{array} \right| \cdot \left| \begin{array}{c|c} R^0K^D + R^2K^R & R^1K^R \\ \hline R^1K^R & R^0K^R \end{array} \right| = \left| \begin{array}{c|c} R^0K^D + R^2K^R & R^1K^R \\ \hline R^1K^R & R^0K^R \end{array} \right|$$

Therefore, the equivalence operation does not change the parametric form of $\triangle_j$ in terms of internal and external loads.

<u>For The Distributed Load $\varphi_m^{(m)}$</u>

The proof in this case involves the equivalence only, premultiplying matrix $\overline{H}$ by P_s^{v}. By using matrix $\overline{H}$, the proof for H_j^m applies to h_j^m.

COMPUTING THE INDETERMINATE LOAD $\phi_h^{h-1} = \triangle\phi_h$

In steps three of the "Actual Solution of The Ring" we solve the boundary equation for $\triangle\phi_n$, which is actually internal load ϕ_n^{n-1}.

We now must find under what conditions the parametric form of ϕ_n^{n-1} is the same as for the basic vector ϕ_p, for both given loads (external) $\triangle\phi_m$ and $\varphi_m^{(m)}$. The key to the problem is the inverse of stiffness matrix K_n^n. We can use the last expression of $\triangle\phi_n$ and restrict our proof to one term of each sum. The resulting expression of $\triangle\phi_n$ is

$$\triangle\Phi_n = -\left[K_n^n\right]^{-1}\left\{P_n^m K_m^m \triangle\Phi_m + \left[P_n^{m-1} K_{m-1}^{m-1} \rho_{m-1}^m + P_n^m h_m^m\right]\varphi_m^{(m)}\right\}$$

From the previous study of parametric forms of the stiffness matrices H_j^m, K_m^m and h_j^m we know

1st. $P_n^m K_m^m$ has the form of $K_m^m \equiv R^1 H$.

2nd. Since ρ_{m-1}^m has the form of $R^1 \pi$, K_{m-1}^{m-1} ρ_{m-1}^m has the form of $R^1 \cdot K_m^m \equiv R^2 \overline{H}$, which is the form of matrix h_j^m.

3rd. $P_n^m h_m^m \equiv R^2 H$.

Therefore $\triangle\phi_n$ form is $R^{-1} (\overline{H})^{-1}\left\{R^1 \overline{H}\triangle\phi_m + R^2 \overline{H} \varphi_m^{(m)}\right\}$ and the problem narrows down to the inverse of matrix $\overline{H}$.

Let us write the full form of $\bar{H}$ as $\left|\begin{array}{c|c} R^0 a^D K^D + R^2 a^R K^R & R^1 b K^R \\ \hline R^1 c K^R & R^0 d K^R \end{array}\right|$

where in a specific case a^D, a^R, b, c, and d are known matrices of the 3rd order. Inversing this matrix $\bar{H}$ is not straight forward, if the powers of R are to be retained. Moreover, the determinant of H is

$$\left(R^0 a^D K^D + R^2 a^R K^R\right)\left(R^0 d K^R\right) - \left(R^1 b K^R\right)\left(R^1 c K^R\right)$$

so that the denominator of the inverse will be a polynomial of the 2nd power in R. This results from the existence of the section-property matrix K^D. Should this matrix be $\equiv 0$, or the effect of the EA and GA_s negligible, H could be inversed independently from R and the optimization would be simplified.

Case Where $K^D \equiv 0$

We start from $\Delta_n = K_n^n \Delta\phi_n$. Let us replace this equation by a symbolic one using $\bar{H}$, such as

$$\delta_n = \bar{H}_n^n \varphi_n \text{ or } \begin{vmatrix} d \\ r \end{vmatrix} = \left|\begin{array}{c|c} R^2 a^R K^R & R^1 b K^R \\ \hline R^1 c K^R & R^0 d K^R \end{array}\right| \cdot \begin{vmatrix} f \\ m \end{vmatrix}$$ leaving out m

For the moment the vectors δ and φ are rescaled to

$$\begin{vmatrix} R^{-1} d \\ R^0 r \end{vmatrix} \text{ and } \begin{vmatrix} R^1 f \\ R^0 m \end{vmatrix}$$

As a result we can write $\begin{vmatrix} R^1 d \\ R^0 r \end{vmatrix} = \left|\begin{array}{c|c} a^R K^R & b K^R \\ \hline c K^R & d K^R \end{array}\right| \cdot \begin{vmatrix} R^1 f \\ R^0 m \end{vmatrix}$

This matrix can be inversed independently from R.

Let $\left|\begin{array}{c|c} A & B \\ \hline C & D \end{array}\right| = \left|\begin{array}{c|c} a^R K^R & b K^R \\ \hline c K^R & d K^R \end{array}\right|^{-1}$ then $\begin{vmatrix} R^1 f \\ R^0 m \end{vmatrix} = \left|\begin{array}{c|c} A & B \\ \hline C & D \end{array}\right| \cdot \begin{vmatrix} R^{-1} d \\ R^0 r \end{vmatrix}$

Now the vectors are restored to their original form δ & φ

Finally $\varphi = \begin{vmatrix} f \\ m \end{vmatrix} = \begin{vmatrix} R^{-2}A & R^{-1}B \\ R^{-1}C & R^{0}D \end{vmatrix} \cdot \begin{vmatrix} d \\ r \end{vmatrix}$ thus $(\bar{H})^{-1} = \begin{vmatrix} R^{-2}A & R^{-1}B \\ R^{-1}C & R^{0}D \end{vmatrix}$

The expression $\Delta\phi_n$ is $= -R^{-1}\,(\bar{H}_n)^{-1}\left\{R^{1}\,\bar{H}_m\,\Delta\phi_m + R^{2}\,\bar{h}_m\,\varphi_m^{(m)}\right\}$

Now $(\bar{H}_n)^{-1}\bar{H} = \begin{vmatrix} R^{-2}A_n & R^{-1}B_n \\ R^{-1}C_n & R^{0}D_n \end{vmatrix} \cdot \begin{vmatrix} R^{2}a^{R}K^{R} & R^{1}bK^{R} \\ R^{1}cK^{R} & R^{0}dK^{R} \end{vmatrix} =$

$$\begin{vmatrix} R^{0}[A_n a^{R}K^{R} + B_n cK^{R}] & R^{-1}[A_n bK^{R} + B_n dK^{R}] \\ R^{1}[C_n a^{R}K^{R} + D_n cK^{R}] & R^{0}[C_n bK^{R} + D_n dK^{R}] \end{vmatrix} \equiv \begin{vmatrix} R^{0} & R^{-1} \\ R^{1} & R^{0} \end{vmatrix}$$

Finally $\Delta\Phi_n \equiv \begin{vmatrix} R^{0} & R^{-1} \\ R^{1} & R^{0} \end{vmatrix} \begin{vmatrix} \Delta F_m \\ \Delta M_m \end{vmatrix} + \begin{vmatrix} R^{1} & R^{0} \\ R^{2} & R^{1} \end{vmatrix} \begin{vmatrix} f_m \\ m_m \end{vmatrix}$

Therefore, the indeterminate $\Delta\phi_n = \phi_n^{n-1}$ has the same parametric form as ϕ_m. As a result, all the products of the back substitution, namely $\phi_j^{(m)}$ and $\Delta_j^{(m)}$ have the same parametric form through the solution.

OPTIMIZATION OF THE CIRCULAR RING

It was just found that when the section properties EA and GA_s have little effect, the matrix property K^D can be cancelled and the radius R drops out as an independent variable.

It was also found that when the angle θ_m of the principal axes has little effect, as it is the case with the out-of-plane loading, the in-plane problem can be separated from the out-of-plane problem. As a result, the $(EI)_y$ can be made infinite in matrix K_m^R. Moreover, the inspection of the stiffness matrices K_m^m, H_j^m, and h_j^m shows that one property, for instance, K_X^R can be taken out.

As a result the matrix K^R can be written

$$K^R = \begin{vmatrix} K_X^R, 0, 0 \\ 0, K_Y^R, 0 \\ 0, 0, K_Z^R \end{vmatrix} \equiv \begin{vmatrix} K_X^R, 0, 0 \\ 0, 0, 0 \\ 0, 0, K_Z^R \end{vmatrix} = K_X^R \begin{vmatrix} 1, 0, 0 \\ 0, 0, 0 \\ 0, 0, \frac{K_Z^R}{K_X^R} \end{vmatrix}$$

Originally we had nine independent parameters to consider for the optimization of the circular uniform ring; R, the elastic line radius, φ_m, the angle of the station, θ_m, the angle of the principal axes with the basic system at Station 0, and the six section properties in K_m.

The preceding study has reduced the independent parameters from nine to two, the angle φ_m and the ratio $K_Z^R/K_X^R = GJ/(EI)_Z$.

The final internal loads obtained with $R = 1$ and $K_X^R = 1$ need to be scaled only for R, as given in the "Parametric Form of the Basic Vectors", after the determination of indeterminate $\Delta\phi_n$.

The final deflections obtained with $R = 1$ and $K_X^R = 1$ must be multiplied by the actual $K_X^R = 1/GJ$ and also scaled for R, as shown by their parametric form.

It is interesting to note that the internal loads are independent of K_X^R, depending only on the ratio K_Z^R/K_X^R.

Section B

THE UNIT SOLUTION

OF THE

SHELL SUPPORTED RINGS

FOREWORD

In Section A, we learned to compute at Station m the internal loads ϕ_m^{m-1} and the deflections Δ_m of the elastic center of a ring fixed at Station 0. Concentrated loads $\Delta\phi_p$ were applied at any Station p of the elastic center and a unit distributed load $\varphi_p^{(p)}$ along the elastic line of the element p. At Station 0 we assume a support which applies to the ring an external load $\Delta\phi_0$ which balances the others.

The reference system of the ring X, Y, Z, at the ring center has its ZX plane parallel to the plane of the contact line between the ring and the supporting shell. It is assumed that the supporting reactions of the shell are concentrated at points of contact located at the Stations m and assumed at the shell mid-surface at a radial distance R + a from the ring center, or at a radial distance a, oriented outwards, from the elastic line point m. It is assumed that a is constant, positive if the shell is outside of the ring and negative when inside.

ELEMENT m OF THE SHELL RING STRUCTURE

Figure 4 shows element $\overline{m}$, which starts at the middle of ring element m and ends at the middle of ring element m + 1. The angle of this element is $\varphi_{\overline{m}}$ (the shell-ring contact point at Station m is called $\overline{m}$).

$$\varphi_{\overline{m}} = \frac{\varphi_{m+1} - \varphi_m}{2} + \frac{\varphi_m - \varphi_{m-1}}{2} = \frac{\varphi_{m+1} - \varphi_{m-1}}{2}$$

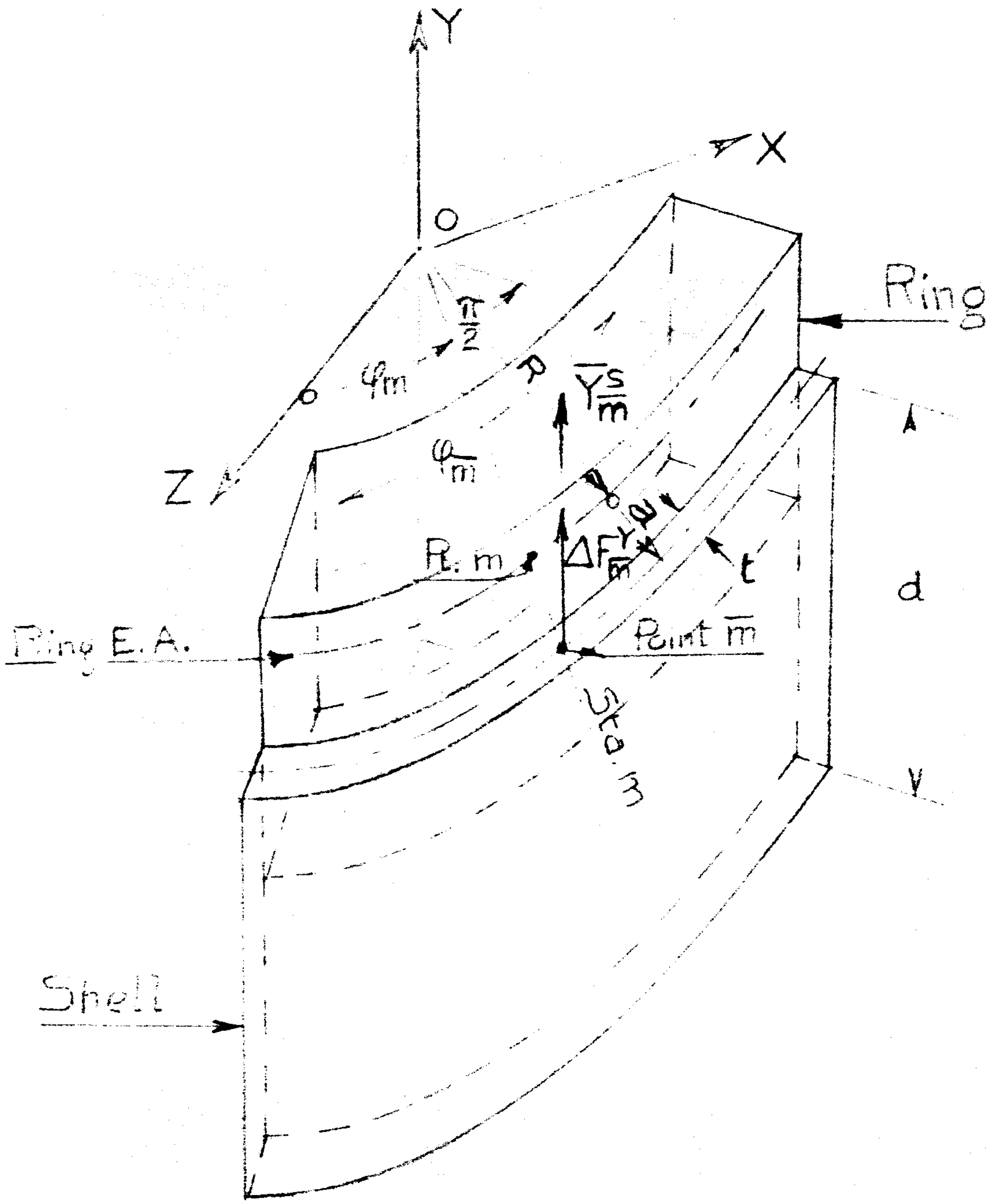


Figure 4. Shell - Ring Element $\bar{m}$

The concentrated reaction of the shell to the ring, equivalent to the shell reaction along element $\bar{m}$, is $\Delta F^{Y}_{\bar{m}}$, as shown. Assuming that it is uniformly distributed alone the element $\bar{m}$, letting the shell thickness be t, the unit pressure on the shell is

$$\Delta F^{Y}_{\bar{m}}/(R + a)\, \varphi_{\bar{m}}\, t$$

If we assume that at a normal distance d from the ring contact line, the shell is fixed in the Y direction, the displacement $\bar{Y}^{s}_{\bar{m}}$ of the shell under the ring load is

$$\bar{Y}^{s}_{\bar{m}} = \frac{-d}{E(R+a)\varphi_{\bar{m}} t} \Delta F^{Y}_{\bar{m}} = -K^{s}_{\bar{m}} \Delta F^{Y}_{\bar{m}} \quad \text{(S for shell)}$$

$K^{s}_{\bar{m}} = \dfrac{d}{E\,(R + a)\, \varphi_{\bar{m}}\, t}$ is the spring constant of shell element $\bar{m}$.

In our present case $K_s = 0$, as an approximation justified by the complexity of an elastic shell solution. However, it will be kept as $\neq 0$ in the following study for any possible use in the future.

PARAMETRIC SOLUTION OF SHELL-RING STRUCTURE

The algebraic solution of the shell-ring structure is very simple. However, we must find in what conditions the parametric form of the internal load vector ϕ^{m-1}_{m} and deflection vector Δ_m of the ring supported by the shell, which are used for optimization, remain the same as those of the ring alone, or at least are compatible with optimization.

The parametric solution will achieve this result, while describing clearly the solution itself.

DEFLECTION $Y^R_{\overline{m}}$ OF THE RING AT POINT m (R FOR RING)

The equivalence of the shell reaction $\Delta F^Y_{\overline{m}}$ at the point m of the elastic axis is $\Delta F^Y_m = \Delta F^Y_{\overline{m}} \ (\Delta^m F^v_m)$

and with $a = \alpha R$, $\Delta M^u_m = -a \cdot \Delta F^Y_{\overline{m}} = -\alpha R \ \Delta F^Y_{\overline{m}}$

α (= a/R) ratio is an independent parameter of the shell-ring solution, bringing the total to three, φ_m, the running station, $K^R_Z/K^R_X = GJ/(EI)_Z$ and α.

Now at any Station m, the deflection $\Delta^{R,p}_m$ of the elastic center due to the shell reaction $\Delta F^Y_{\overline{p}}$ applied at point p of Station p is

$$\Delta^{R,p}_m = \begin{vmatrix} D^{R,p}_m \\ R^{R,p}_m \end{vmatrix} \equiv \begin{vmatrix} R^3 & R^2 \\ R^2 & R^1 \end{vmatrix} \cdot \begin{vmatrix} \Delta F^Y_{\overline{p}} \\ \Delta M^u_p \end{vmatrix} = \begin{vmatrix} R^3 & R^2 \\ R^2 & R^1 \end{vmatrix} \cdot \begin{vmatrix} 1 \\ -\alpha R \end{vmatrix} \Delta F^Y_{\overline{p}}$$

The resulting deflection of the ring at point m of the shell is

$$\overline{Y}^{R,p}_{\overline{m}} = \overline{Y}^{R,p}_m - \alpha R \, \vec{u}^{R,p}_m \equiv \left\{ (R^3 - \alpha R^3) - \alpha R (R^2 - \alpha R^2) \right\} \Delta F^Y_{\overline{p}}$$

where $\vec{u}$ is the u_m component of $R^{R,p}_m$ at Station m.

Finally

$$\overline{Y}^{R,p}_{\overline{m}} \equiv f^p_m(\alpha) R^3 \Delta F^Y_{\overline{p}}$$

Now we identify by ℓ the external load $\Delta\phi$ and φ. Similarly

$$\Delta^{R,\Phi}_m = \begin{vmatrix} D^{R,\Phi}_m \\ R^{R,\Phi}_m \end{vmatrix} \equiv \begin{vmatrix} R^3 & R^2 \\ R^2 & R^1 \end{vmatrix} \cdot \begin{vmatrix} \Delta F \\ \Delta M \end{vmatrix}$$

$$\Delta^{R,\varphi}_m = \begin{vmatrix} D^{R,\varphi}_m \\ R^{R,\varphi}_m \end{vmatrix} \equiv \begin{vmatrix} R^4 & R^3 \\ R^3 & R^2 \end{vmatrix} \cdot \begin{vmatrix} \ell \\ m \end{vmatrix}$$

The resulting deflection of the ring at Point $\bar{m}$ of the shell is

$$\overline{Y}^{R,\ell}_{\bar{m}} = \overline{Y}^{R,\Phi}_{m} + \overline{Y}^{R,\varphi}_{m} - \alpha R\left\{\vec{u}^{R,\Phi}_{m} + \vec{u}^{R,\varphi}_{m}\right\}$$

$$\equiv R^3 \Delta F + R^2 \Delta M + R^4 \ell + R^3 m$$

Finally, the equivalence at point $\bar{m}$ of an arbitrary displacement Δ_c at the origin, Station 0, is

$$\Delta^{o}_{\bar{m}} = P^{o}_{\bar{m}} \Delta_o \therefore \begin{vmatrix} D^{o}_{\bar{m}} \\ R^{o}_{\bar{m}} \end{vmatrix} = \begin{vmatrix} I & G^{o}_{\bar{m}} \\ O & I \end{vmatrix} \cdot \begin{vmatrix} D_o \\ R_o \end{vmatrix}$$

The resulting deflection of the ring at point $\bar{m}$ of the shell is

$$\overline{Y}^{R,o}_{\bar{m}} = \overline{Y}_o + Z^{o}_{\bar{m}} \overline{\varphi}^{x}_{o} - X^{o}_{\bar{m}} \overline{\varphi}^{z}_{o}$$

With

$$Z^{o}_{\bar{m}} = Z_o - Z_{\bar{m}} = R\left[1 - (1+\alpha)\cos\varphi_m\right]$$

$$X^{o}_{\bar{m}} = X_o - X_{\bar{m}} = R\left[0 - (1+\alpha)\sin\varphi_m\right]$$

Finally

$$\overline{Y}^{R,o}_{\bar{m}} \equiv \left| R^o, R^1, R^1 \right| \cdot \begin{vmatrix} \overline{Y}_o \\ \overline{\varphi}^{x}_{o} \\ \overline{\varphi}^{z}_{o} \end{vmatrix}$$

SHELL-RING DEFLECTION EQUATIONS

$$\overline{Y}^{R}_{\overline{m}} = \sum_{p} \overline{Y}^{R,p}_{\overline{m}} + \overline{Y}^{R,\ell}_{\overline{m}} + \overline{Y}^{R,o}_{\overline{m}} = \overline{Y}^{S}_{\overline{m}} = -K^{S}_{\overline{m}} \Delta F^{Y}_{\overline{m}}$$

Using the preceding values of $\overline{Y}$'s , this equation is

$$\equiv \sum_{p} R^3 \Delta F^{Y}_{\overline{p}} + K^{S}_{\overline{m}} \Delta F^{Y}_{\overline{m}} + \left|R^3, R^2\right| \cdot \left|\begin{matrix} \Delta F \\ \Delta M \end{matrix}\right| + \left|R^4, R^3\right| \cdot \left|\begin{matrix} f \\ m \end{matrix}\right| + \left|R^0, R^1, R^1\right| \cdot \left|\begin{matrix} \overline{Y}_o \\ \overline{\varphi}^{x}_{o} \\ \overline{\varphi}^{z}_{o} \end{matrix}\right|$$

Rearranging

$$\left(R^3 + K^{S}_{\overline{m}}\right) \Delta F^{Y}_{\overline{p}} = -\left|R^0, R^1, R^1\right| \cdot \left|\begin{matrix} \overline{Y}_o \\ \overline{\varphi}^{x}_{o} \\ \overline{\varphi}^{z}_{o} \end{matrix}\right| - \left|R^3, R^2\right| \Delta\Phi - \left|R^4, R^3\right| \varphi$$

If $K^{S}_{\overline{m}}$ is of R^3 dimension or = 0; we can solve for $\Delta F^{Y}_{\overline{p}}$

$$\Delta F^{Y}_{\overline{p}} \equiv -\left|R^{-3}, R^{-2}, R^{-2}\right| \cdot \left|\begin{matrix} \overline{Y}_o \\ \overline{\varphi}^{x}_{o} \\ \overline{\varphi}^{z}_{o} \end{matrix}\right| - \left|R^0, R^{-1}\right| \Delta\Phi - \left|R^1, R^0\right| \varphi$$

Although $\Delta F^{Y}_{\overline{p}}$ are external loads for the ring, they are internal loads for the shell-ring structure. Their parametric forms, relative to R, for $\Delta\phi$ and φ check the forms of $\phi^{m-1}_{\overline{m}}$. We must solve for Δ_0 in terms of $\Delta\phi$ and φ in order to prove that the whole expression of $\Delta F^{Y}_{\overline{p}}$ check them also. Δ_0 is solved with the help of the equilibrium equations.

NOTE ON $K^{S}_{\overline{m}}$. If $K^{S}_{\overline{m}}$ is not proportional to R^3, R must be an additional independent parameter in the optimization problem, but only for the part of the solution included in Section B. However, if t decreases when R increases ($t = R^{-1} \tau$), the element $\overline{m}$ depends only on $\varphi_{\overline{m}}$ (number of elements is fixed) and d varies as the square of R ($d = R^3 \delta$), then

$$K^{S}_{\overline{m}} = \frac{d}{E\,(R + a)\,\varphi_{\overline{m}}\, t} = \frac{\delta R^3}{ER\,(1 + \alpha)\,\varphi_{\overline{m}}\,\frac{\tau}{R}} \quad \frac{R^3\,\delta}{E\,(1 + \alpha)\,\varphi_{\overline{m}}\,\tau}$$

In this case, R can be left out and the independent parameter is

$K^{s}_{\overline{m}} \cdot \varphi_{\overline{m}} = \delta/E\,(1+\alpha)\,2$

It is seen that acceptable optimization is still possible when $K^{s}_{\overline{m}}$ is not zero (i.e., $d \neq 0$).

RING SUPPORT EQUATIONS

At the ring support there is the shell reaction $\Delta F^{Y}_{\overline{0}}$. Its equivalence at Station 0 is

$$\Delta F^{Y}_{0} = \Delta F^{Y}_{\overline{0}}, \quad \Delta M^{u}_{0} = -\alpha R \Delta F^{Y}_{\overline{0}}$$

Since there is no deformation involved $\overline{Y}^{R}_{\overline{0}} = \overline{Y}_{0} - \alpha R \overline{\varphi}^{x}_{0}$ but $\overline{Y}^{s}_{\overline{0}} = -K^{s}_{\overline{0}} \cdot \Delta F^{Y}_{\overline{0}}$. The boundary equation is

$$\overline{Y}^{R}_{\overline{0}} = \overline{Y}^{s}_{\overline{0}} \quad \therefore \quad \overline{Y}_{0} - \alpha R \overline{\varphi}^{x}_{0} = -K^{s}_{\overline{0}} \Delta F^{Y}_{\overline{0}}$$

which can be solved for $\overline{Y}_{0} = -K^{s}_{\overline{0}} \Delta F^{Y}_{\overline{0}} + \alpha R \overline{\varphi}^{x}_{0}$

Therefore the vector

$$\begin{vmatrix} \overline{Y}_{0} \\ \overline{\varphi}^{x}_{0} \\ \overline{\varphi}^{z}_{0} \end{vmatrix} = \begin{vmatrix} -K^{s}_{\overline{0}} \\ 0 \\ 0 \end{vmatrix} \Delta F^{Y}_{\overline{0}} + \begin{vmatrix} \alpha R \overline{\varphi}^{x}_{0} \\ \overline{\varphi}^{x}_{0} \\ \overline{\varphi}^{z}_{0} \end{vmatrix}$$

EQUILIBRIUM EQUATIONS

The equilibrium equations are

$$\sum_{p=1}^{n-1} \Delta F^{Y}_{p} + \Delta F + R f + \Delta F^{Y}_{0} = 0$$

$$\sum_{p=1}^{n-1} \Delta M^{u}_{p} + R \Delta F + \Delta M + R^{2} f + R m + \Delta M^{u}_{0} = 0$$

Solving the first for $\Delta F_0^y = \Delta F_{\bar{0}}^y$ gives

$$\Delta F_{\bar{0}}^{Y} = -\left\{\sum_p \Delta F_{\bar{p}}^{Y} + \Delta F + R f\right\}$$

Now, the second is written explicitly

$$\sum_p \alpha R \Delta F_{\bar{p}}^{Y} + R\Delta F + \Delta M + R^2 f + R m = -\Delta M_0^u$$

but since the shell cannot resist M_0^u at point $\bar{0}$

$$\Delta M_{\bar{0}}^u = \Delta M_0^u + \alpha R \Delta F_0^Y = 0 \therefore \Delta M_0^u = -\alpha R \Delta F_0^Y.$$

the right hand side of the moment equation becomes

$$-\Delta M_0^u = \alpha R \Delta F_0^Y = -\alpha R\left\{\sum_p \Delta F_{\bar{p}}^{Y} + \Delta F + R f\right\}$$

If $K_{\bar{0}}^s$, like $K_{\bar{m}}^s$, is proportional to R^3, using the solution for ΔF_p^y from the shell-ring equations, reduces the moment equations (specifically the M^x and M^z) to.

$$R^{-1}\begin{vmatrix}\bar{\varphi}_0^x \\ \bar{\varphi}_0^z\end{vmatrix} = |R^1, R^0| \cdot \begin{vmatrix}\Delta F \\ \Delta M\end{vmatrix} + |R^2, R^1| \cdot \begin{vmatrix} f \\ m\end{vmatrix}$$

which can be solved for $\bar{\varphi}_0^x$ and $\bar{\varphi}_0^z$. Substituting for their value in ΔF_p^y gives

$$\Delta F_{\bar{p}}^{Y} = |R^0, R^{-1}| \cdot \begin{vmatrix}\Delta F \\ \Delta M\end{vmatrix} + |R^{-1}, R^0| \cdot \begin{vmatrix} f \\ m\end{vmatrix}$$

which is the parametric form of ϕ_m^{m-1} in the ring solution.

CONCLUSIONS

In the ring solution, Section A, it was found that if the section property matrix K_m^D has no effect, which is the case in our problem, or is proportional to R^2, the parametric forms relative to R are:

For the internal loadings

$$\Phi = \begin{vmatrix} R^0 & R^{-1} \\ R^1 & R^0 \end{vmatrix} \Delta\Phi + \begin{vmatrix} R^1 & R^0 \\ R^2 & R^1 \end{vmatrix} \varphi$$

For the deflections

$$\Delta = \begin{vmatrix} R^2 & R^1 \\ R^1 & R^0 \end{vmatrix} \Delta\Phi + \begin{vmatrix} R^3 & R^2 \\ R^2 & R^1 \end{vmatrix} \varphi$$

In the shell-supported ring solution, Section B, it was found that if the shell is infinitely rigid ($K_m^S = 0$) or that if K_m^S is proportional to R^3, the ring parametric forms above still apply and optimization can be done letting R = 1.

However, the solution, as presented in Sections A and B, is general and can be used for any values of K_m, K_m^S and R, even when these values change with the element m.

In the present contract there are only three independent parameters, φ_m, the station angle, $K_z^R/K_x^R = GJ/(EI)_z$, the ratio of section properties, and $\alpha = a/R$, the ratio of the oriented distance of the elastic curve to the shell to the radius of the elastic curve.

PART II

PART II NOMENCLATURE

A list of the more easily defined symbols for Part II is given below. Symbols too complex to be described in this brief section are defined in the text of Part II.

A_m = cross-sectional area of element m.

C = radial distance-ring elastic axis to shell.

D_z = normal deflection (results).

E = modulus of elasticity.

f is used as a superscript to indicate a function of a distributed force.

F is used as a superscript to indicate a function of a concentrated force.

F_Z = internal normal load (results).

G = shear modulus of elasticity.

I_{ν} = moment of inertia about the principal axis nearest to element axis ν.

I_w = moment of inertia about the principal axis nearest to element axis w.

J = twist coefficient, (twist = (torque)(length)/JG)

k used as a subscript indicates the station number of an applied load.

l_m = length of element m (l_m is the distance from station m to station m + 1).

m used as a superscript indicates a function of a distributed moment.

m is the station number when used as a subscript.

m_x = applied distributed moment about the x axis.

m_y = applied distributed moment about the y axis.

$\left[m_x\right]$ = a matrix of distributed moments about the x axis.

$\left[m_y\right]$ = a matrix of distributed moments about the y axis.

M is used as a superscript to indicate a function of a concentrated moment.

M = internal moment (results).

$\left[M_x \right]$ = a matrix of concentrated moments about the x axis.

$\left[M_y \right]$ = a matrix of concentrated moments about the y axis.

R = radius of ring elastic axis.

R_x = rotation about the x axis (results).

R_y = rotation about the y axis (results).

T = internal torque (results).

u = element reference axis or long axis of an element.

v = element reference axis perpendicular to u and w.

ν_k = applied distributed load.

$\left[\nu \right]$ = a matrix of distributed forces.

$\left[V \right]$ = a matrix of concentrated forces.

w = element reference axis perpendicular to u and to v.

X_m = the distance in the X direction from the origin of the reference axes to station m.

Y_m = the distance in the Y direction from the origin of the reference axes to station m.

Z_m = the distance in the Z direction from the origin of the reference axes to station m.

$\bar{Z}$ = deflection of ring elastic axis in the Z direction.

θ = angle of rotation of the principal axis from element axis v.

ψ = angle from x axis to station m.

Ω_x = rotation about the x axis (analytical solution).

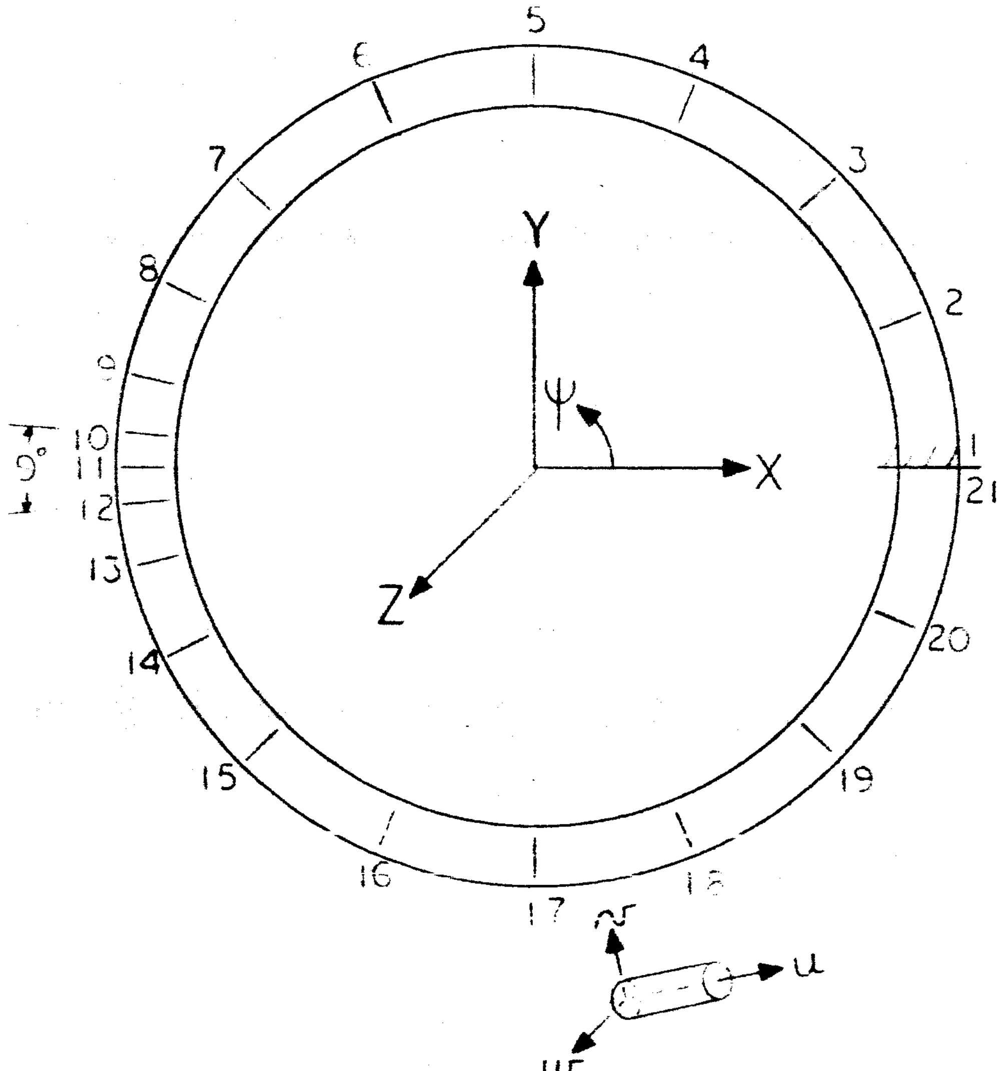
Ω_y = rotation about the y axis (analytical solution).

ANALYTICAL SOLUTION

This portion of the study deals with the analytical solution employed to achieve the results presented herein. It may be considered as the working model of the general solution described in Part I. Some changes in nomenclature and convention were made in order to better fit the computer subroutines that were already in existence when the study was started. However all quantities used in this part are fully identified as needed. Moreover the coordinate system and station numbering systems are shown in figures 5 and 6. Therefore this section is self contained and has all the necessary equations for producing a computer program; in keeping with its practical aspect the explanations are brief and limited mainly to programming information and data presentation.

RING-SHELL SOLUTION

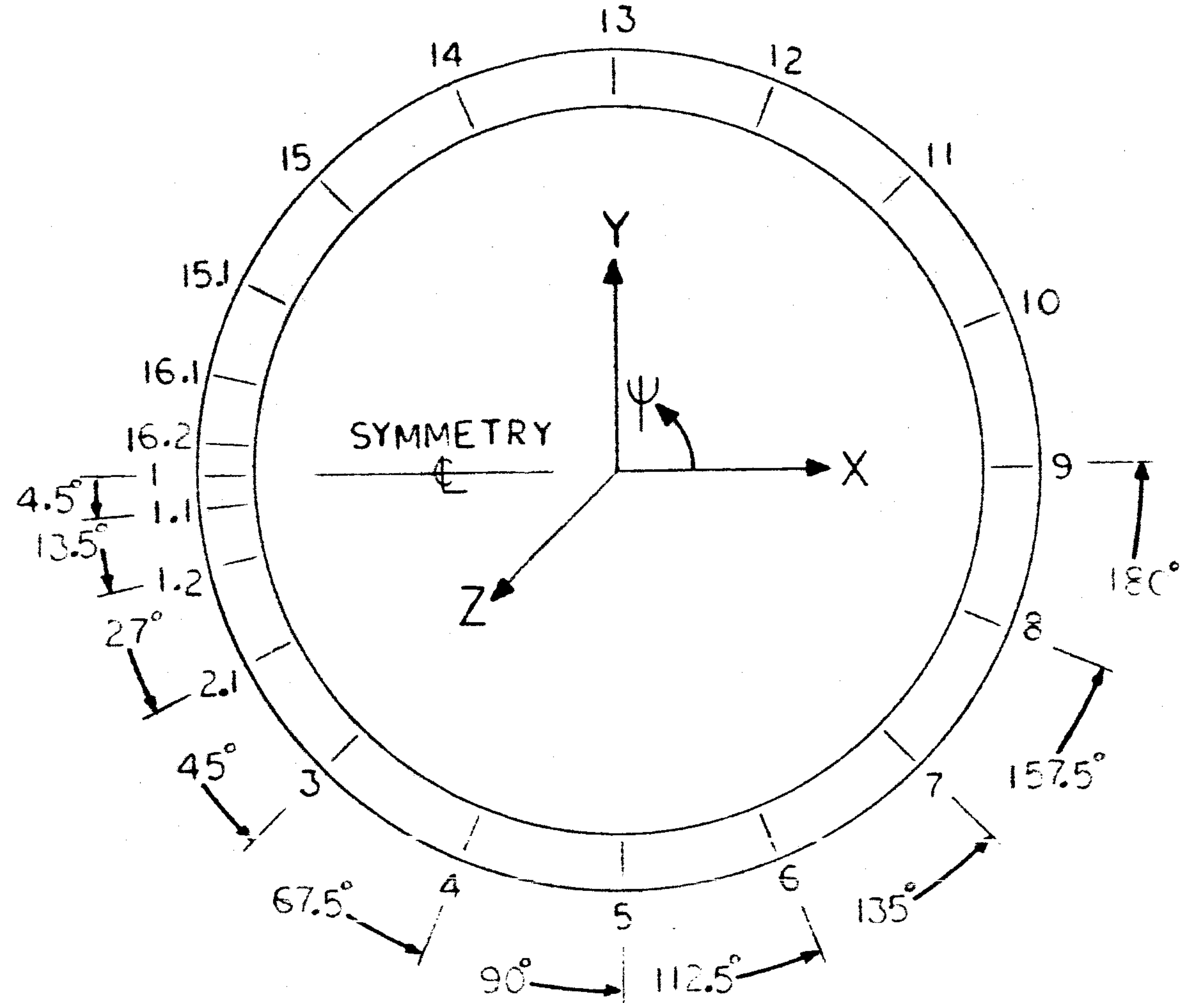
Figure 5 shows the coordinate system relative to the station numbering system used in the computer program. This station numbering system, while convenient for the computer program, was found to be unsuitable for the presentation of the graphical data. Therefore, the stations were renumbered, as shown in figure 6, for data presentation. This undesirable but necessary complication should cause little trouble if it is remembered that pages 52 through 68 of this section used the figure 5 numbering system with the remainder of the report depending on the figure 6 station numbering system.



Element Coordinate System
u and v are in the x-y plane
w is in the direction of Z.

NOTE: External concentrated loads are applied to the elastic center of Station 11. External distributed loads are applied over a 9° arc symmetrical about Station 11.

Figure 5. Ring Station Numbering System for Computation



NOTE: External concentrated loads are applied to the elastic center of Station 1. External distributed loads are applied over a 9° arc symmetrical about Station 1.

Figure 6. Ring Station Numbering System for Data Presentation

RING-SHELL SOLUTION

RING SOLUTION

Each point of contact of the ring with the shell is identified as a station (see figure 5). Each station m has three coordinates X_m, Y_m, and Z_m. The solution described here places the ring in the x-y plane so $Z_m = 0$. Starting with these station coordinates the following quantities are computed:

$$\Delta X_m = X_m - X_{m-1}$$
$$\Delta Y_m = Y_m - Y_{m-1}$$
$$\ell_m = \left[(\Delta X_m)^2 + (\Delta Y_m)^2\right]^{1/2}$$
$$\alpha_{um} = \Delta X_m / \ell_m$$
$$\beta_{um} = \Delta Y_m / \ell_m$$
$$a_m = \left[(\alpha_m)^2 + (\beta_m)^2\right]^{1/2}$$

The angle of rotation of the principal axis is called θ. Additional quantities are:

$$\alpha_{vm} = -\beta_{um} \cos \theta_m$$
$$\beta_{vm} = \alpha_{um} \cos \theta_m$$
$$\alpha_{wm} = \beta_{um} \sin \theta_m$$
$$\beta_{wm} = -\alpha_{um} \sin \theta_m$$
$$\delta_{wm} = a_m \cos \theta_m$$

More quantities are obtained from the elastic properties of ring material. They are:

$$d^F_{um} = \ell_m / EA_m$$
$$d^F_{vm} = \ell_m / GA_m + \ell_m^3 / 3EI_{wm}$$
$$d^F_{wm} = \ell_m / GA_m + \ell_m^3 / 3EI_{vm}$$
$$d^M_{wm} = \ell_m^2 / 2EI_{wm}$$
$$d^M_{vm} = \ell_m^2 / 2EI_{vm}$$
$$d^f_{um} = \ell_m / 2EA_m$$
$$d^f_{vm} = \ell_m / 2GA_m + \ell_m^3 / 8EI_{wm}$$
$$d^f_{wm} = \ell_m / 2GA_m + \ell_m^3 / 8EI_{vm}$$
$$d^m_{wm} = \ell_m^2 / 3EI_{wm}$$
$$d^m_{vm} = \ell_m^2 / 3EI_{vm}$$
$$r^F_{vm} = \ell_m^2 / 2EI_{wm}$$
$$r^F_{wm} = \ell_m^2 / 2EI_{vm}$$
$$r^M_{um} = \ell_m / GJ_m$$
$$r^M_{vm} = \ell_m / EI_{vm}$$
$$r^M_{wm} = \ell_m / EI_{wm}$$
$$r^f_{vm} = \ell_m / 6EI_{wm}$$
$$r^f_{wm} = \ell_m / 6EI_{vm}$$
$$r^m_{um} = \ell_m / 2GJ_m$$
$$r^m_{vm} = \ell_m / 2EI_{vm}$$
$$r^m_{wm} = \ell_m / 2EI_{wm}$$

Matrices are now formed as follows:

$$[T] = \begin{bmatrix} 1 & 0 & \cdot & \cdot & \cdot & 0 \\ 1 & 1 & 0 & & & \cdot \\ \cdot & & \cdot & \cdot & & \cdot \\ \cdot & & & \cdot & \cdot & \cdot \\ \cdot & & & & \cdot & 0 \\ 1 & 1 & \cdot & \cdot & \cdot & 1 \end{bmatrix}, \quad [\Delta^F_X] = \begin{bmatrix} 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \Delta X_{21} & 0 & & & & \cdot \\ 0 & \Delta X_{20} & \cdot & & & \cdot \\ \cdot & \cdot & \cdot & \cdot & & \cdot \\ \cdot & & \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & \cdot & 0 & \Delta X_2 & 0 \end{bmatrix}, \quad [\Delta^F_Y] = \begin{bmatrix} 0 & \cdot & \cdot & \cdot & \cdot & 0 \\ \Delta Y_{21} & 0 & & & & \cdot \\ 0 & \Delta Y_{20} & \cdot & & & \cdot \\ \cdot & \cdot & \cdot & \cdot & & \cdot \\ \cdot & & \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & \cdot & 0 & \Delta Y_2 & 0 \end{bmatrix}$$

Arrays $[\alpha_u]$ through $[r^M_w]$ below are diagonal matrices:

$$[\alpha_u] = [\alpha_{u21}, \alpha_{u20}, \cdot \cdot \cdot \alpha_{u2}, 0]$$

$$[\alpha_v] = [\alpha_{v21}, \alpha_{v20}, \cdot \cdot \cdot \alpha_{v2}, 0]$$

$$[\alpha_w] = [\alpha_{w21}, \alpha_{w20}, \cdot \cdot \cdot \alpha_{w2}, 0]$$

$$[\beta_u] = [\beta_{u21}, \beta_{u20}, \cdot \cdot \cdot \beta_{u2}, 0]$$

$$[\beta_v] = [\beta_{v21}, \beta_{v20}, \cdot \cdot \cdot \beta_{v2}, 0]$$

$$[\beta_w] = [\beta_{w21}, \beta_{w20}, \cdot \cdot \cdot \beta_{w2}, 0]$$

$$[\gamma_w] = [\gamma_{w21}, \gamma_{w20}, \cdot \cdot \cdot \gamma_{w2}, 0]$$

$$[d^F_u] = [d^F_{u21}, d^F_{u20}, \cdot \cdot \cdot d^F_{u2}, 0]$$

$$[d^F_v] = [d^F_{v21}, d^F_{v20}, \cdot \cdot \cdot d^F_{v2}, 0]$$

$$[d^F_w] = [d^F_{w21}, d^F_{w20}, \cdot \cdot \cdot d^F_{w2}, 0]$$

$$[d^M_w] = [d^M_{w21}, d^M_{w20}, \cdot \cdot \cdot d^M_{w2}, 0]$$

$$[d_v^M] = [d_{v21}^M, d_{v20}^M, \cdot \cdot \cdot d_{v2}^M, 0]$$

$$[d_u^f] = [d_{u21}^f, d_{u20}^f, \cdot \cdot \cdot d_{u2}^f, 0]$$

$$[d_v^f] = [d_{v21}^f, d_{v20}^f, \cdot \cdot \cdot d_{v2}^f, 0]$$

$$[d_w^f] = [d_{w21}^f, d_{w20}^f, \cdot \cdot \cdot d_{w2}^f, 0]$$

$$[d_w^m] = [d_{w21}^m, d_{w20}^m, \cdot \cdot \cdot d_{w2}^m, 0]$$

$$[d_v^m] = [d_{v21}^m, d_{v20}^m, \cdot \cdot \cdot d_{v2}^m, 0]$$

$$[r_v^F] = [r_{v21}^F, r_{v20}^F, \cdot \cdot \cdot r_{v2}^F, 0]$$

$$[r_w^F] = [r_{w21}^F, r_{w20}^F, \cdot \cdot \cdot r_{w2}^F, 0]$$

$$[r_u^M] = [r_{u21}^M, r_{u20}^M, \cdot \cdot \cdot r_{u2}^M, 0]$$

$$[r_w^M] = [r_{w21}^M, r_{w20}^M, \cdot \cdot \cdot r_{w2}^M, 0]$$

$$[r_u^M] = [r_{u21}^M, r_{u20}^M, \cdot \cdot \cdot r_{u2}^M, 0]$$

Matrix equations give other quantities.

$$\sigma_X^F = [T][\Delta_X^F][T]$$

$$\sigma_Y^F = [T][\Delta_Y^F][T]$$

$$\sigma_X^f = \sigma_X^F - [T][\Delta_X^F][\tfrac{1}{2} I]$$

$$\sigma_Y^f = \sigma_Y^F - [T][\Delta_Y^F][\tfrac{1}{2} I]$$

In effect larger matrices are formed by using the above matrices as subarrays. It should be noted that the computer program stores only required data. For instance $[\alpha_u]$, $[\beta_u]$, etc., are stored as vectors. $[T]$ is not formed but its action is accomplished by a subroutine, and null matrices are never stored. But schematically

$$\Pi_F = \begin{bmatrix} [T] & 0 & 0 & 0 & 0 & 0 \\ 0 & [T] & 0 & 0 & 0 & 0 \\ 0 & 0 & [T] & 0 & 0 & 0 \\ 0 & 0 & \sigma_Y^F & [T] & 0 & 0 \\ 0 & 0 & -\sigma_X^F & 0 & [T] & 0 \\ -\sigma_Y^F & \sigma_X^F & 0 & 0 & 0 & [T] \end{bmatrix} \qquad \Pi_F^* = \begin{bmatrix} [T]^* & 0 & 0 & 0 & 0 & -(\sigma_Y^F)^* \\ 0 & [T]^* & 0 & 0 & 0 & (\sigma_X^F)^* \\ 0 & 0 & [T]^* & (\sigma_Y^F)^* & -(\sigma_X^F)^* & 0 \\ 0 & 0 & 0 & [T]^* & 0 & 0 \\ 0 & 0 & 0 & 0 & [T]^* & 0 \\ 0 & 0 & 0 & 0 & 0 & [T]^* \end{bmatrix}$$

The * indicates that the matrix is transposed.

$$\Lambda = \begin{bmatrix} [\alpha_u] & [\beta_u] & 0 & 0 & 0 & 0 \\ [\alpha_v] & [\beta_v] & 0 & 0 & 0 & 0 \\ [\alpha_w] & [\beta_w] & [\gamma_w] & 0 & 0 & 0 \\ 0 & 0 & 0 & [\alpha_u] & [\beta_u] & 0 \\ 0 & 0 & 0 & [\alpha_v] & [\beta_v] & 0 \\ 0 & 0 & 0 & [\alpha_w] & [\beta_w] & [\gamma_w] \end{bmatrix} \qquad \Lambda^* = \begin{bmatrix} [\alpha_u] & [\alpha_v] & [\alpha_w] & 0 & 0 & 0 \\ [\beta_u] & [\beta_v] & [\beta_w] & 0 & 0 & 0 \\ 0 & 0 & [\gamma_w] & 0 & 0 & 0 \\ 0 & 0 & 0 & [\alpha_u] & [\alpha_v] & [\alpha_w] \\ 0 & 0 & 0 & [\beta_u] & [\beta_v] & [\beta_w] \\ 0 & 0 & 0 & 0 & 0 & [\gamma_w] \end{bmatrix}$$

$$\mu_I = \begin{bmatrix} [d_u^F] & 0 & 0 & 0 & 0 & 0 \\ 0 & [d_v^F] & 0 & 0 & 0 & [d_w^M] \\ 0 & 0 & [d_w^F] & 0 & [-d_v^M] & 0 \\ 0 & 0 & 0 & [r_u^M] & 0 & 0 \\ 0 & 0 & [-r_w^F] & 0 & [r_v^M] & 0 \\ 0 & [r_v^F] & 0 & 0 & 0 & [r_w^M] \end{bmatrix} \qquad \mu_i = \begin{bmatrix} [d_u^f] & 0 & 0 & 0 & 0 & 0 \\ 0 & [d_v^f] & 0 & 0 & 0 & [d_w^m] \\ 0 & 0 & [d_w^f] & 0 & [-d_v^m] & 0 \\ 0 & 0 & 0 & [r_u^m] & 0 & 0 \\ 0 & 0 & [-r_w^f] & 0 & [r_v^m] & 0 \\ 0 & [r_v^f] & 0 & 0 & 0 & [r_w^m] \end{bmatrix}$$

$$\Pi_f = \begin{bmatrix} [T] & 0 & 0 & 0 & 0 & 0 \\ 0 & [T] & 0 & 0 & 0 & 0 \\ 0 & 0 & [T] & 0 & 0 & 0 \\ 0 & 0 & \sigma_Y^f & [T] & 0 & 0 \\ 0 & 0 & -\sigma_X^f & 0 & [T] & 0 \\ -\sigma_Y^f & \sigma_X^f & 0 & 0 & 0 & [T] \end{bmatrix}$$

Unit concentrated external loads, (one for each load component and ring station), are grouped in matrices as follows:

$$[V] = [\Delta V_{21}, \Delta V_{20}, \cdot \quad \cdot \quad \cdot \quad \Delta V_2]$$
$$[M_X] = [\Delta M_{21}, \Delta M_{20}, \cdot \quad \cdot \quad \cdot \quad \Delta M_2]$$
$$[M_Y] = [\Delta M_{21}, \Delta M_{20}, \cdot \quad \cdot \quad \cdot \quad \Delta M_2]$$

Unit distributed loads are applied to several ring segments, thus

$$[v] = [\Delta v_i, \Delta v_{i-1}, \cdot \quad \cdot \quad \cdot \quad \Delta v_{i-a}]$$
$$[m_X] = [\Delta m_{Xi}, \Delta m_{Xi-1}, \cdot \quad \cdot \quad \cdot \quad \Delta m_{Xi-a}]$$
$$[m_Y] = [\Delta m_{Yi}, \Delta m_{Yi-1}, \cdot \quad \cdot \quad \cdot \quad \Delta m_{Yi-a}]$$

These load arrays also become subarrays within larger arrays, or:

$$\Delta\Phi = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & [V] & 0 & 0 & 0 \\ 0 & 0 & 0 & [M_X] & 0 & 0 \\ 0 & 0 & 0 & 0 & [M_Y] & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \quad \Delta\varphi = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & [v] & 0 & 0 & 0 \\ 0 & 0 & 0 & [m_X] & 0 & 0 \\ 0 & 0 & 0 & 0 & [m_Y] & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

A solution for the ring, (rigidly fixed at station 1, 21 but completely free at all other stations), is now obtained for the above unit applied loads. In matrix form the equations for this solution are:

$$\Phi_F = \Pi_F \Delta\Phi$$
$$\Phi_f = (\Pi_f - I)\Delta\varphi$$
$$D_\Phi = \Pi_F^* \Lambda^* \mu_I \Lambda$$
$$\Delta_F = D_\Phi \Phi_F$$
$$D_f = \Pi_F^* \Lambda^* \mu_i \Lambda$$
$$\Delta_f = D_\Phi \Phi_f + D_f \Delta\varphi$$
$$\Delta_\Phi = D_\Phi \Pi_F$$

A matrix B_u^e is formed from selected elements of Δ_Φ according to the scheme below where the $b_{i,j}$ are the elements of B_u^e and $\delta_{p,q}$ are the elements of Δ_Φ. Or, since the number of rows and columns in Δ_Φ is 6 ¢ 21, the $b_{i,j}$ become:

$$b_{i,j} = \delta_{k,l} \;, \quad i,j = 1, 2, \cdots 6 \;, \quad k = 1 + 21(i-1) \;, \quad l = 1 + 21(j-1)$$

Other matrices are formed from Δ_F and Δ_f by selecting out rows, or:

$$\Delta_F^{21} = \left[\text{ROW } 1, 22, 43, \cdots 106 \text{ OF } \Delta_F \right]$$

$$\Delta_f^{21} = \left[\text{ROW } 1, 22, 43, \cdots 106 \text{ OF } \Delta_f \right]$$

Up to this point the ring has been treated as a circular cantilever beam clamped at Station 1 but free to move at all other stations (see figure 5). When loaded this beam would deflect in such a way that Station 21 would, in general, be separated from Station 1. The internal loads at all stations, (for loads externally applied to this beam) are given in matrices Φ_F and Φ_f. The corresponding deflection and rotations are given in matrices Δ_F and Δ_f. It now becomes necessary to rejoin ring Stations 1 and 21. This is done mathematically through the following matrix operations.

$$\Delta\Phi_{RF}^{21} = -\left(B_u^e\right)^{-1} \Delta_F^{21}$$

$$\Delta\Phi_{Rf}^{21} = -\left(B_u^e\right)^{-1} \Delta_f^{21}$$

The matrices $\Delta\Phi_{RF}^{21}$ and $\Delta\Phi_{Rf}^{21}$ represent loads which, if applied to the free end of the circular cantilever beam, (Station 21), would bring this free end back into proper contact with the fixed end, (Station 1).

Matrices $\Delta\Phi_{RF}^{21}$ and $\Delta\Phi_{Rf}^{21}$ are now expanded, in effect, into 132 row null matrices. Thus, schematically

$$\Delta\Phi_{Ra} = \begin{bmatrix} \Delta\Phi_{Ra}^{21}, \text{ ROW } 1 \\ 0 \\ \cdot \\ 0 \\ \Delta\Phi_{Ra}^{21}, \text{ ROW } 2 \\ 0 \\ \cdot \\ 0 \\ \Delta\Phi_{Ra}^{21}, \text{ ROW } 3 \\ 0 \\ \cdot \\ 0 \\ \Delta\Phi_{Ra}^{21}, \text{ ROW } 4 \\ 0 \\ \cdot \\ 0 \\ \Delta\Phi_{Ra}^{21}, \text{ ROW } 5 \\ 0 \\ \cdot \\ 0 \\ \Delta\Phi_{Ra}^{21}, \text{ ROW } 6 \\ 0 \\ \cdot \\ 0 \end{bmatrix} \begin{matrix} 1 \\ \cdot \\ \cdot \\ \cdot \\ 22 \\ \cdot \\ \cdot \\ \cdot \\ 43 \\ \cdot \\ \cdot \\ \cdot \\ 64 \\ \cdot \\ \cdot \\ \cdot \\ 85 \\ \cdot \\ \cdot \\ \cdot \\ 106 \\ \cdot \\ \cdot \\ 132 \end{matrix}, \quad a = F \text{ OR } f$$

This permits the determination of the internal load, deflections and rotations of the continuous ring as shown below.

$$\Phi_C^F = \Phi_F - \Pi_F \Delta\Phi_{RF}$$
$$\Delta_C^F = \Delta_F - D_\Phi \Pi_F \Delta\Phi_{RF}$$
$$\Phi_C^f = \Phi_f - \Pi_F \Delta\Phi_{Rf}$$
$$\Delta_C^f = \Delta_f - D_\Phi \Pi_F \Delta\Phi_{Rf}$$

Where Φ_C^F contains the internal loading due to unit concentrated forces and/or moments. Δ_C^F contains the related deflections and rotations. Φ_C^f and Δ_C^f are the corresponding load and deflection matrices for unit distributed forces and moments. These results are shown schematically in figure 7.

The results obtained above complete the solution of a ring fixed at Station 1, 21 free at all others. These results are of value mainly in that they are used as input data in next steps of the solution, namely the determination of reactions at ring-shell attachment points and the finding of the final loads and deflections.

$$\Phi_C^F = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ F_V & F_{MX} & F_{MY} \\ M_V^X & M_{MX}^X & M_{MY}^X \\ M_V^Y & M_{MX} & M_{MY} \\ 0 & 0 & 0 \end{bmatrix} \qquad \Phi_C^f = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ F_v & F_{m_X} & F_{m_Y} \\ M_v^X & M_{mX}^X & M_{mY}^X \\ M_v^Y & M_{mX}^Y & M_{mY}^Y \\ 0 & 0 & 0 \end{bmatrix}$$

$$\Delta_C^F = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ D_V & D_{MX} & D_{MY} \\ R_V^X & R_{MX}^X & R_{MY}^X \\ R_V & R_{MX} & R_{MY} \\ 0 & 0 & 0 \end{bmatrix} \qquad \Delta_C^f = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ D_v & D_{mX} & D_{mY} \\ R_v^X & R_{mX}^X & R_{mY}^X \\ R_v^Y & R_{mX}^Y & R_{mY}^Y \\ 0 & 0 & 0 \end{bmatrix}$$

Figure 7. Result Matrices From the Ring Solution

RING SHELL TIE

The basic assumption used in the solution of the ring shell tie is; the shell is infinitely rigid along its axis of revolution. This means that no deflection normal to the ring occurs where the ring attaches to the shell. This condition gives a boundary equation which is the basis for the solution. Symbolically then:

$$\bar{Z}^{S}_{m} = \bar{Z}^{R}_{m} + C_m \bar{\Phi}_m = 0$$

where $\bar{Z}^{S}_{m}$ is the deflection normal to the ring at the ring shell tie Station m.

$\bar{Z}^{R}_{m}$ is the normal deflection of the ring at the elastic axis.

C_m is the distance from the ring elastic axis to the shell at Station m.

$\bar{\Phi}_m$ is the rotation about the elastic axis at point m.

In terms of the reference system the rotation $\bar{\Phi}_m$ and the deflection $\bar{Z}^{S}_{m}$ become,

$$\bar{\Phi}_m = \bar{\Phi}^{Y}_{m} \cos\Psi_m - \bar{\Phi}^{X}_{m} \sin\Psi_m$$

$$\bar{Z}^{S}_{m} = \bar{Z}^{R}_{m} + C_m(\bar{\Phi}^{X}_{m} \sin\Psi_m - \bar{\Phi}^{Y}_{m} \cos\Psi_m) + \bar{Z}^{R}_{1} - \bar{\Phi}^{Y}_{1}[(X_m - X_1) + C_m \cos\Psi_m] + \bar{\Phi}^{X}_{1}[(Y_m - Y_1) + C_m \sin\Psi_m]$$

where Ψ_m is the angle between Station 1 and Station m. But $\bar{Z}^{R}_{m}$, Φ^{X}_{m} and Φ^{Y}_{m} are functions of the loads, (forces and moments), applied to the ring elastic axis. Thus to utilize the ring-shell "tie" reactions in the above equations these reactions must be translated to the ring elastic axis. This translation produces moments in addition to the reaction forces. Or

$$\Delta M^{X}_{m} = C_m \Delta V^{Z}_{m} \sin\Psi_m$$

$$\Delta M^{Y}_{m} = -C_m \Delta V^{Z}_{m} \cos\Psi_m$$

Applying matrix notation to the boundary equations produces the following:

$$[Z^S][\Delta V^S]+[K_Z]\bar{Z}_1^R+[K_{\varphi Y}]\bar{\Phi}_1^Y+[K_{\varphi X}]\bar{\Phi}_1^X+[Z_V^R]\Delta V_K+[Z_{MY}^R]\Delta M_K^Y$$
$$+[Z_{MX}^R]\Delta M_K^X+[Z_{\nu}^R]\nu_K+[Z_{mY}^P]m_Y+[Z_{mx}^R]m_x=0$$

with $[Z^S]=D_V+c(D_{MX}D_S-D_{MY}D_C)+c[D_S R_V^X+c(D_S R_{MX}^X D_S - D_S R_{MY}^X D_C)]-c[D_C R_V^Y+c(D_C R_{MX}^Y D_S - D_C R_{MY}^Y D_C)]$

D_V, D_{MX}, D_{MY}, R_V^X, R_{MX}^X, R_{MY}^X, R_V^Y, R_{MX}^Y, R_{MY}^Y are from ΔF_C of the ring solution. C is the distance from the ring elastic axis to the shell. D_s and D_c are diagonal matrices of the Sin Ψ_m and Cos Ψ_m respectively.

$$[K_Z]=[1,1,\ldots\ldots 1]$$
$$[K_{\varphi Y}]=[-c\cos\Psi_{21},(x_1-x_{21})-c\cos\Psi_{20},\;\cdot\;\cdot\;\cdot\;\cdot\;(x_1-x_2)-c\cos\Psi_2]$$
$$[K_{\varphi X}]=[c\sin\Psi_{21},c\sin\Psi_{20}-(Y_1-Y_{20}),\;\cdot\;\cdot\;\cdot\;\cdot\;c\sin\Psi_2-(Y_1-Y_2)]$$
$$[Z_V^R]=[D_{VK}+c(D_S R_{VK}^X-D_C R_{VK}^Y)]$$

where subscript k represents the column corresponding to the external load application station.

$$[Z_{MY}^R]=[-D_{MYK}-c(D_S R_{MYK}^X-D_C R_{MYK}^Y)]$$
$$[Z_{\nu}^R]=[D_{\nu K}+c(D_S R_{\nu}^X-D_C R_{\nu}^Y)]$$
$$[Z_{mY}^R]=[-D_{mYK}-c(D_S R_{mYK}^X-D_C R_{mYK}^Y)]$$

$[Z_{MX}^R]$ and $[Z_{mx}^R]$ are not included here because they are not needed to obtain the graphical and tabular results.

$[\Delta V^S]$ is the matrix of ring-shell reactions forces.

ΔV_K is the applied concentrated force.

ΔM^Y_K and ΔM^X_K are applied concentrated moments.

$\mathcal{V}_K$ is the applied distributed force.

m_X and m_Y are the applied distributed moments.

The unknowns in the boundary equations are reaction vector $[\Delta V^S]$, Station 1 deflection $\bar{Z}^R_1$ and Station 1 rotations $\bar{\varphi}^X_1$ and $\bar{\varphi}^Y_1$. There are 20 equations and 23 unknowns. Three additional equations are supplied by ring-shell equilibrium. Vectors representing the equilibrium equations are:

$$[K^I_e] = [1, 1, \cdot \cdot \cdot \cdot \; 1, 0, 0, 0]$$

$$[K^X_e] = [X_{21}, X_{20}, \cdot \cdot \cdot \cdot \; X_2, 0, 0, 0]$$

$$[K^Y_e] = [Y_{21}, Y_{20}, \cdot \cdot \cdot \cdot \; Y_2, 0, 0, 0]$$

$$[K^C_e] = -C[\cos\psi_{21}, \cos\psi_{20}, \cdot \quad \cdot \quad \cdot \; \cos\psi_2, 0, 0, 0]$$

$$[K^S_e] = C[\sin\psi_{21}, \sin\psi_{20}, \cdot \quad \cdot \quad \cdot \; \sin\psi_2, 0, 0, 0]$$

$$[K^{XK}_e] = \left[X_K, 1, \left(\frac{X_K + X_{K+1}}{2}\right), 1\right]$$

$$[K^{YK}_e] = \left[Y_K, C, \left(\frac{Y_K + Y_{K+1}}{2}\right), C\right]$$

$$[K^V_e] = [1, 0, 1, 0]$$

Matrices Q and R are formed from the components described immediately above.

$$[Q] = \begin{bmatrix} [Z^S], [K_Z], [K_{\phi Y}], [K_{\phi X}] \\ [K_e^I] \\ [K_e^X] - [K_e^C] \\ [K_e^Y] + [K_e^S] \end{bmatrix}$$

$$[R] = \begin{bmatrix} [\bar{Z}^R_V], [Z^R_{MY}], [Z^R_{\nu}], [Z^R_{mY}] \\ [K_e^V] \\ [K_e^{XK}] \\ [K_e^{YK}] \end{bmatrix}$$

$$[S] = \begin{bmatrix} [\Delta V^S] \\ [\bar{Z}^R_T] \\ [\bar{\Phi}_{Y1}] \\ [\bar{\Phi}_{X1}] \end{bmatrix}$$

Then or

$$[Q][S] + [R] = 0 \qquad\qquad [S] = -[Q]^{-1}[R]$$

The internal loads, deflections and rotations can now be determined from $[S]$ and matrices Φ^F_c, Φ^f_c, Δ^F_c and Δ^f_c of the ring solution.

INTERNAL LOADS, DEFLECTIONS AND ROTATIONS

First the reaction forces are translated to the ring elastic axis, or:

$$[S_{MX}] = C[D_S][\Delta V^S]$$

$$[S_{MY}] = -C[D_C][\Delta V^S]$$

Next the internal loads are computed, or:

$$\Phi_V = [F_V][\Delta V^S] + [F_{MX}][S_{MX}] + [F_{MY}][S_{MY}] + \left([F_V]_K \Delta V_K,\ [F_{MY}]_K \Delta M_K^Y,\ [F_\nu]_K \nu_K,\ [F_{mY}]_K m_Y\right)$$

$$\Phi_{MX} = [M_V^X][\Delta V^S] + [M_{MX}^X][S_{MX}] + [M_{MY}^X][S_{MY}] + \left([M_V^X]_K \Delta V_K,\ [M_{MY}^X]_K \Delta M_K^Y,\ [M_\nu^X]_K \nu_K,\ [M_m^X]_K m_Y\right)$$

$$\Phi_{MY} = [M_V^Y][\Delta V^S] + [M_{MX}^Y][S_{MX}] + [M_{MY}^Y][S_{MY}] + \left([M_V^Y]_K \Delta V_K,\ [M_{MY}^Y]_K \Delta M_K^Y,\ [M_\nu^Y]_K \nu_K,\ [M_{mY}^Y]_K m_Y\right)$$

The deflection normal to the ring plane is

$$\Delta \bar{Z} = [D_V][\Delta V^S] + [D_{MX}][S_{MX}] + [D_{MY}][S_{MY}] + \left([D_V]_K \Delta V_K,\ + [D_{MY}]_K \Delta M_K^Y,\ [D_\nu]_K \nu_K,\ [D_{mY}]_K m_Y\right) + \bar{Z}_1^R + \bar{\Phi}_1^Y [K_{\phi Y}]$$

Rotations about the x and y axis are:

$$\Delta \bar{\Phi}_X = [R_V^X][\Delta V^S] + [R_{MX}^X][S_{MX}] + [R_{MY}^X][S_{MY}] + \left([R_V^X]_K \Delta V_K,\ [R_{MY}^X]_K \Delta M_K^Y,\ [R_\nu^X]_K \nu_K,\ [R_{mY}^X]_K m_Y\right)$$

$$\Delta \bar{\Phi}_Y = [R_V^Y][\Delta V^S] + [R_{MX}^Y][S_{MX}] + [R_{MY}^Y][S_{MY}] + \left([R_V^Y]_K \Delta V_K,\ [R_{MY}^Y]_K \Delta M_K^Y,\ [R_\nu^Y]_K \nu_K,\ [R_{mY}^Y]_K m_Y\right) + \bar{\Phi}_1^Y$$

At each station two additional quantities are computed. They are the torque about the elastic axis and the moment about the axis normal to the elastic axis and in the plane of the ring. Or:

$$[T] = [D_C]\Phi_{MY} - [D_S]\Phi_{MX}$$

$$[M] = [D_C]\Phi_{MX} + [D_S]\Phi_{MY}$$

PART III

CONCLUSIONS AND RECOMMENDATIONS

The analytical solution developed herein is an accurate and practical solution of the problem of shell supported ring frames loaded out-of-plane within the framework of the conditions and assumptions stipulated. For a large number of current aerospace applications, a workable tool of acceptable engineering accuracy has been provided, but each individual user must decide for himself whether his problem lies within the stated ground rules or, if not, whether its deviation is significant. The general solution of Part I and the principles underlying it are fundamental, and the detail analysis presented in this program is only one example of the many allied developments which could be built upon this foundation.

It is recommended that serious consideration be given to next extending the analysis of this program to a broader scope of applicability. Typical avenues of extension which could be the subject of further programs are: the ability to include dynamic loading as well as static; the incorporation of an elastic shell into the problem to replace the idealized shell of this program; or a study of the interaction of the ring with the structure which loads it, in contrast to the ideal, point source, fixed vector load application used herein. Another direction to be considered in further development of this analysis is in the experimental verification of both the basis and the results of the present program. Such a test program, even of modest scope, would be worthwhile in demonstrating the validity of the current program and generating confidence in its use.

NA-65-1015
Appendix I

SERIAL NO

STUDY OF SHELL SUPPORTED RING FRAMES
WITH
OUT-OF-PLANE LOADING

FINAL REPORT

24 JUNE 1965 TO 28 DECEMBER 1965

CONTRACT NO. NAS8-20097

REQUEST NO. RFQ NO. DCN 1-5-53-01066-01

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FOREWORD

Presented herein is Appendix 1 to the Final Report for Contract No. NAS8-20097, "Study of Shell Supported Ring Frames With Out-of-Plane Loadings".

APPENDIX 1

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

APPENDIX NOMENCLATURE

A ring cross-section is formed by passing through the origin a plane which is parallel to the Z axis. The elastic axis is defined by the line joining the centroids of the ring cross-section.

C = radial distance from ring elastic axis to shell, (inches).

D_Z = normal deflection, (inches). See figure 2.

E = modulus of elasticity, (pounds per square inch).

F_Z = internal normal force, (pounds). See figure 2.

G = shearing modulus of elasticity, (pounds per square inch).

I = the moment of inertia of a ring cross-section about a radial axis, ($inches^4$).

J = twist coefficient, ($inches^4$). Twist = ((torque)(length)/JG).

K_{DZ} = normal deflection coefficient.

K_{FZ} = internal normal force coefficient.

K_M = internal moment coefficient.

K_{RX} = coefficient of rotation about the X axis.

K_{RY} = coefficient of rotation about the Y axis.

K_T = internal torque coefficient.

M = internal moment, (inch-pounds). See figure 2.

ΔM_K^Y = applied concentrated moment, (inch-pounds). See figure 1.

m_K^Y = applied distributed moment, (inch-pounds). See figure 1.

R = radius of ring elastic axis, (inches).

R_X = rotation about the X axis, (radians). See figure 2.

R_Y = rotation about the Y axis, (radians). See figure 2.

T = internal torque, (inch-pounds). See figure 2.

ΔV_K = external concentrated force, (pounds). See figure 1.

$\mathcal{N}_K$ = external distributed force,(pounds). See figure 1.

X = reference axis in the plane of the ring. See figure 1.

Y = reference axis in the plane of the ring and perpendicular to the X axis. See figure 1.

Z = reference axis perpendicular to the ring. See figure 1.

TABLE OF CONTENTS FOR GRAPHICAL RESULTS

PARAMETER SETS

1. C/R = 0.01, GJ/EI = 2.00,0.20,0.02
2. C/R = 0.05, GJ/EI = 2.00,0.20,0.02
3. C/R = 0.09, GJ/EI = 2.00,0.20,0.02
4. GJ/EI = 0.02, C/R = 0.01,0.05,0.09
5. GJ/EI = 0.20, C/R = 0.01,0.05,0.09
6. GJ/EI = 2.00, C/R = 0.01,0.05,0.09

TABLE OF CONTENTS FOR GRAPHICAL RESULTS

PARAMETER SETS	
1. - C/R = 0.01, GJ/EI = 2.00,0.20,0.02	4. GJ/EI = 0.02, -C/R = 0.01,0.05,0.09
2. - C/R = 0.05, GJ/EI = 2.00,0.20,0.02	5. GJ/EI = 0.20, -C/R = 0.01,0.05,0.09
3. - C/R = 0.09, GJ/EI = 2.00,0.20,0.02	6. GJ/EI = 2.00, -C/R = 0.01,0.05,0.09

TABLE OF CONTENTS FOR TABULAR RESULTS

PARAMETER SETS

1. $C/R = 0.01$, $GJ/EI = 2.00, 0.20, 0.02$
2. $C/R = 0.05$, $GJ/EI = 2.00, 0.20, 0.02$
3. $C/R = 0.09$, $GJ/EI = 2.00, 0.20, 0.02$
4. $GJ/EI = 0.02$, $C/R = 0.01, 0.05, 0.09$
5. $GJ/EI = 0.20$, $C/R = 0.01, 0.05, 0.09$
6. $GJ/EI = 2.00$, $C/R = 0.01, 0.05, 0.09$

PARAMETER SETS

1. $-C/R = 0.01$, $GJ/EI = 2.00, 0.20, 0.02$
2. $-C/R = 0.05$, $GJ/EI = 2.00, 0.20, 0.02$
3. $-C/R = 0.09$, $GJ/EI = 2.00, 0.20, 0.02$
4. $GJ/EI = 0.02$, $-C/R = 0.01, 0.05, 0.09$
5. $GJ/EI = 0.20$, $-C/R = 0.01, 0.05, 0.09$
6. $GJ/EI = 2.00$, $-C/R = 0.01, 0.05, 0.09$

Use of Graphs

There are two hundred and eighty-eight pages of graphs and forty eight pages of tabulated values in the appendix. These pages contain the quantitative output of this study. Displayed are the results for three internal loads, two rotations and one deflection at each of eleven stations for four types of applied loading and nine values of the two parameters. The internal loads are the normal force F_z, T the torque about the elastic axis, and M the moment about the axis in the plane of the ring perpendicular to the elastic axis. The deflection D_z is measured perpendicular to the plane of the ring at the ring elastic axis. Rotations R_x and R_y are relative to the x and y reference axis respectively. External loading is composed of a unit concentrated force ΔV_K, a unit distributed force $\mathcal{V}_K$, a unit concentrated torque ΔM_K^Y and a unit distributed torque m_K^Y.

Each graph has three curves which are functions of either three values of the parameter GJ/EI with the parameter C/R constant of three values of C/R with GJ/EI constant. Also, each graph contains the particular result equation that pertains to that plot. There are twelve of these equations; two each for internal force F_z, internal moments T and M, normal deflection D_z and rotation R_x and R_y. These equations are the same for both concentrated and distributed loading but differ for forces and moments. They are:

Applied Force	Applied Moment
$F_z = K_{FZ}$	$F_z = K_{FZ}/R$
$T = K_T R$	$T = K_T$
$M = K_M R$	$M = K_M$
$D_z = K_{DZ}\ (R^3/EI)$	$D_z = K_{DZ}\ (R^2/EI)$

$R_x = K_{RX} \, (R^2/EI)$ $R_x = K_{RX} \, (R/EI)$

$R_y = K_{RY} \, (R^2/EI)$ $R_y = K_{RY} \, (R/EI)$

The graphs are arranged in the appendix according to, first the applied loading, second, the result type and third the parameter type and value, (see the appendix table of contents). Each page of tabulated answers contains output for one type of result due to a single loading condition but for all stations and all parameter combinations. These pages list not only the points plotted on the graphs but in addition the unplotted symmetrical point values. Where results are needed at discrete station points either the graphs or tabulated results will serve equally well, but for values between stations the graphs are more convenient.

Values of the parameters GJ/EI and C/R will not, in general, coincide with those shown on the graphs. It is necessary to interpolate twice to arrive at a result when neither GJ/EI nor C/R are represented by the curves. This interpolation can be accomplished in two ways; either by interpolating with respect to GJ/EI from a page with C/R constant then interpolating between pages for the C/R value or by using the pages with GJ/EI constant and interpolating between curves of C/R. An interpolation table is included for the convenience of the user. It is explained below.

Steps:

1. Determine the values of GJ/EI and C/R for the structure involved.
2. Enter the value of C/R from Step 1. in column (1) of the table.
3. Enter the value of GJ/EI from Step 1. in column (7) of the table.
4. From C/R of 0.01, 0.05 or 0.09 select two values such that the one smaller than C/R of Step 2. goes into column (2) and the one larger than C/R of Step 2. goes into column (3).

5. From GJ/EI of 2.00, 0.20 or 0.02 select two values such that the one smaller than GJ/EI of Step 3. goes into column (8) and the one larger than GJ/EI of Step 3 goes into column (9).
6. In column (14) enter the K values, (from the graphs or tabulated results), that correspond to the column (2) value of C/R and the column (8) value of GJ/EI.
7. In column (15) enter the K values that correspond to the column (3) value of C/R and the column (8) value of GJ/EI.
8. In column (16) enter the K values that correspond to the column (2) value of C/R and the column (9) value of GJ/EI.
9. In column (17) enter the K values that correspond to the column (3) value of C/R and the column (9) value of GJ/EI.
10. Complete the table according to steps shown thereon. Column (26) now contains the K values for C/R and GJ/EI of Step 1.
11. Use the values of K from Step 10 to obtain internal loads or deflections.

An example, shown below, is the procedure to be followed to find K_{PZ} where C/R is 0.06 and GJ/EI is 0.15. The completed example table is given on page 6 .

Steps:

1. C/R = 0.06, GJ/EI = 0.15
2. 0.06 is entered into column (1)
3. 0.15 is entered into column (7)
4. 0.05 is entered into column (2) and 0.09 is entered into column (3)
5. 0.02 is entered into column (8) and 0.20 is entered into column (9)

6. From page 301 the values of K_{FZ} for GJ/EI = 0.02, C/R = 0.05 are entered into column (14)
7. From page 301 the values of K_{FZ} for GJ/EI = 0.02, C/R = 0.09 are entered into column (15)
8. From page 301 the values of K_{FZ} for GJ/EI = 0.20, C/R = 0.05 are entered into column (16)
9. From page 301 the values of K_{FZ} for GJ/EI = 0.20, C/R = 0.09 are entered into column (17)
10. The table is completed as shown on page 6.
11. Since K_{FZ} is for a concentrated force it is equal to F_Z. Thus F_Z for 11 stations of the ring have been found for case in question.

INTERPOLATION TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
C/R	C/R	C/R	(1)-(2)	(3)-(2)	(4)/(5)	GJ/EI	GJ/EI	GJ/EI	(7)-(8)	(9)-(8)	(10)/(11)

(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
STA.	K_1	K_2	K_3	K_4	(15) − (14)	(6) X (18)	(14) + (19)
1							
1.1							
1.2							
2.1							
3							
4							
5							
6							
7							
8							
9							

(21)	(22)	(23)	(24)	(25)	(26)
(17) − (16)	(6) X (21)	(16) + (22)	(23) − (20)	(12) X (24)	(20) + (25)

(1) ACTUAL VALUE OF C/R
(2) C/R < C/R OF (1)
(3) C/R > C/R OF (1)
(7) ACTUAL VALUE OF GJ/EI
(8) GJ/EI < GJ/EI OF (7)
(9) GJ/EI > GJ/EI OF (7)
(14) COE. K FROM (2) & (8)
(15) COE. K FROM (3) & (8)
(16) COE. K FROM (2) & (9)
(17) COE. K FROM (3) & (9)
(26) VALUE OF K FOR C/R OF (1) AND GJ/EI OF (7).

INTERPOLATION TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
C/R	C/R	C/R	(1)-(2)	(3)-(2)	(4)/(5)	GJ/EI	GJ/EI	GJ/EI	(7)-(8)	(9)-(8)	(10)/(11)
.06	.05	.09	.01	.04	.25	.15	.02	.20	.13	.18	.72

(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
STA.	K_1	K_2	K_3	K_4	(15) - (14)	(6) X (18)	(14) + (19)
1	-.407	-.433	-.351	-.402	-.026	-.0065	-.414
1.1	-.226	-.283	-.140	-.221	-.057	-.0143	-.240
1.2	-.0916	-.143	-.0540	-.100	-.0514	-.0129	-.105
2.1	-.0300	-.0590	-.0281	-.0482	-.029	-.0073	-.0373
3	-.00847	-.0203	-.0148	-.0252	-.0115	-.00295	-.0114
4	-.00241	-.00697	-.00711	-.0131	-.00446	-.00112	-.00353
5	-.000739	-.00246	-.00367	-.00712	-.00112	-.000430	-.00117
6	-.000231	-.000906	-.00185	-.00279	-.000675	-.000169	-.000400
7	-.0000705	-.000326	-.000946	-.00193	-.000256	-.0000640	-.000135
8	-.0000152	-.0000825	-.000250	-.000547	-.0000643	-.0000161	-.0000343
9	0	0	0	0	0	0	0

(21)	(22)	(23)	(24)	(25)	(26)
(17) - (16)	(6) X (21)	(16) + (22)	(23) - (20)	(12) X (24)	(20) + (25)
-.051	-.013	-.364	.050	.036	-.378
-.081	-.020	-.160	.080	.058	-.182
-.046	-.012	-.066	.039	.028	-.077
-.0201	-.0050	-.033	.0043	.0031	-.034
-.0104	-.0026	-.017	-.0060	-.0043	-.016
-.00599	-.0015	-.0086	-.0051	-.0038	-.0072
-.00345	-.00087	-.0045	-.0033	-.0024	-.0035
-.00194	-.00049	-.0023	-.0019	-.0014	-.0014
-.00114	-.00025	-.0011	-.00096	-.00069	-.00083
-.000297	-.000074	-.00032	-.00028	-.00020	-.00023
0	0	0			

(1) ACTUAL VALUE OF C/R
(2) C/R < C/R OF (1)
(3) C/R > C/R OF (1)
(7) ACTUAL VALUE OF GJ/EI
(8) GJ/EI < GJ/EI OF (7)
(9) GJ/EI > GJ/EI OF (7)
(14) COE. K FROM (2) & (8)
(15) COE. K FROM (3) & (8)
(16) COE. K FROM (2) & (9)
(17) COE. K FROM (3) & (9)
(26) VALUE OF K FOR C/R OF (1) AND GJ/EI OF (7).

Superposition

Practical structures usually have loads applied to several locations around a ring. When this occurs superposition of results is necessary and it can be accomplished by using the tabulated or graphical results presented here. Examples 1 and 2 of Appendix 2 require such superposition. These examples are fully covered in Appendix 2 but the method for superposition is also described below.

Case 1. Superposition of Concentrated Loads

Steps:

1. Select a station numbering system such that each point of load application coincides with a station.
2. Let Station 1 of the tabulated or graphical results coincide with a load point station.
3. Determine the K values at the other selected stations from the values of Step 2. Some interpolation between result stations and selected stations may be necessary.

   (Note that graphical results are for 1/2 of the ring so tabulated results should be consulted to find the signs of unplotted symmetrical points.)
4. Multiply the K values of Step 3 by the load applied to the load point of Step 2.
5. Let Station 1 of the tabulated or graphical result coincide with a load point station different from that of Step 2.
6. Repeat Steps 3 and 4 for the load point of Station 5.
7. Repeat Steps 5 and 6 until all of the load point stations have been operated on.

8. Sum for each station the values of K from the preceding steps. These sums are the K values for the multiple concentrated loads.

Case 2. Superposition of Load Distributed Over Part of A Ring

Steps:

1. Select a station numbering system such that the ends of the load bearing segments coincide with stations.
2. Let Station 1.1 coincide with the end of a segment that is first encountered in a clockwise sweep of the ring. (See figure 3a).
3. Determine the K values at other selected stations from tabulated or graphical results. If graphical results are used consult tabulated values for the signs of the symmetrical points not shown on the graphs. It may be necessary to interpolate between result stations and selected stations.
4. Multiply the K value of Step 3 by the load applied over a nine degree segment starting at Station 1.1.
5. Move Station 1.1 nine degrees in a clockwise direction and repeat Steps 3 and 4.
6. Repeat Step 5 until the load segment end opposite to the starting point is encountered.
7. Sum for each station the values of K from the preceding steps. These sums are the K values for the load distributed over the ring segment.
8. Repeat Steps 2 through 7 for the remaining distributed load segments if any.

9. Sum K values from all distinct load segments. The sums are the K values for the distributed loading condition.

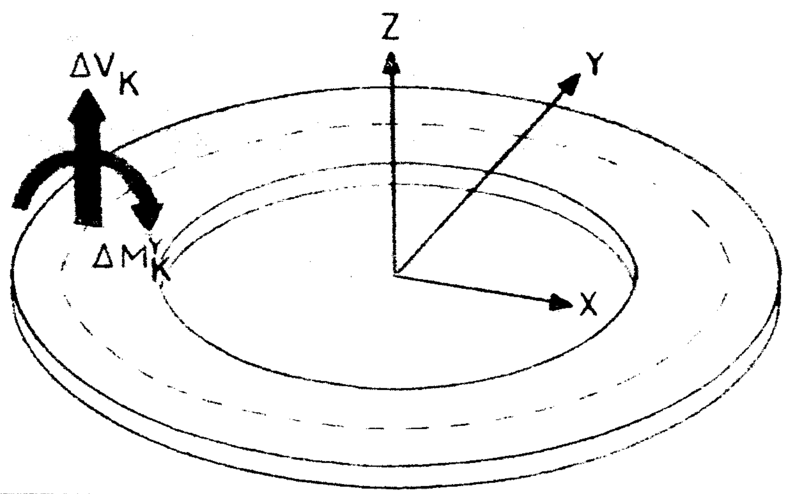
NOTE 1: A segment, in general, will not divide evenly by nine degrees. Therefore, the method described above can be in error by the effect of 4.5 or fewer degrees of load segment. This error can be greatly reduced by approximating the remaining load bearing segment as follows:

a. Multiply the last set of K values from Step 6 by the ratio of angle of segment remaining to nine degrees.

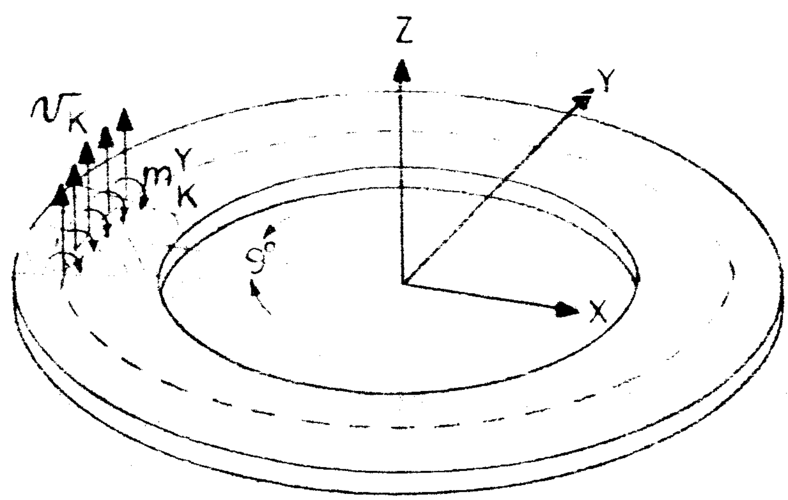
b. Use these K values with those of the preceding parts of the load segment in Step 7. (See figure -5).

NOTE 2: If the load over a segment is uniform the necessary work can be reduced by using preceding results to increase the basic arc covered on each pass through Step 5. Thus after the first pass through Step 5, the results for an arc of eighteen degrees is available. This eighteen degree arc can be used to obtain the results for either a twenty seven or thirty six degree arc, etc.

NOTE 3: If the load over a segment is not uniform it must be approximated by averaging over each nine degree arc segment.

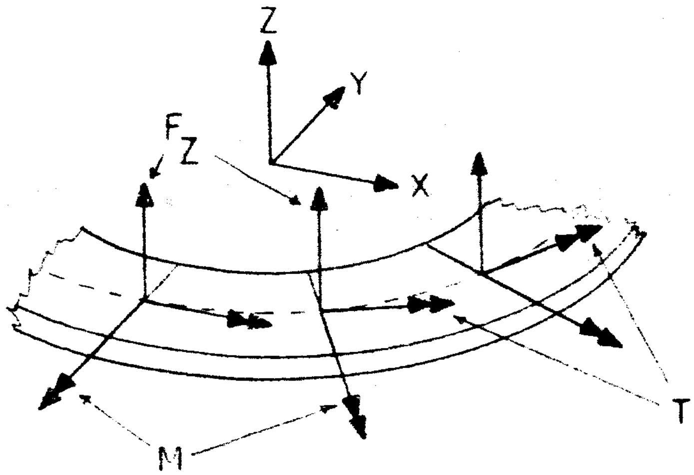


Concentrated Loads

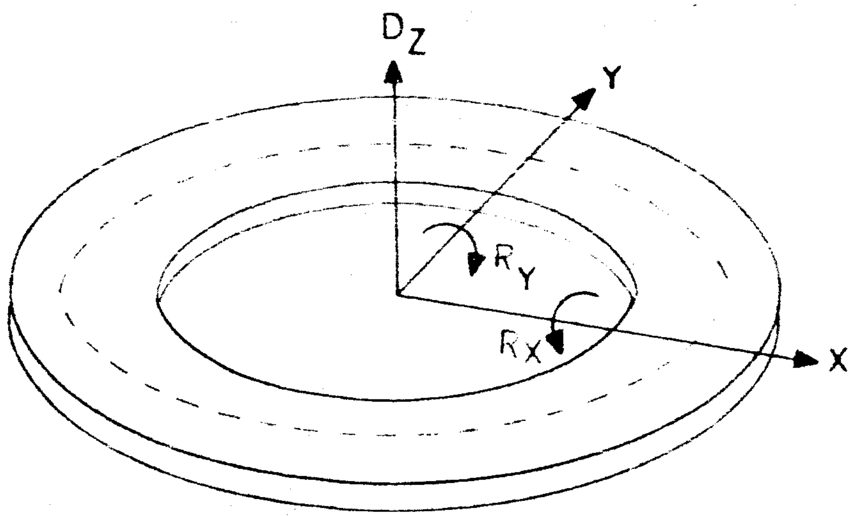


Distributed Loads

Figure 1 Applied Loads



Ring Segment Showing Positive Internal Loads



Deflection and Rotation Convention

D_z, R_X, and R_Y are measured at each station in the directions shown.

Figure . Results

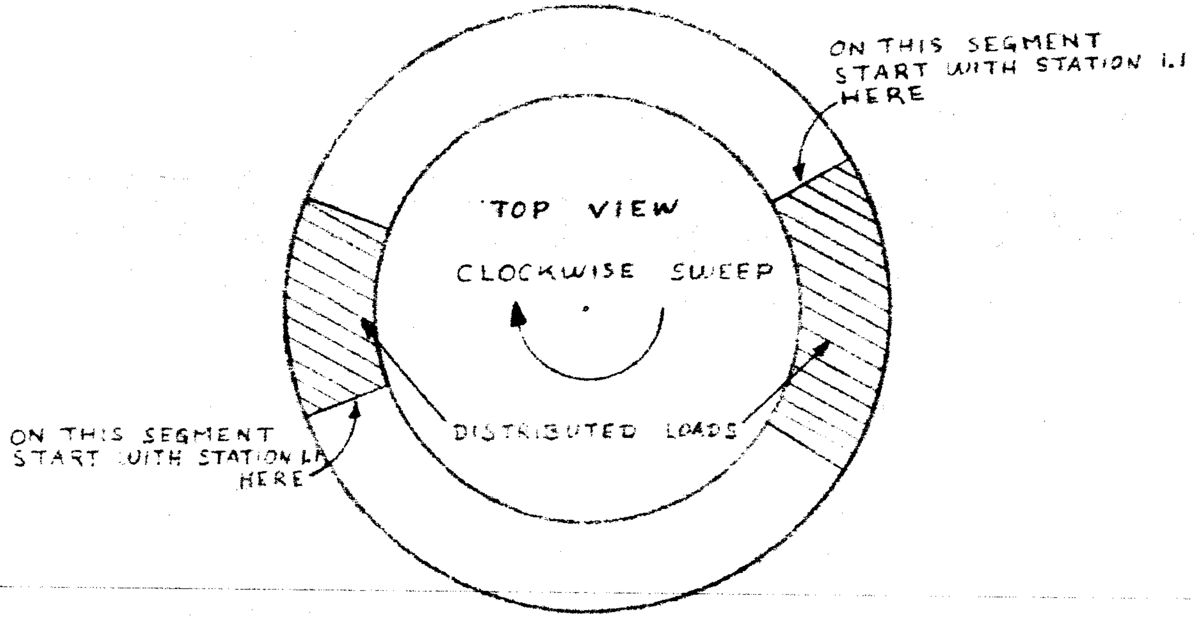


FIGURE 3A. STARTING STATIONS FOR SUPERPOSITION

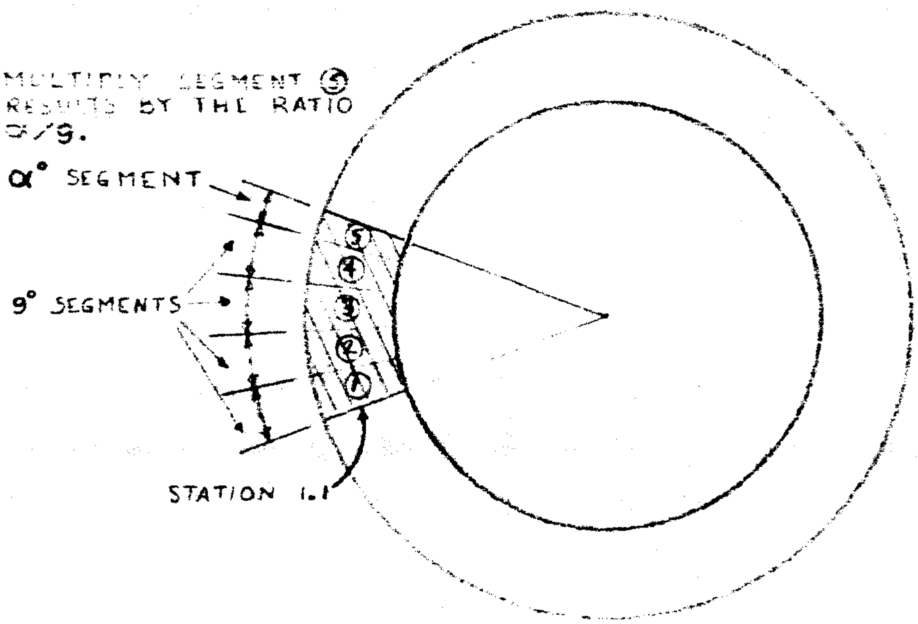
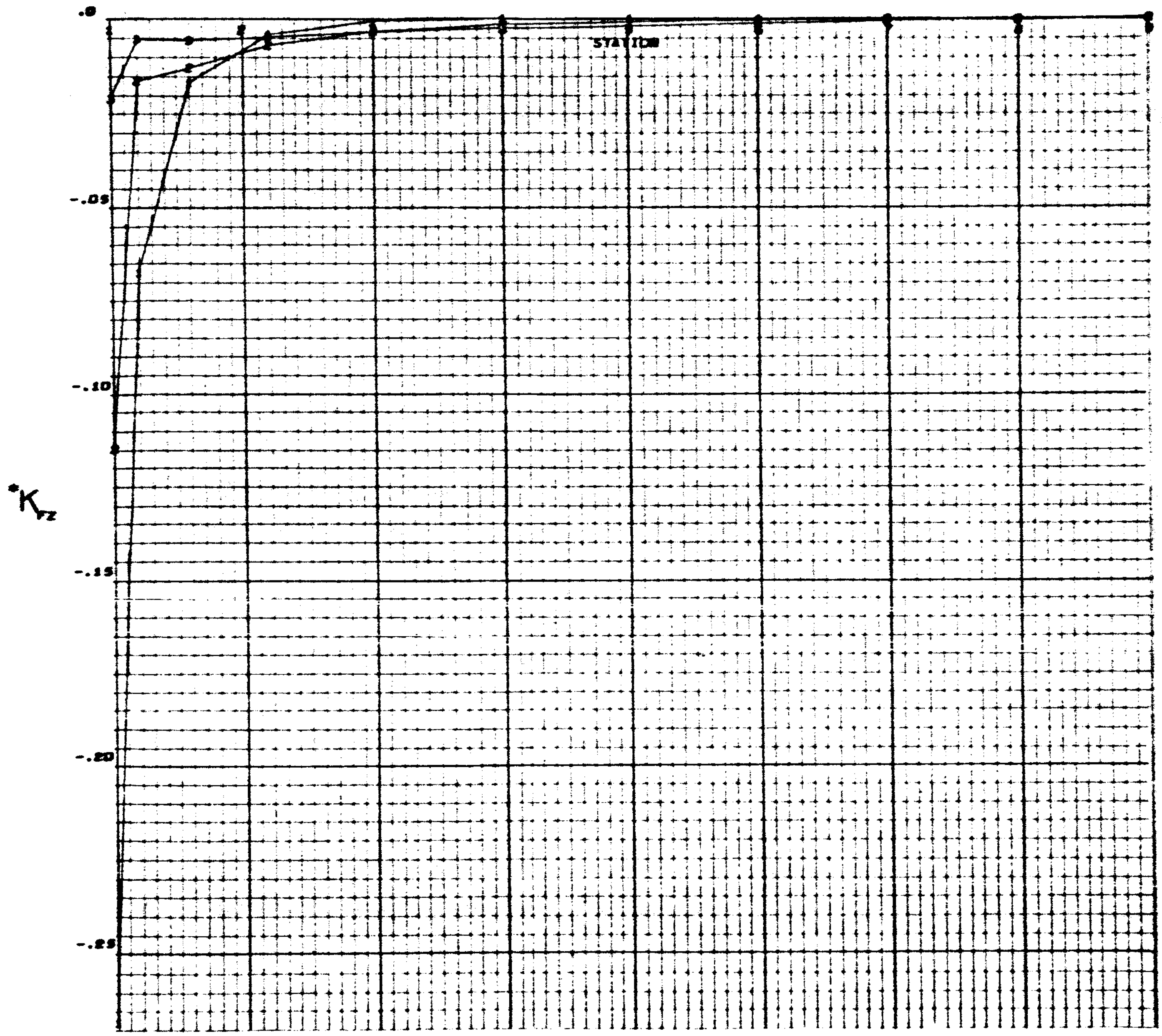


FIGURE 3B. SUPERPOSITION SEGMENTS

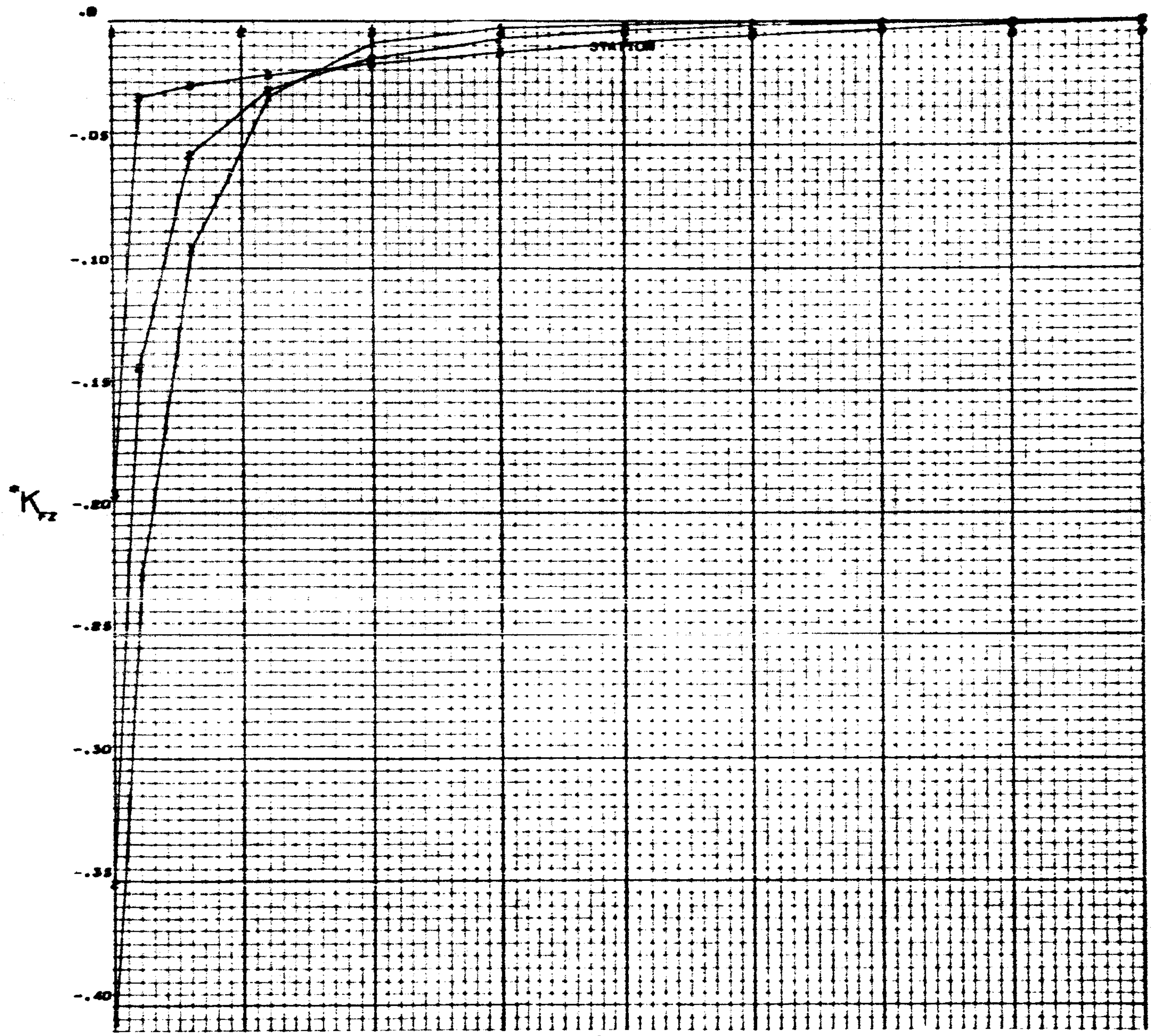
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

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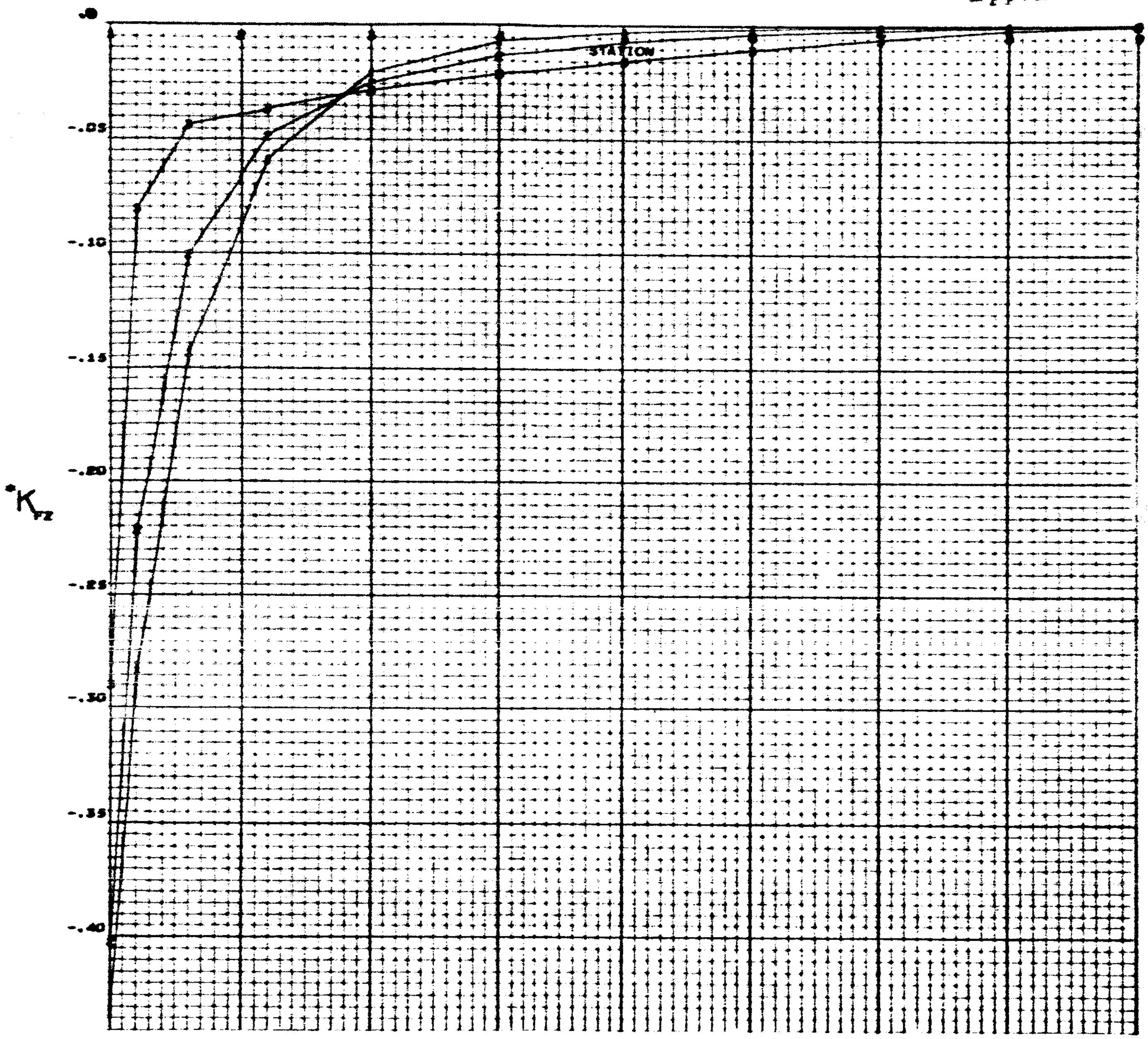
Appendix 1

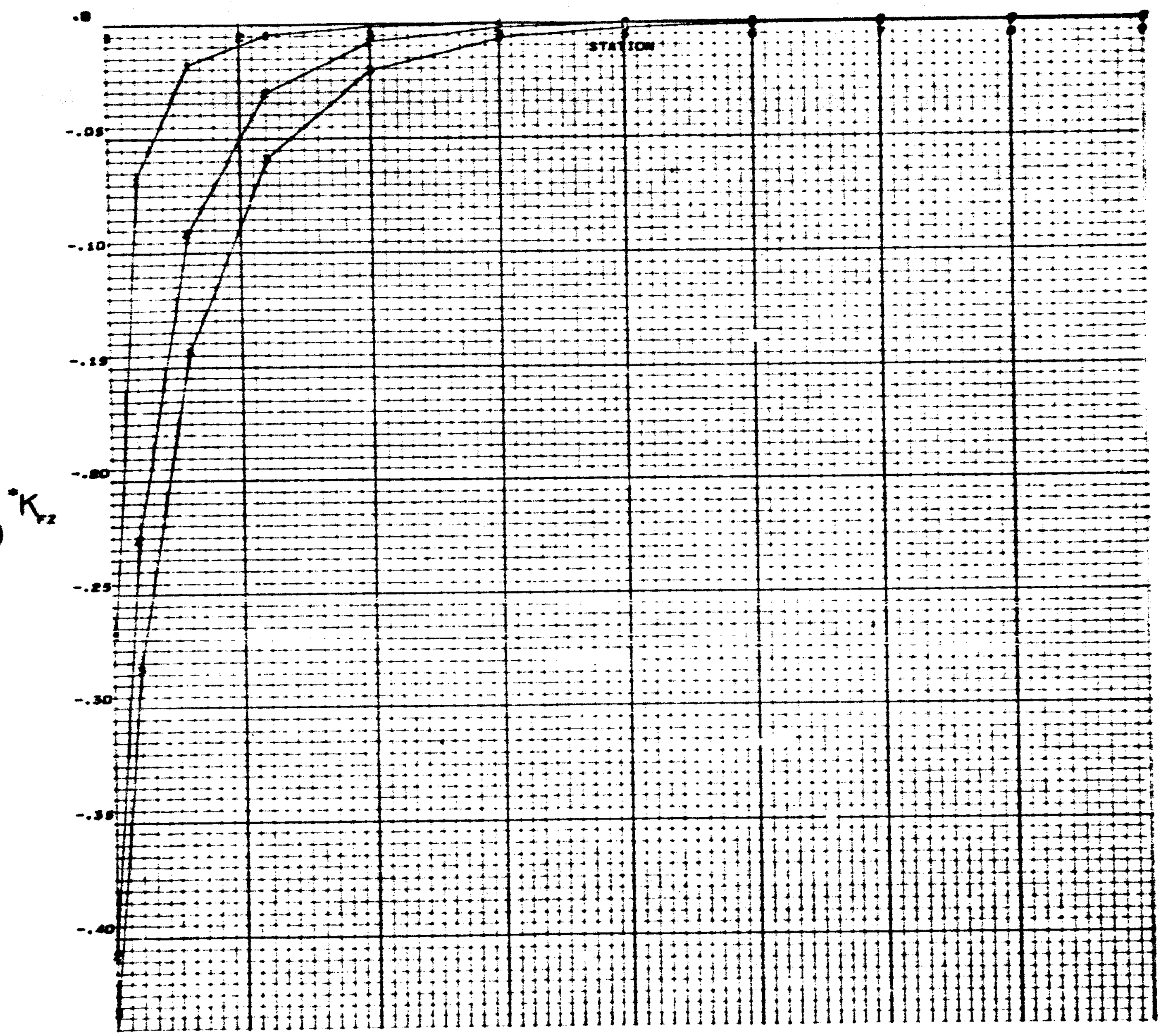
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

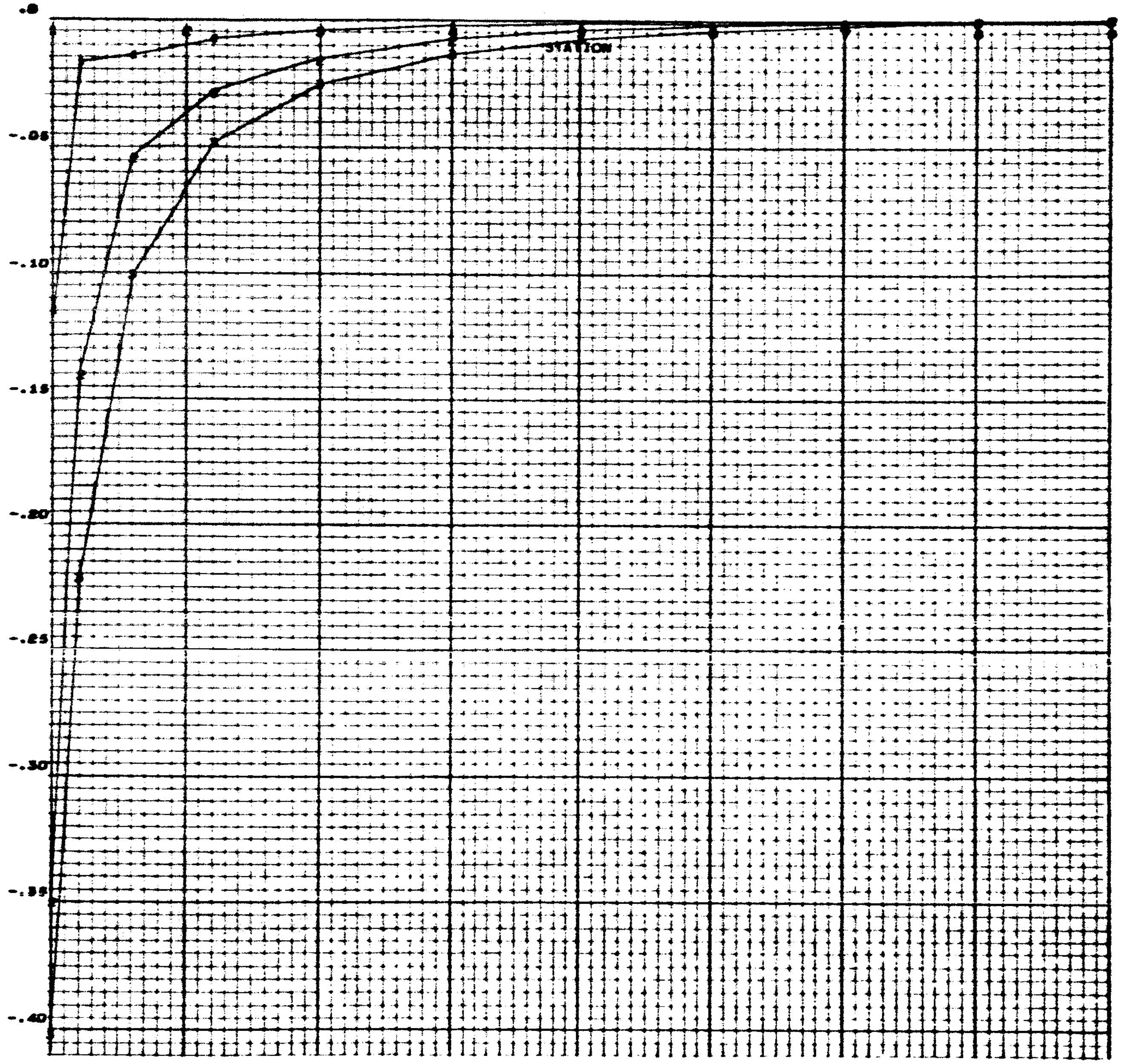
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_z = K_{FZ}$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



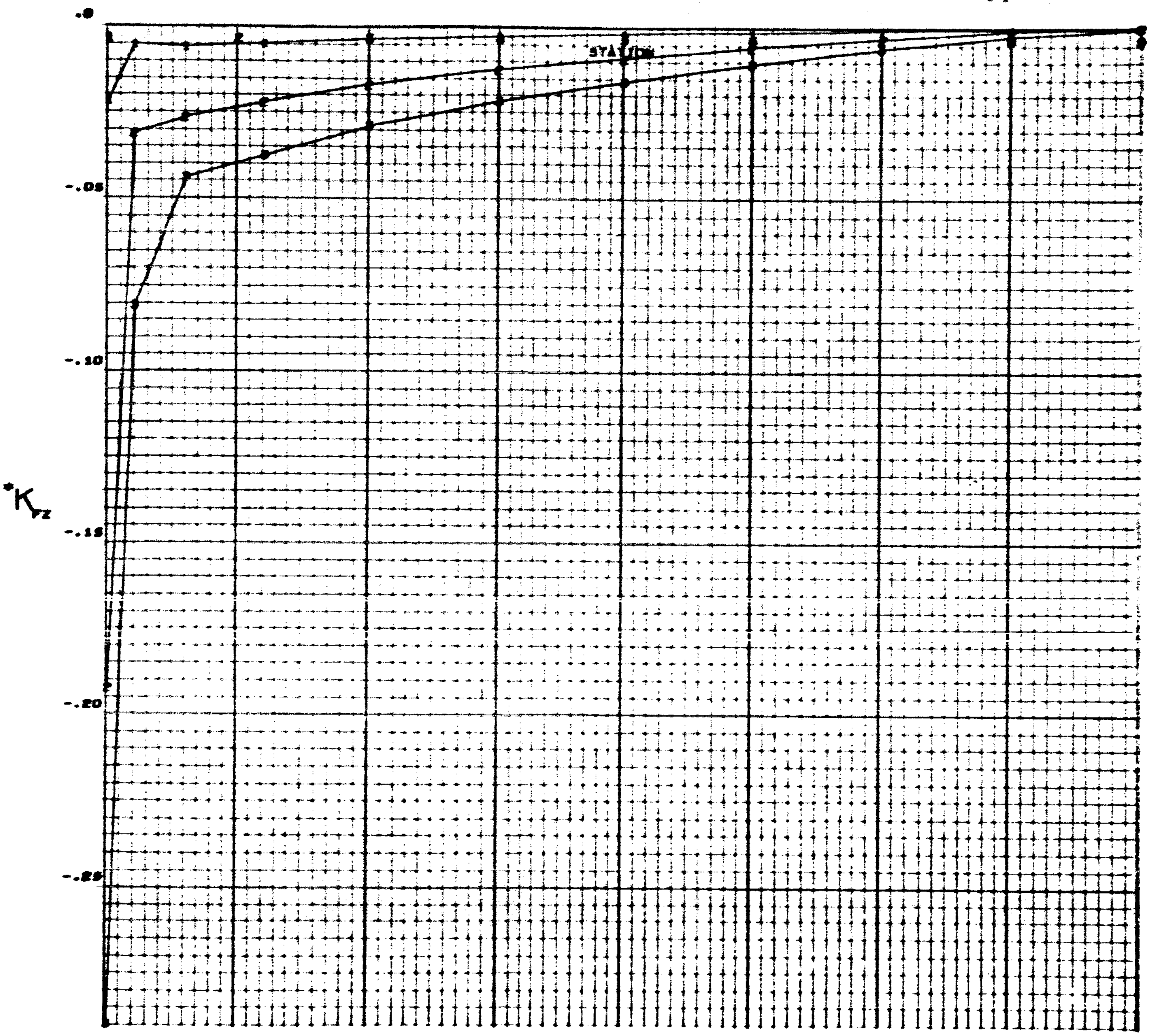
CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER

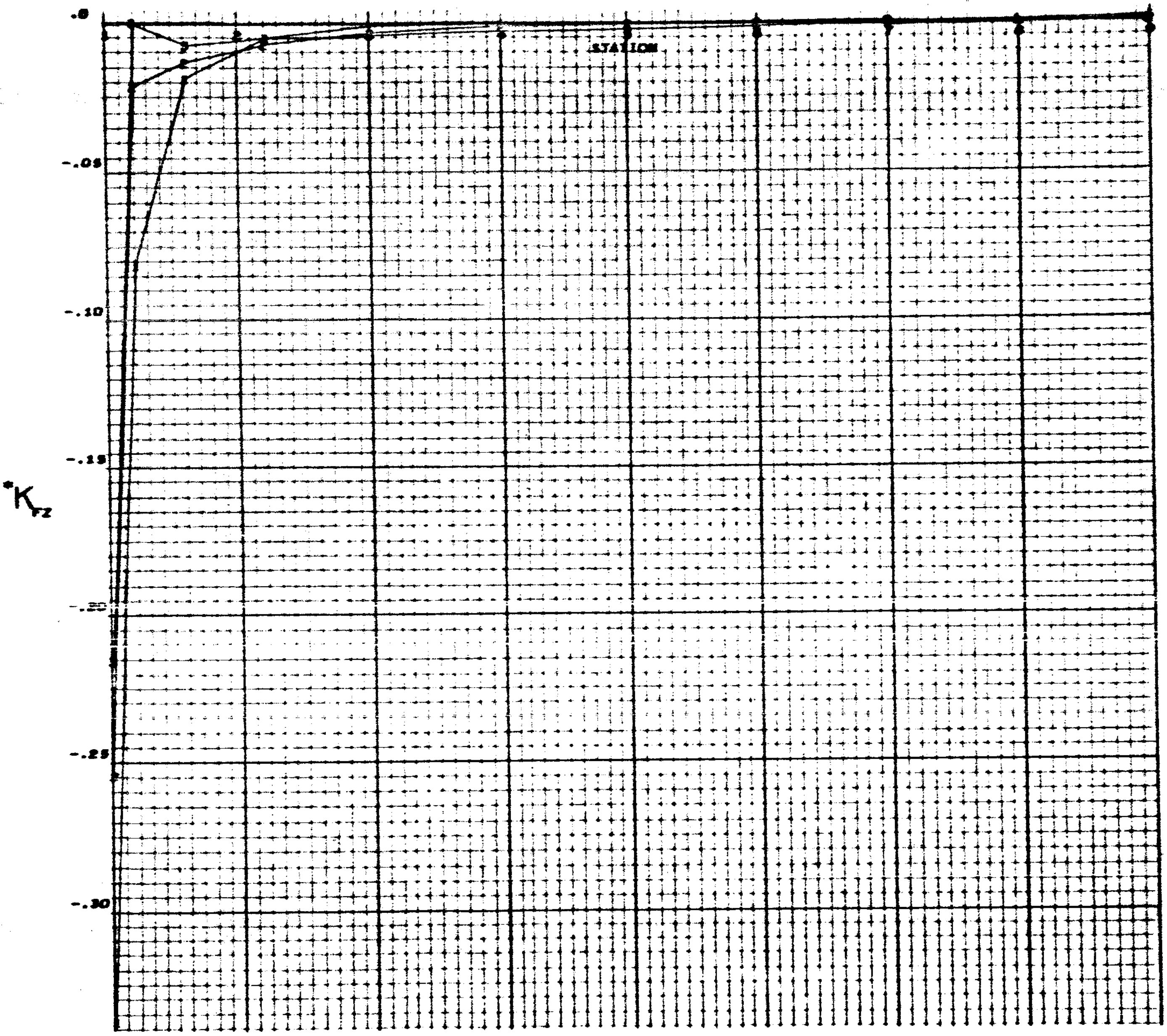
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$.

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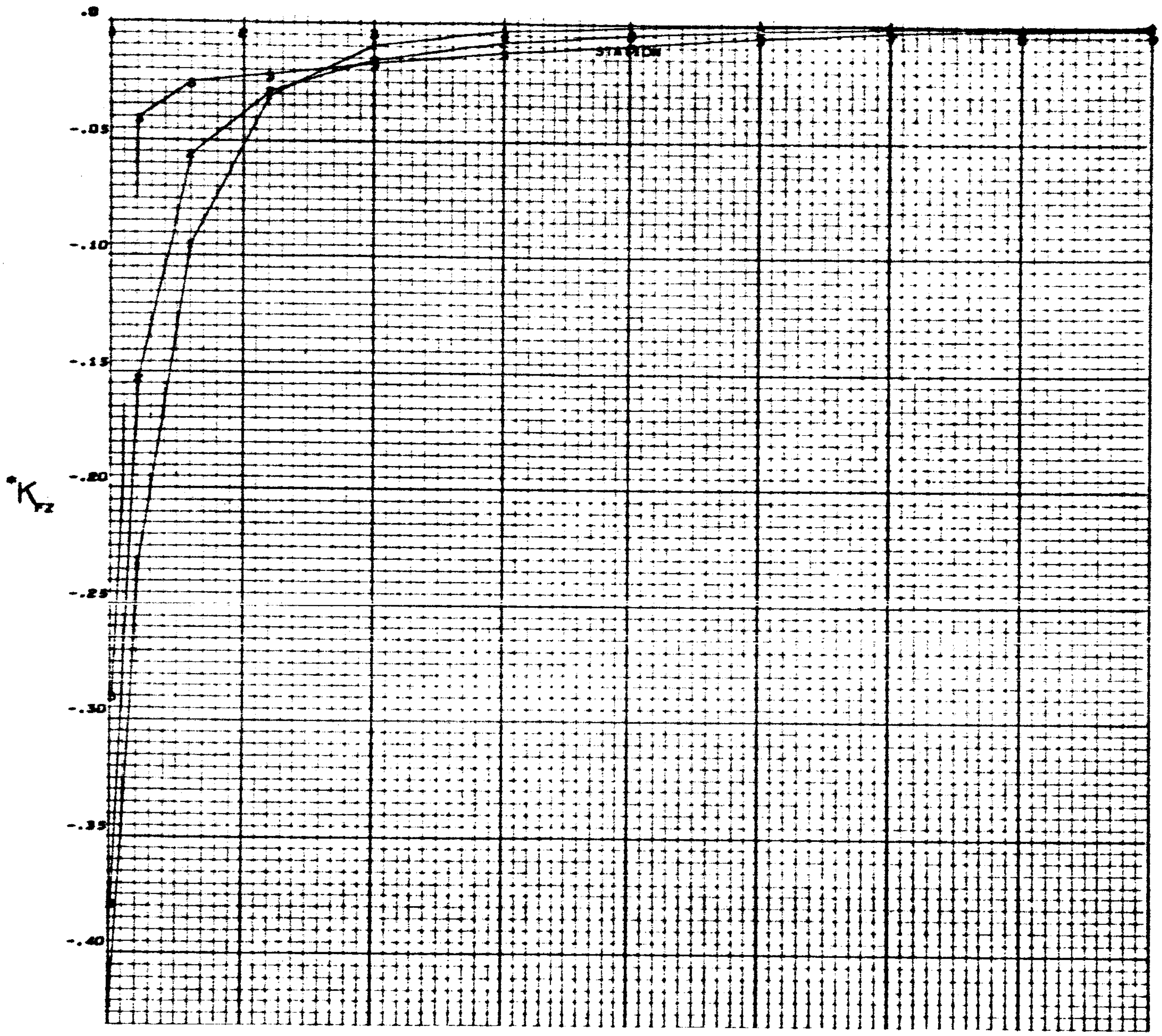
Appendix 1

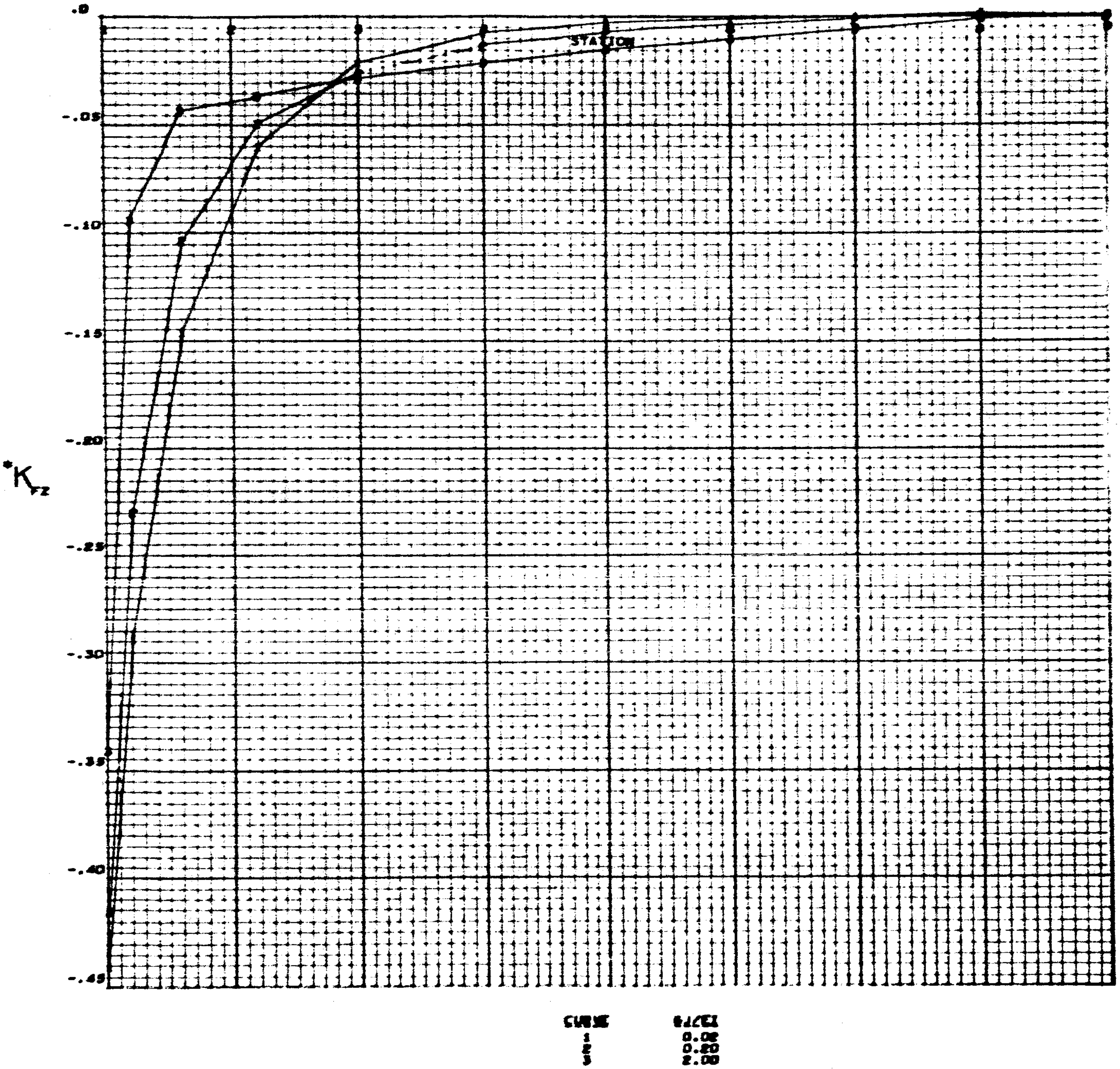
UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

UNIT FORCE DISTRIBUTED OVER ELEMENT I ELASTIC CENTER
F_z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.08, GJ/EI VARIABLE



*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

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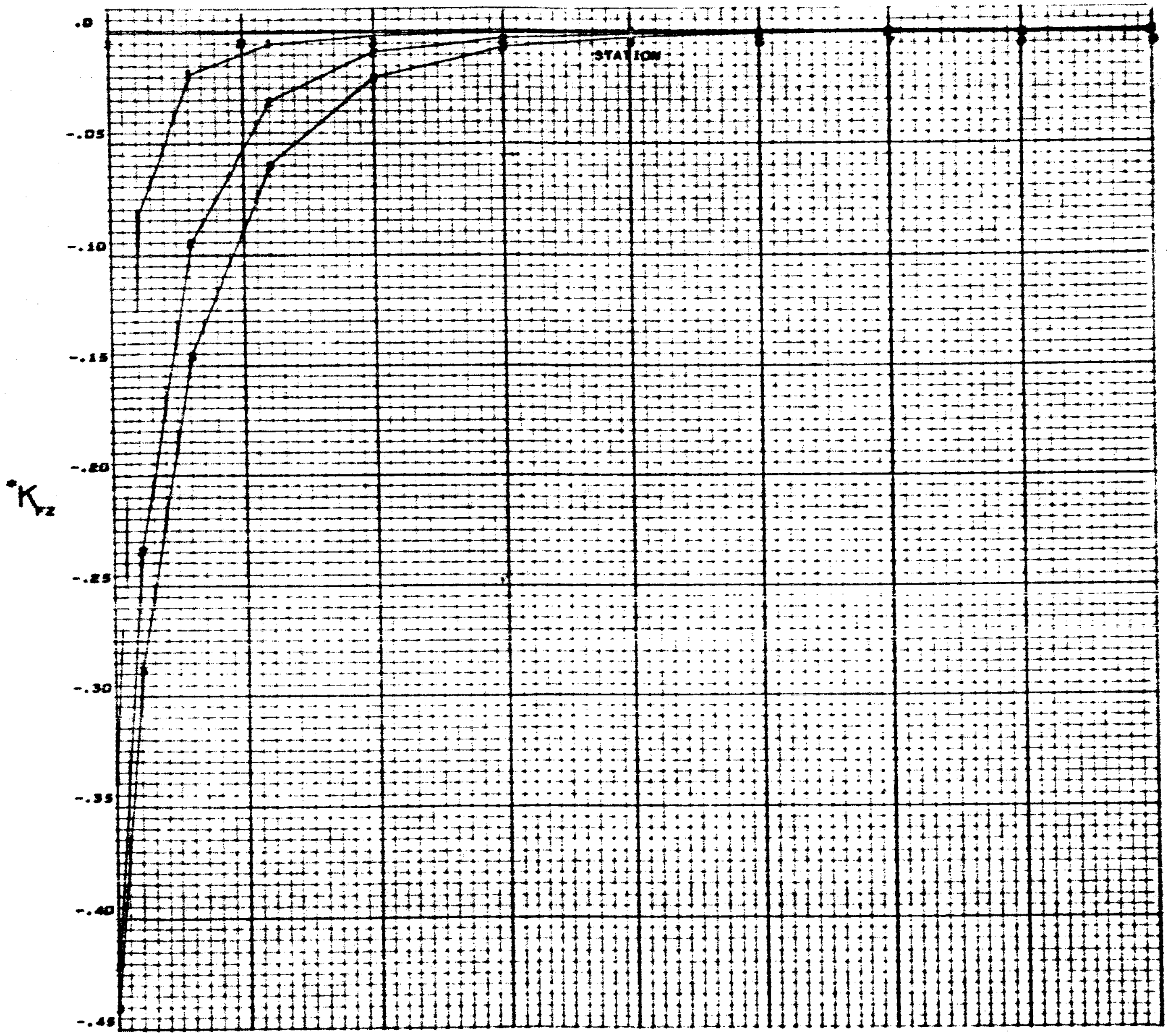
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

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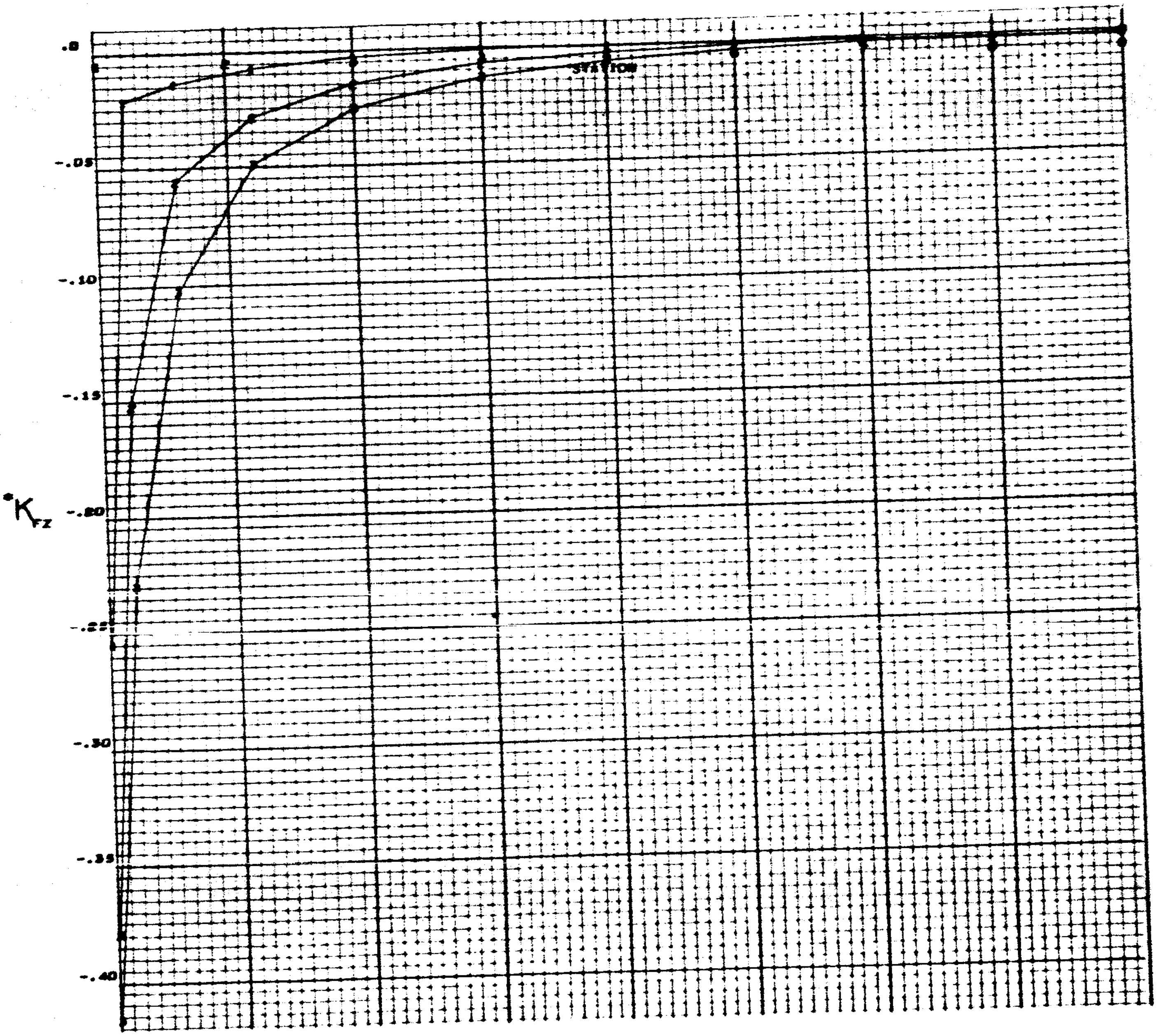
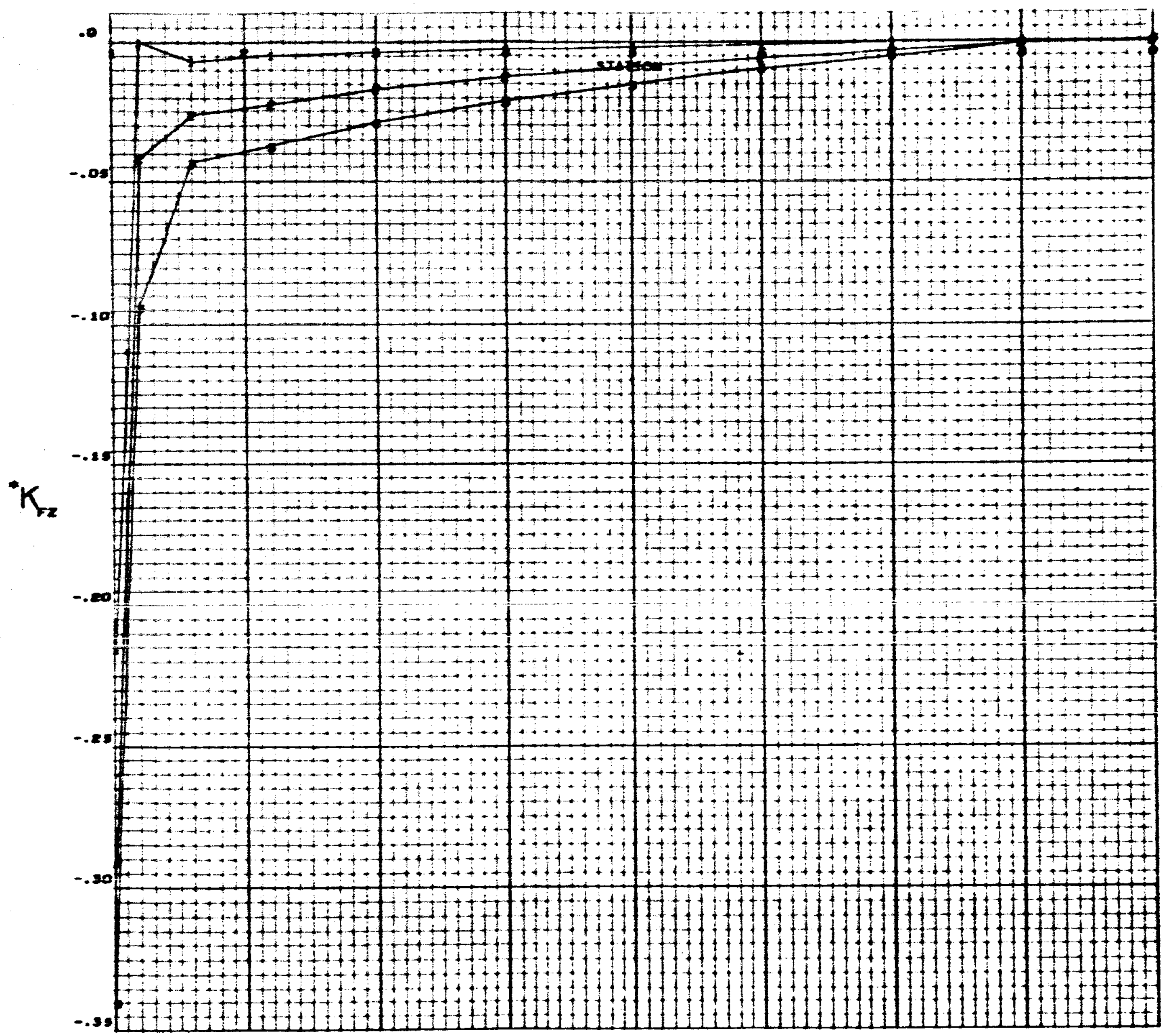
UNIT FORCE DISTRIBUTED OVER ELEMENT ℄ ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

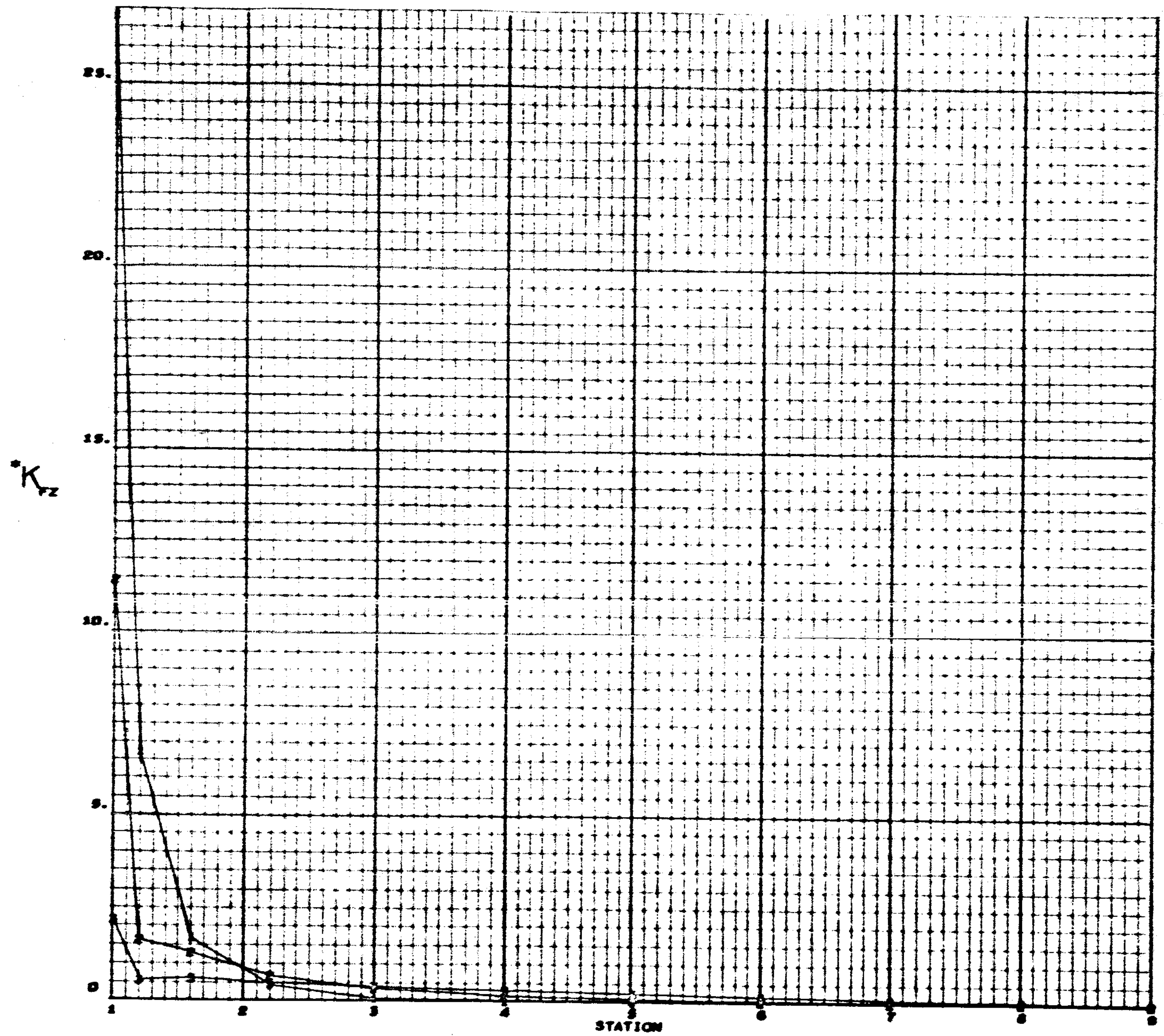
UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
F_Z: INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE

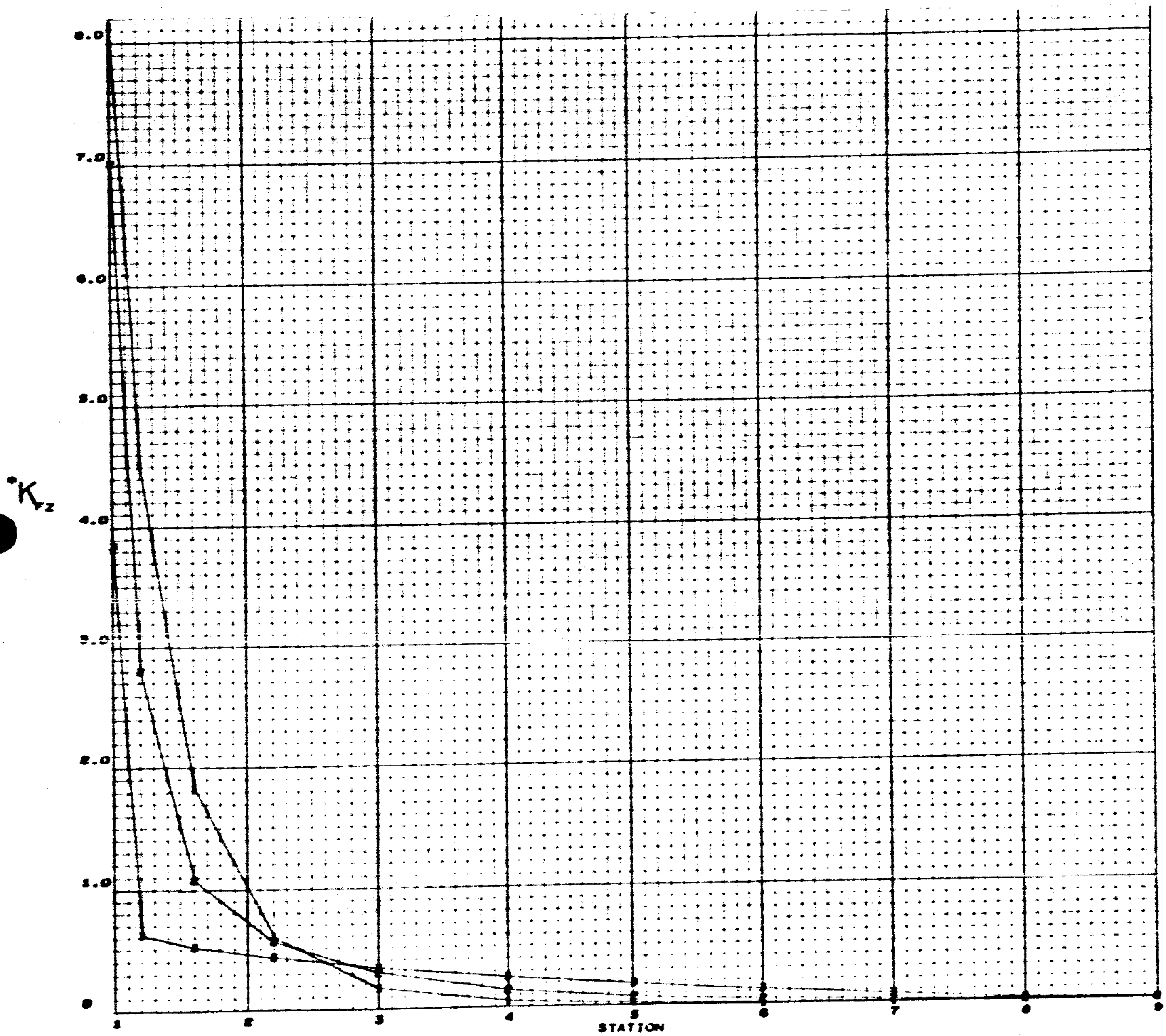


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

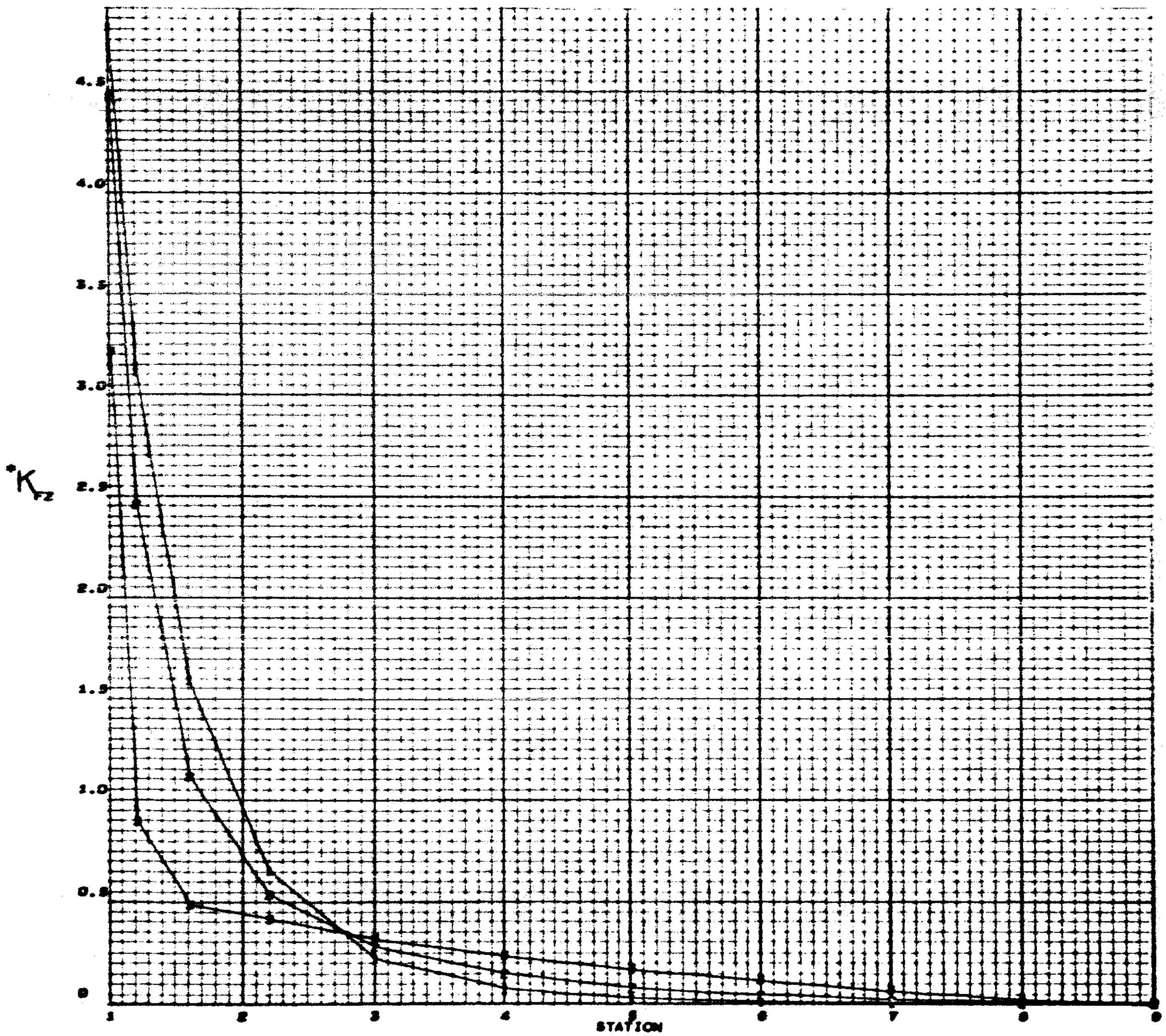
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

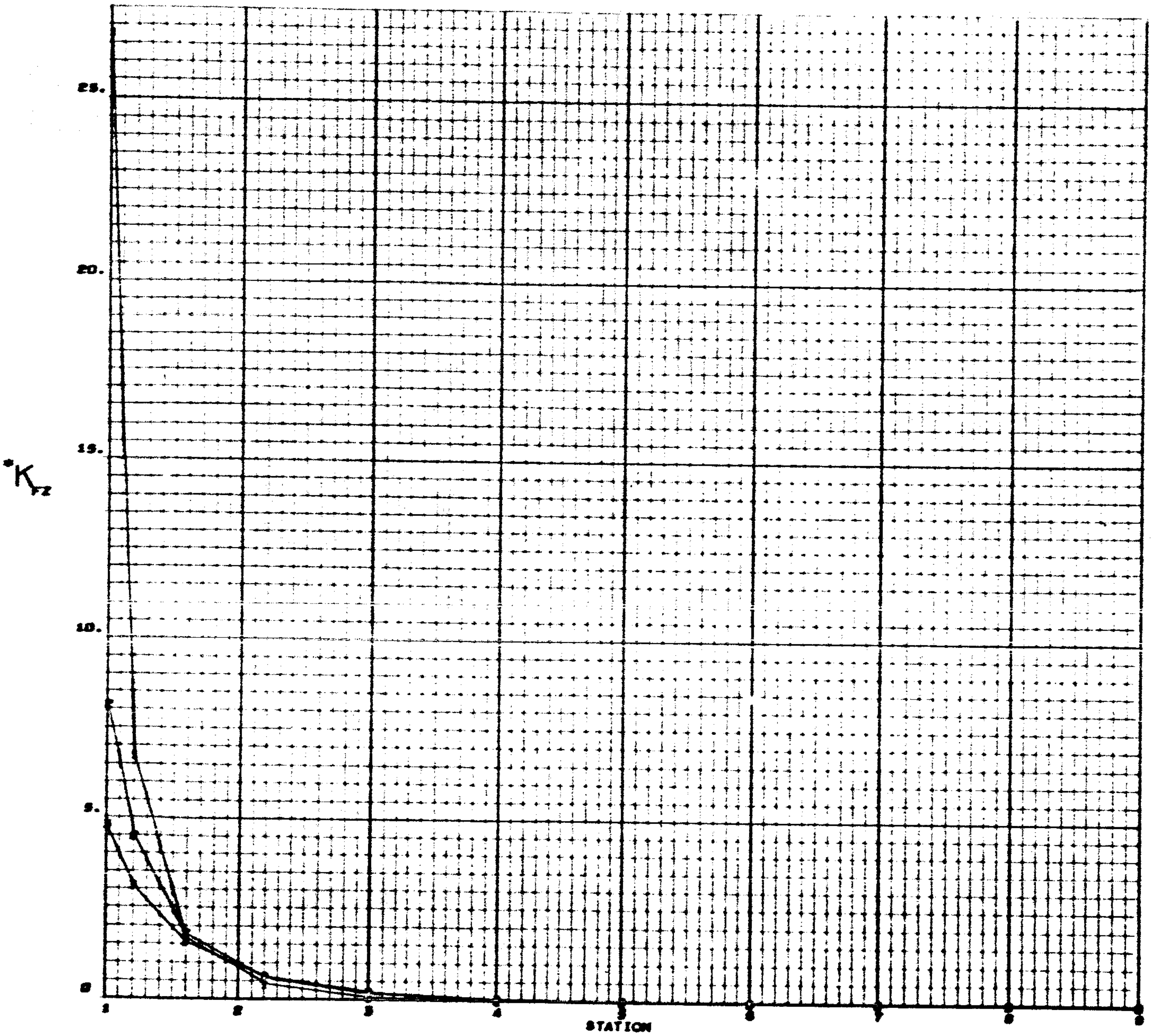
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

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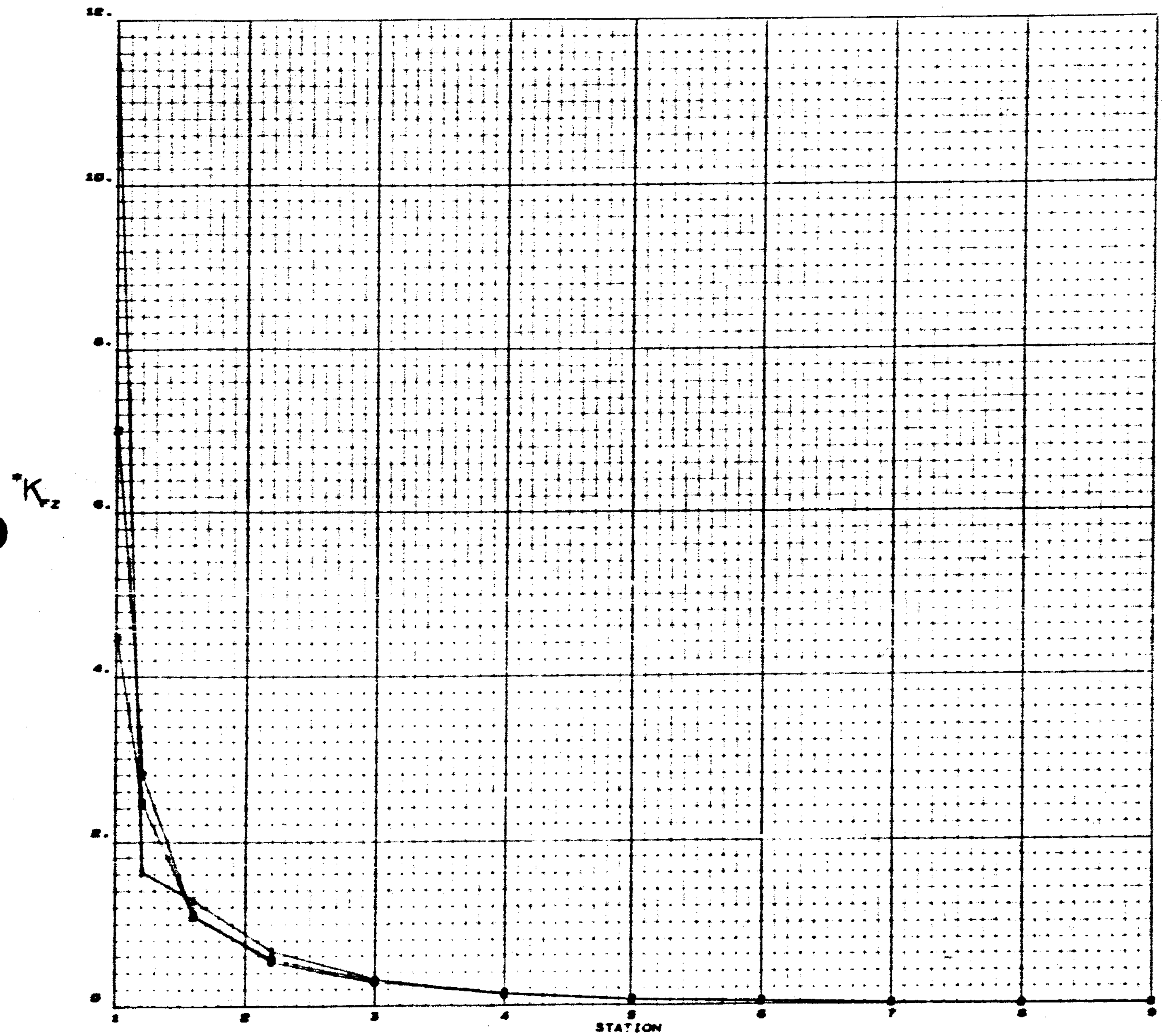
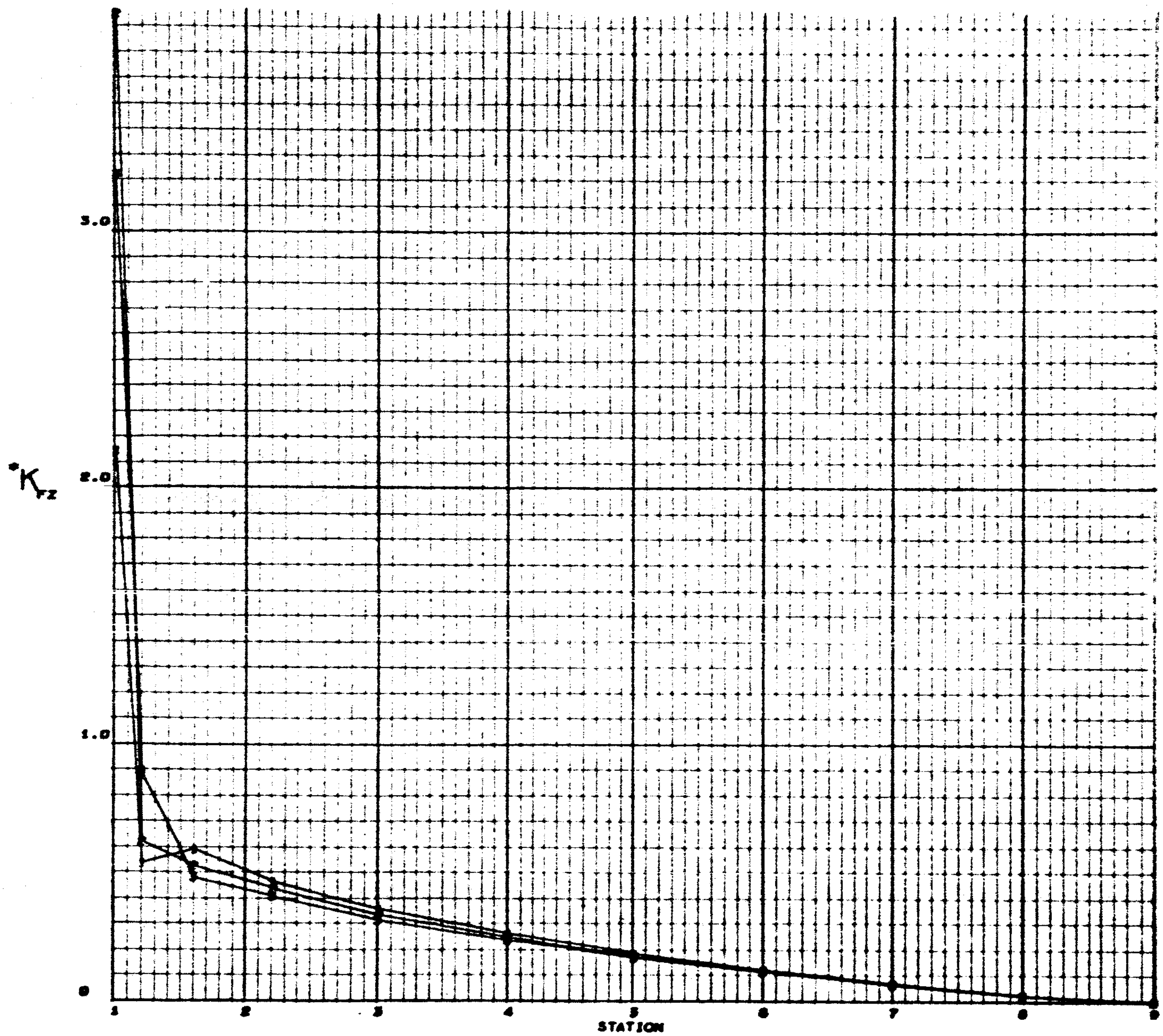
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

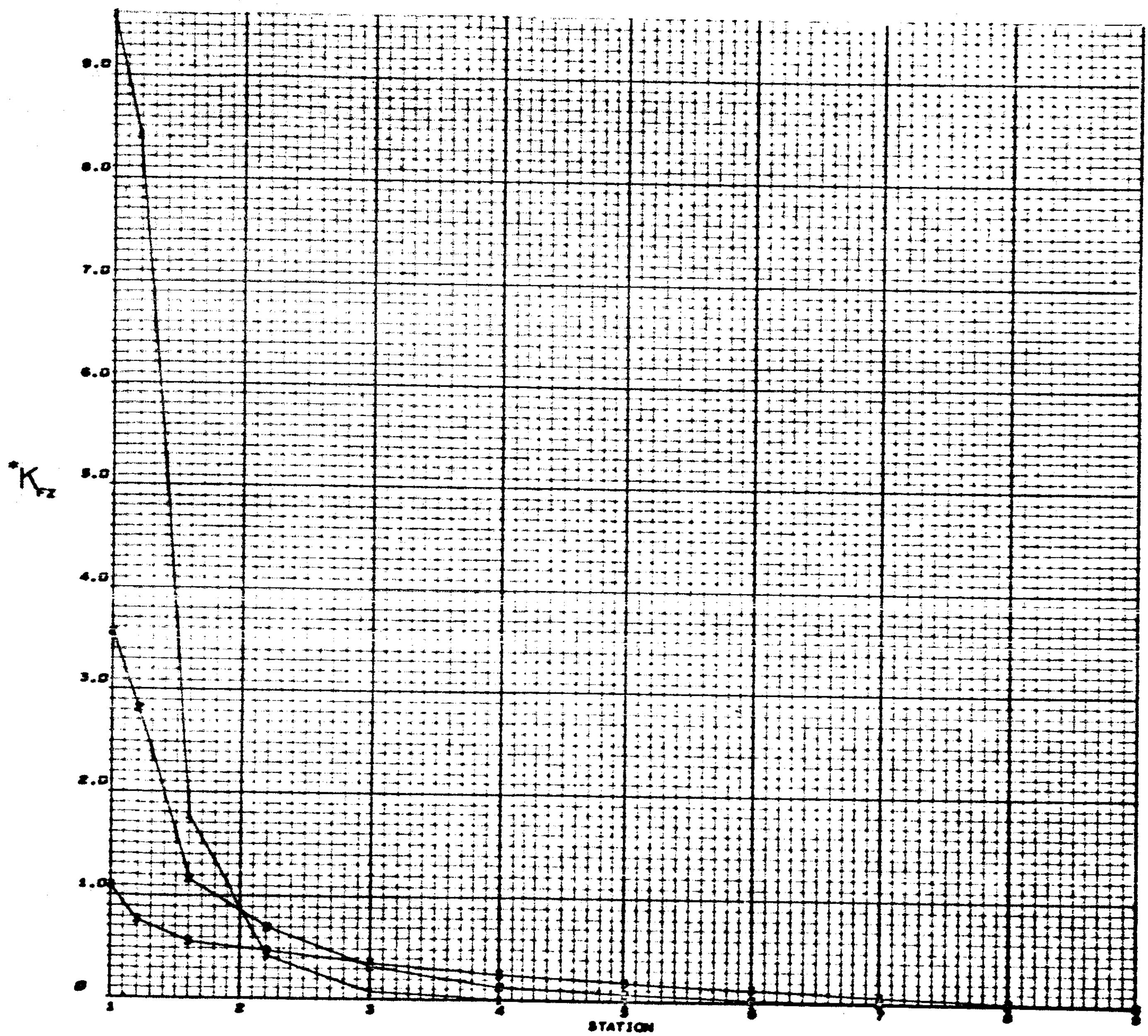
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

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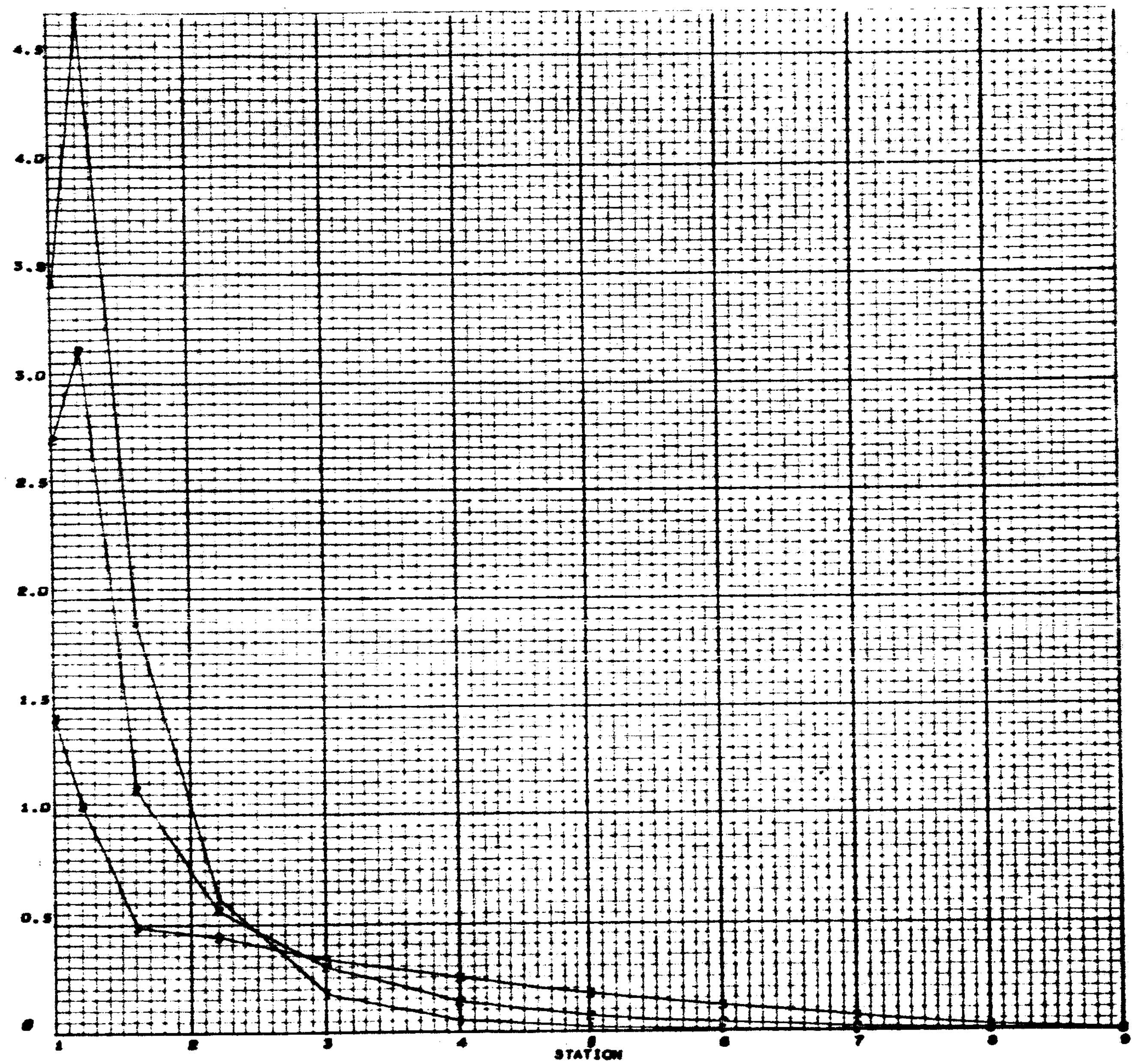
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE

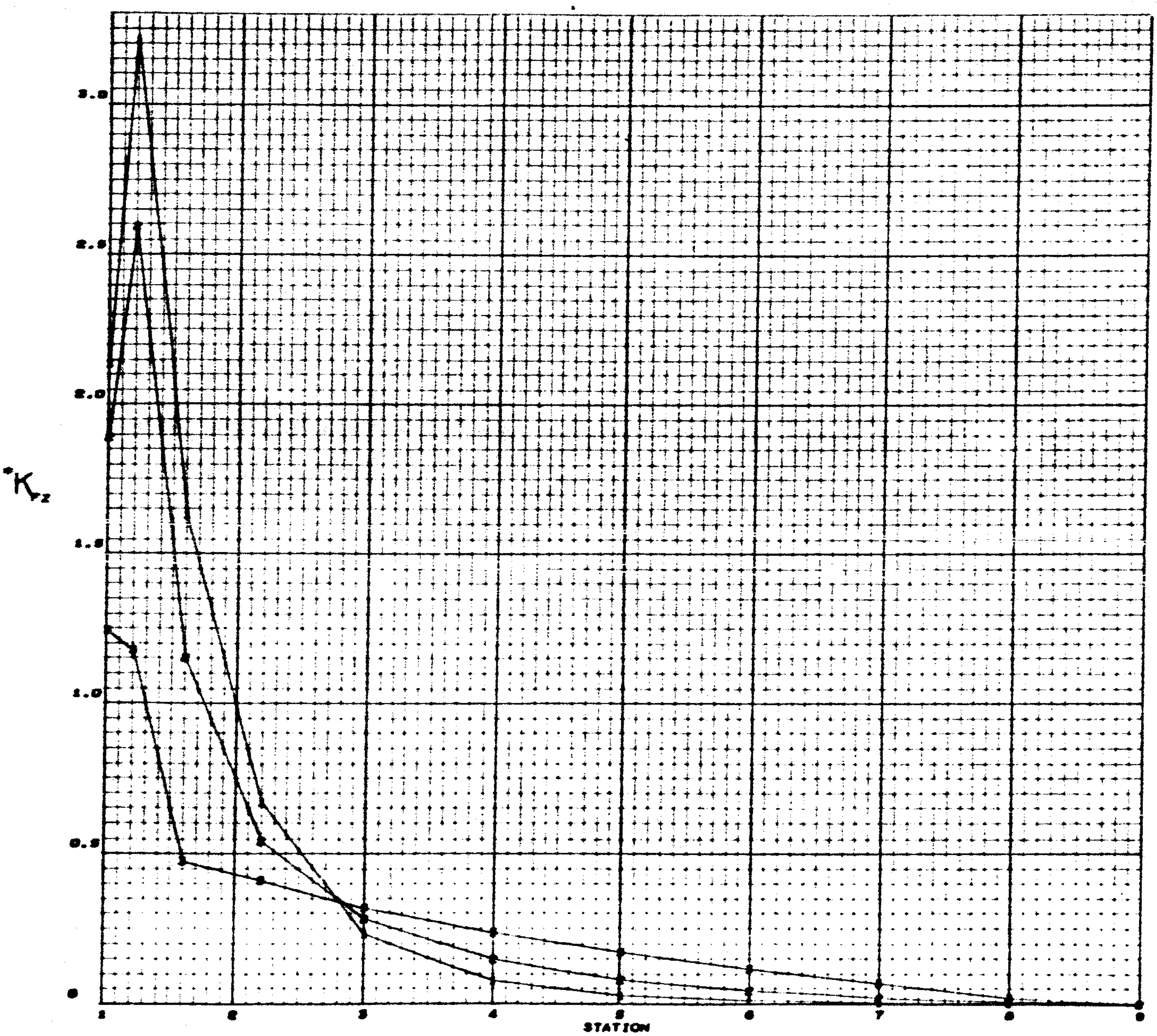


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE

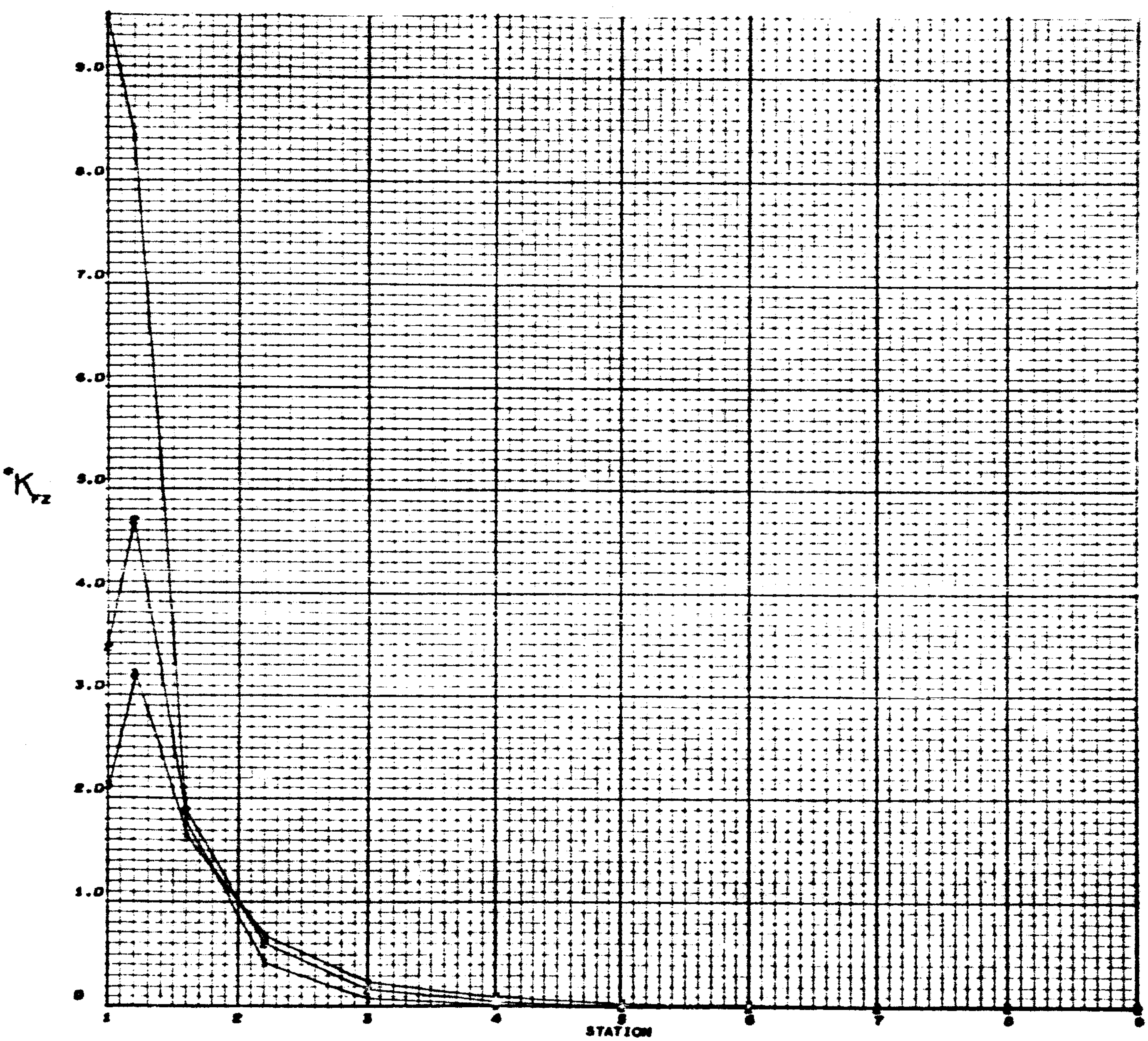


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

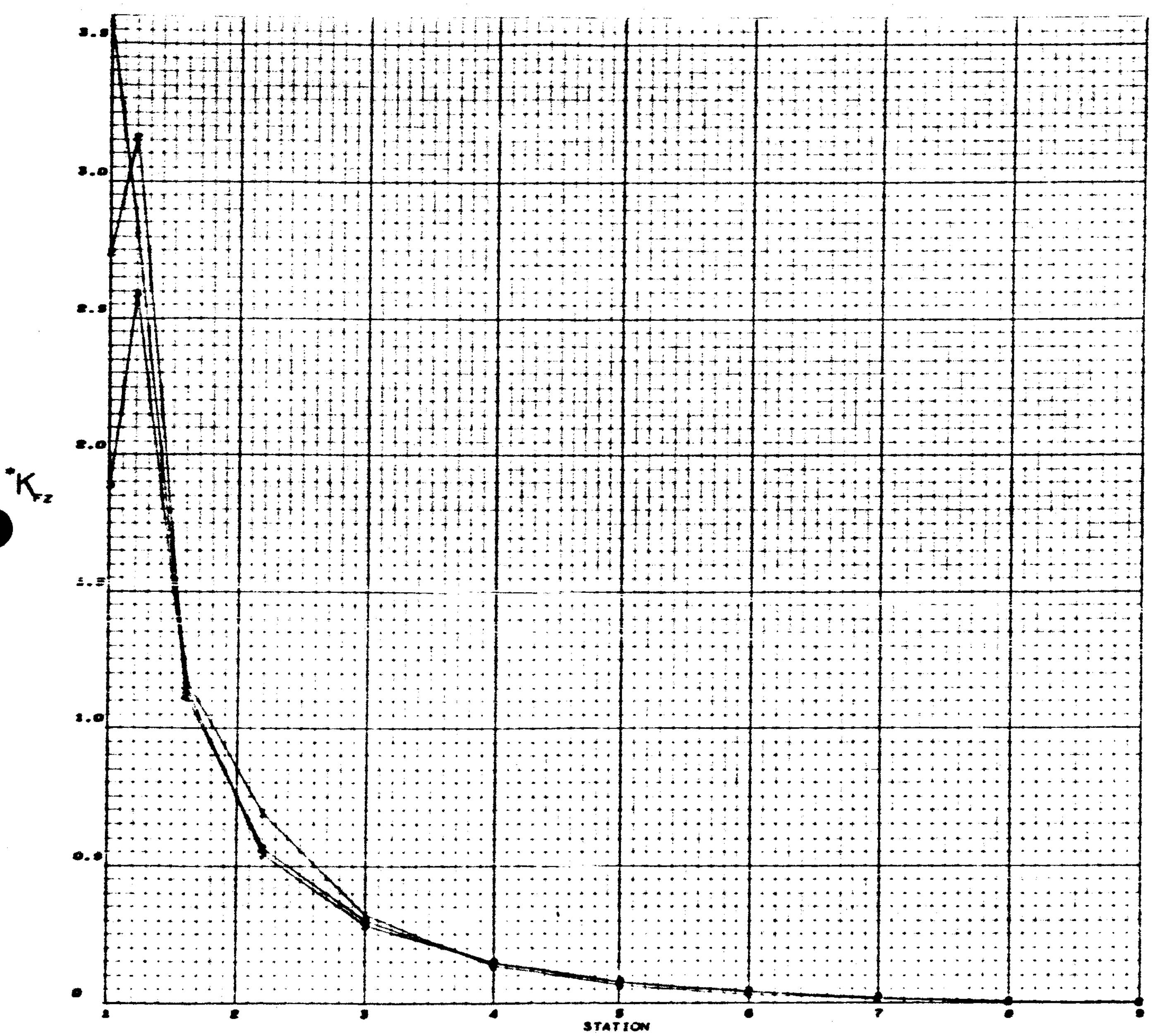
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

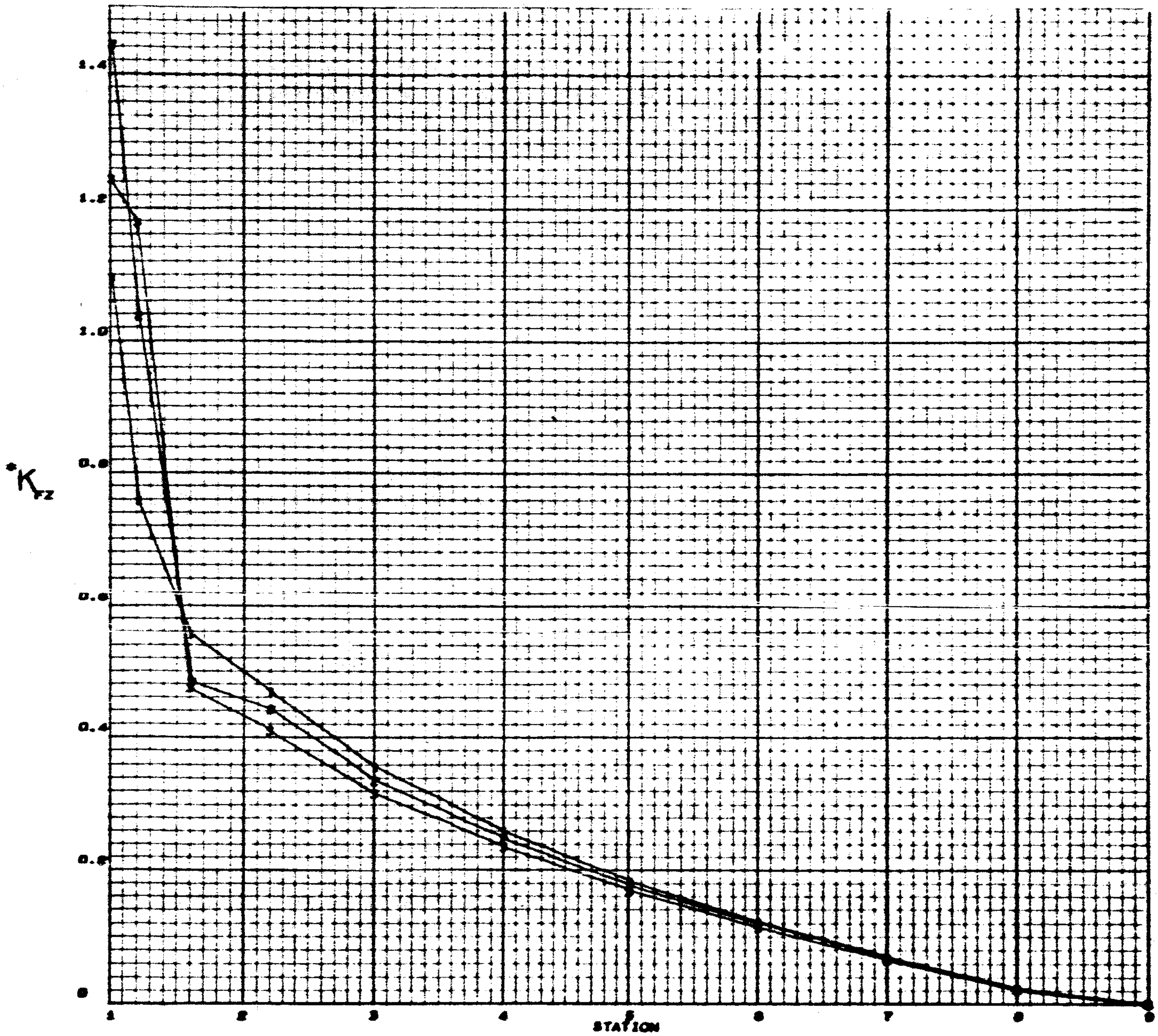
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

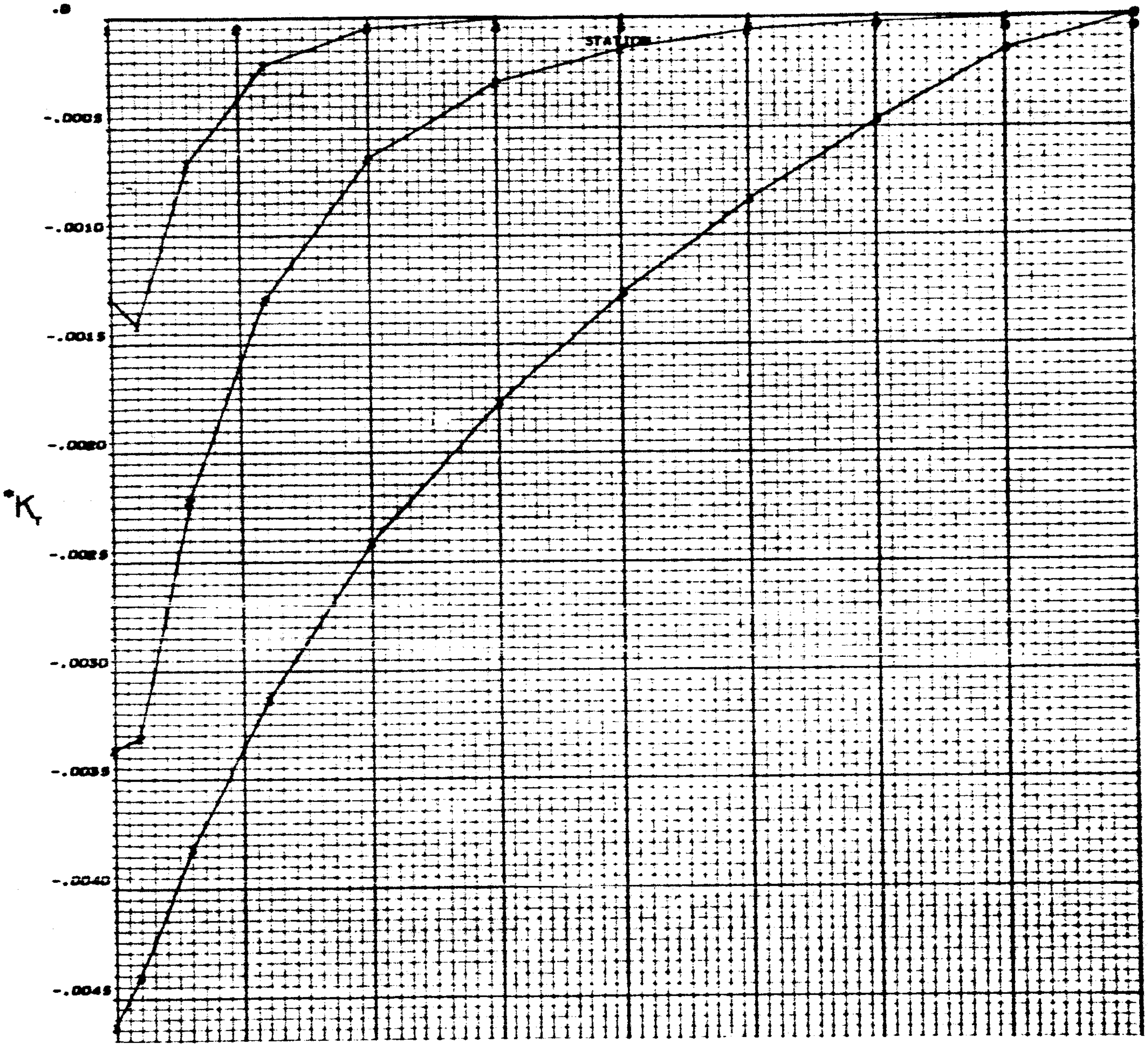
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT I
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}/R$

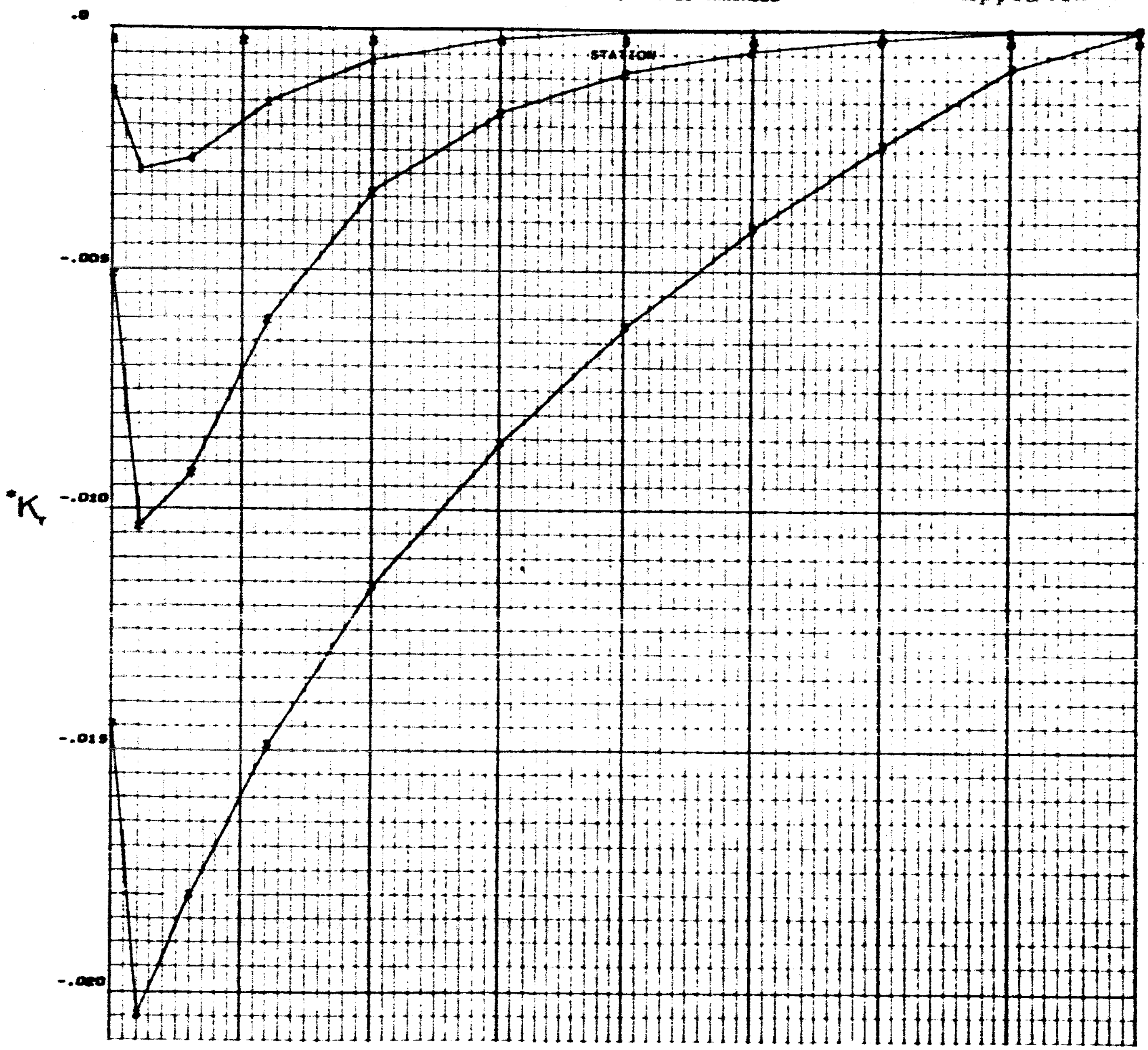
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE

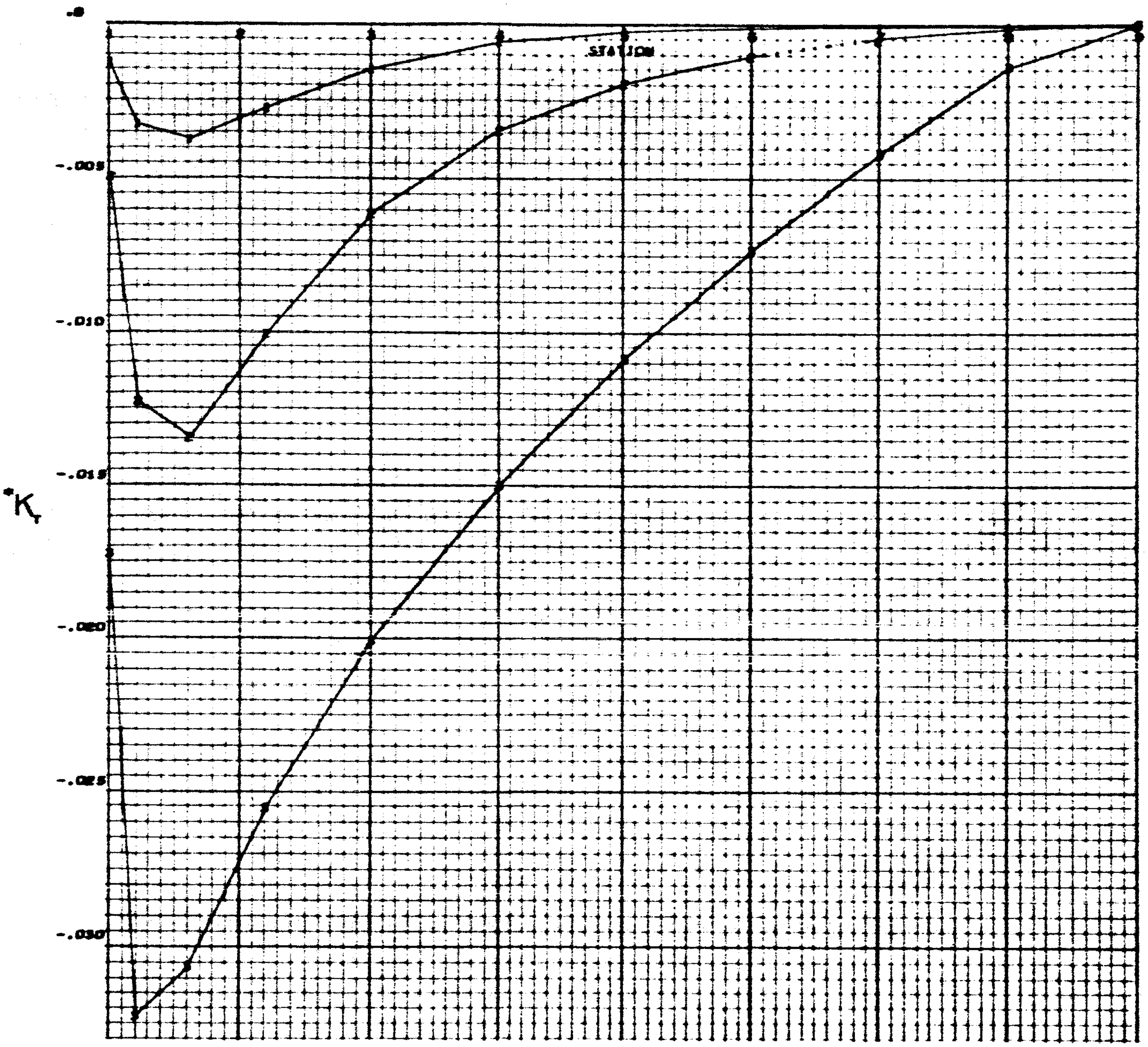


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

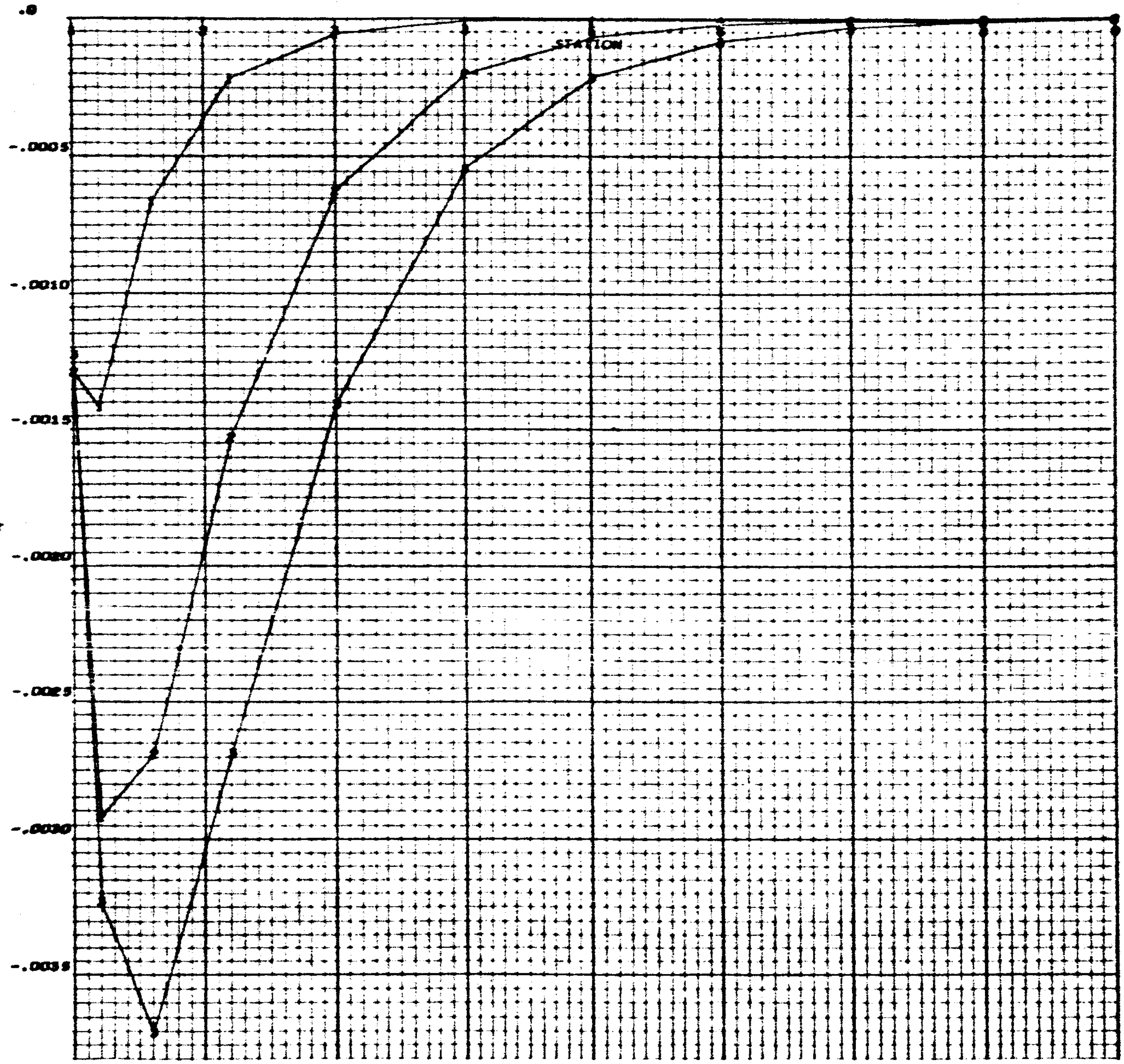
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

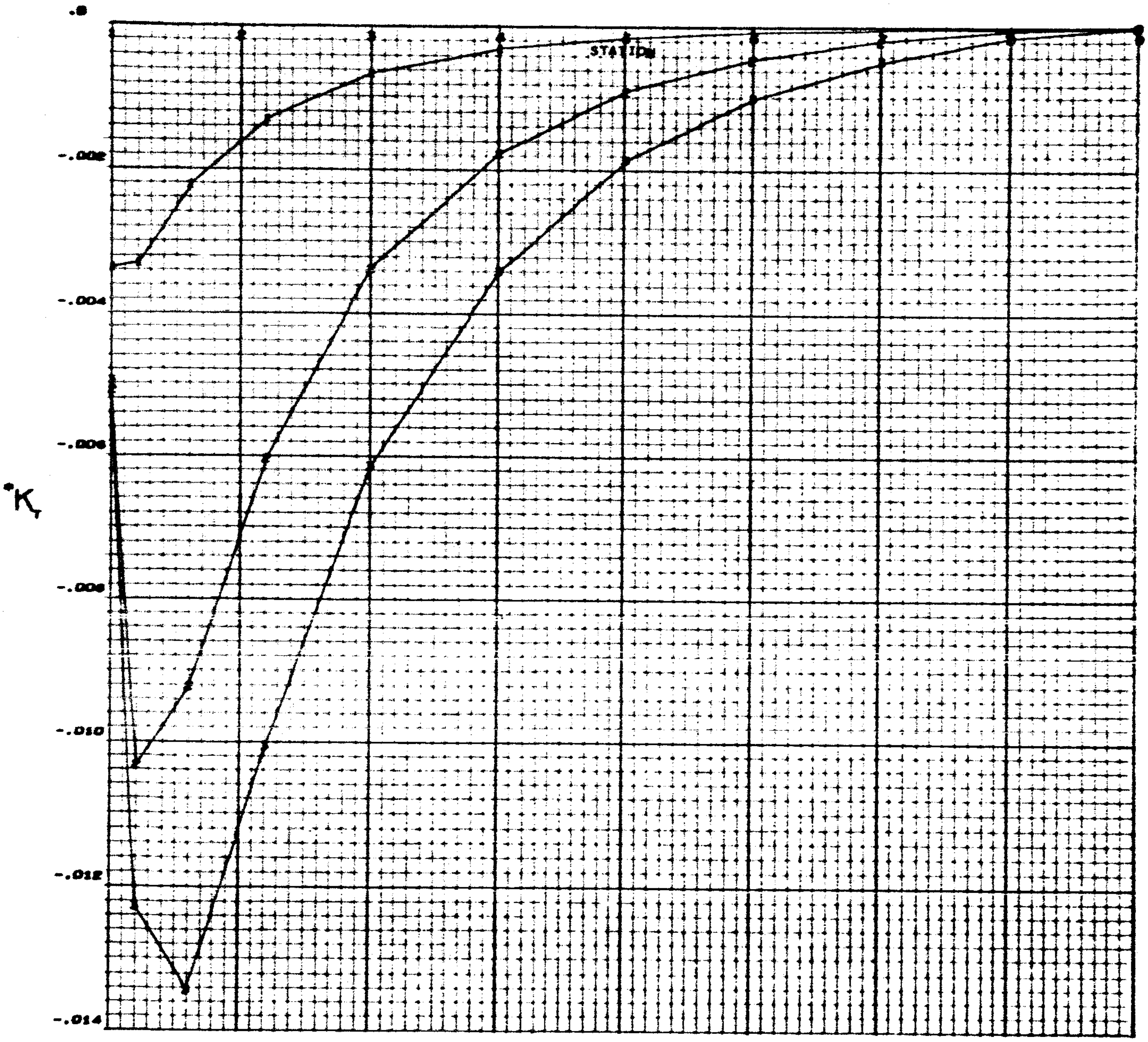
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

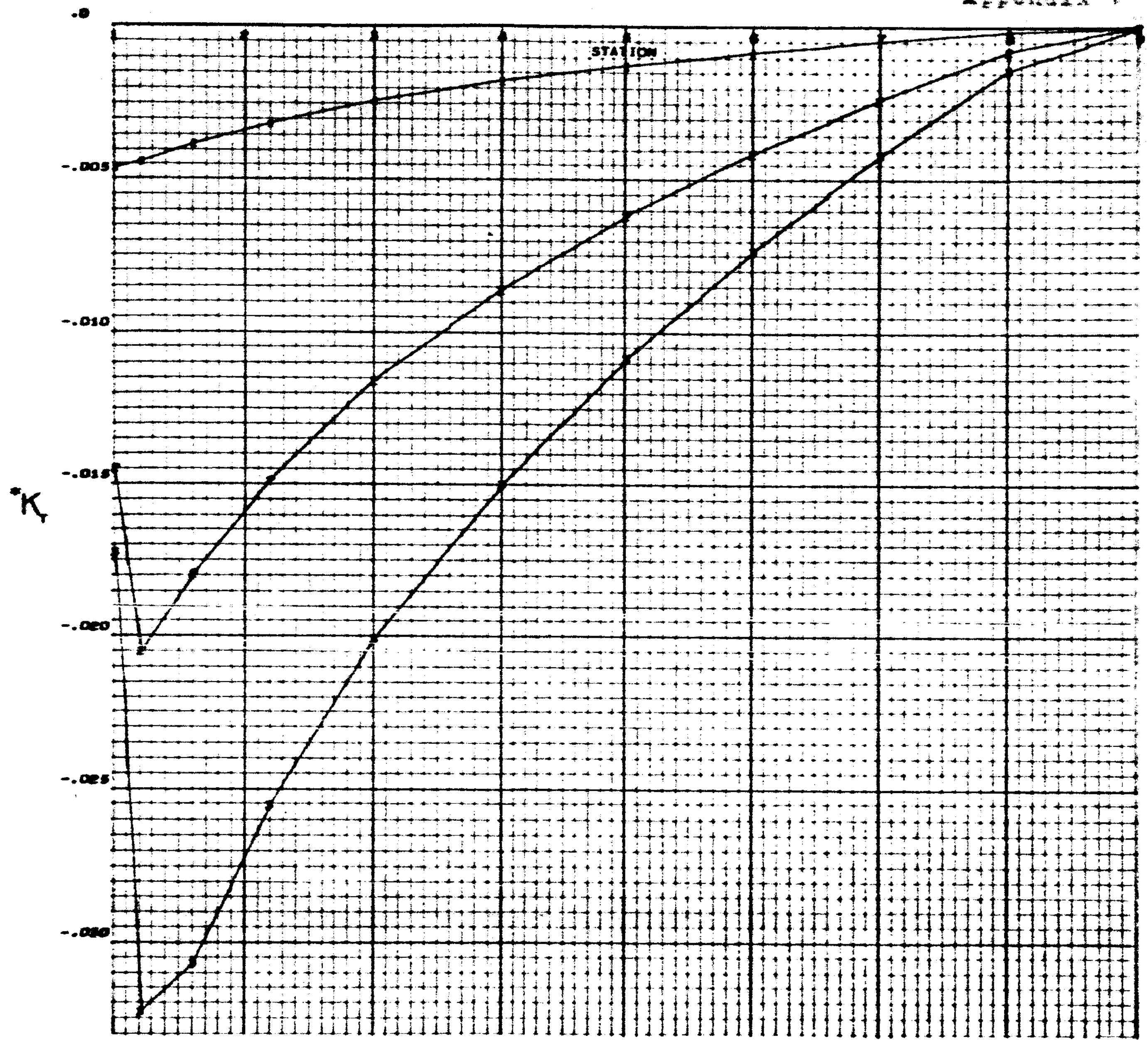
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

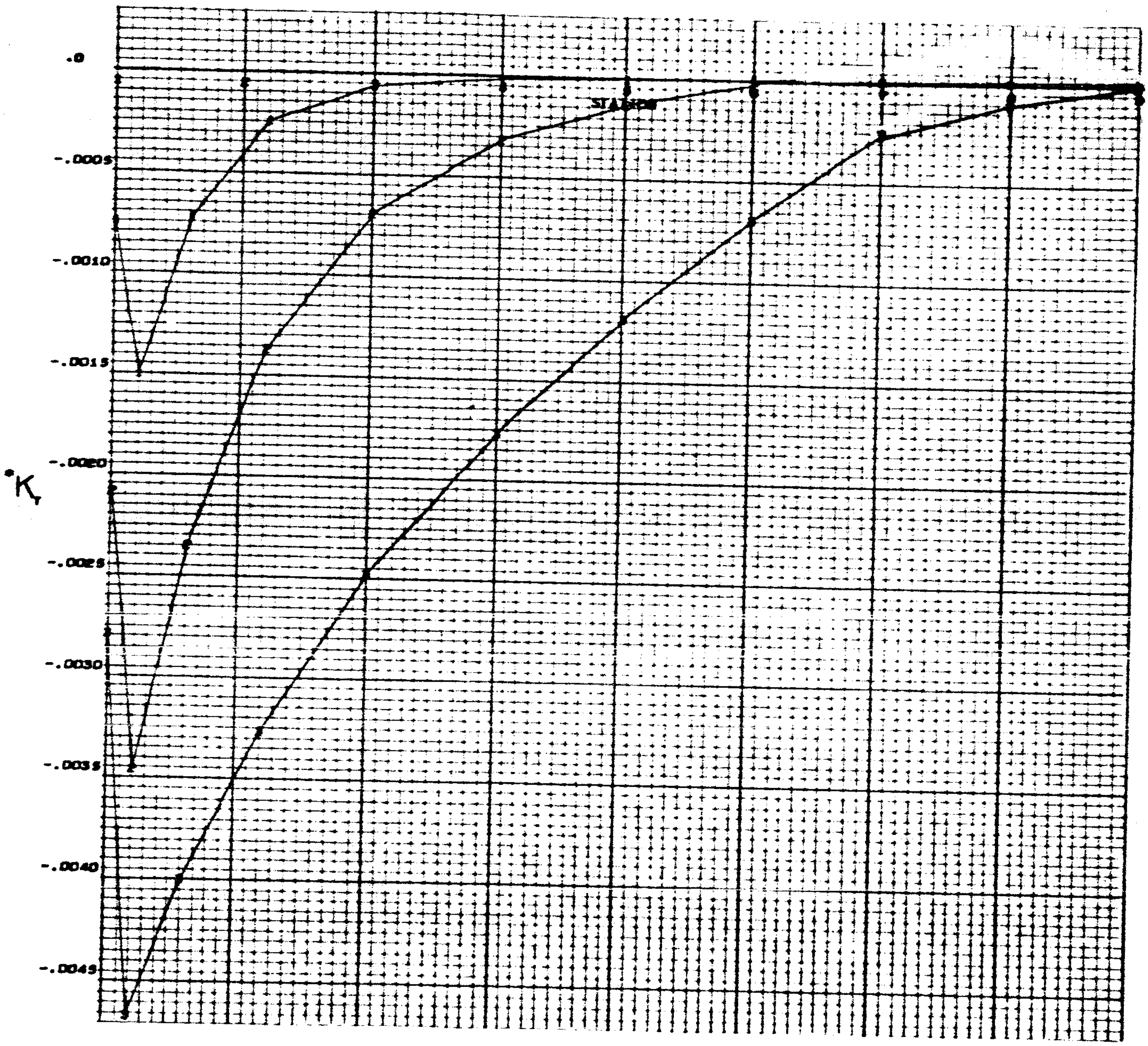


CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

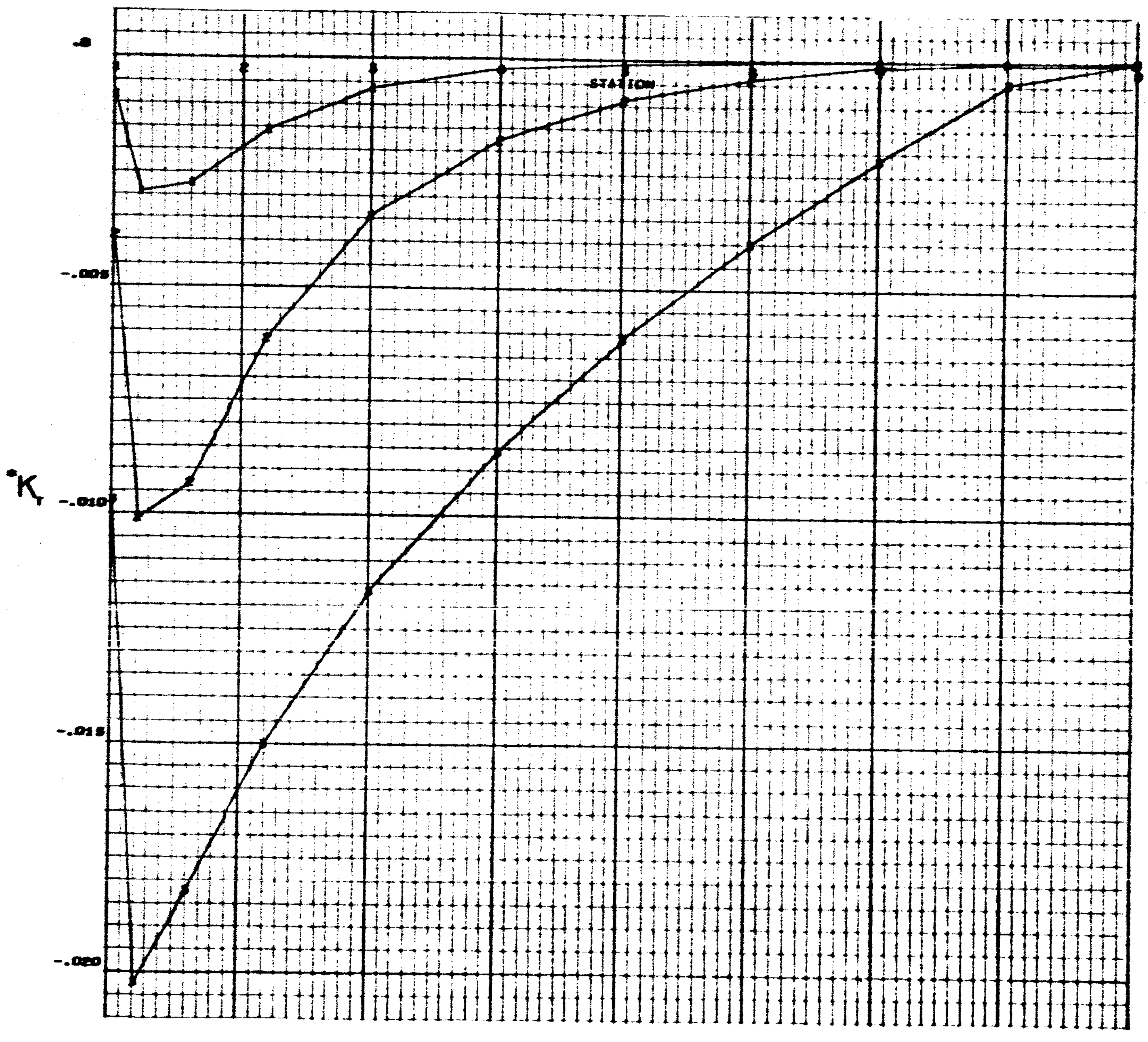
UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

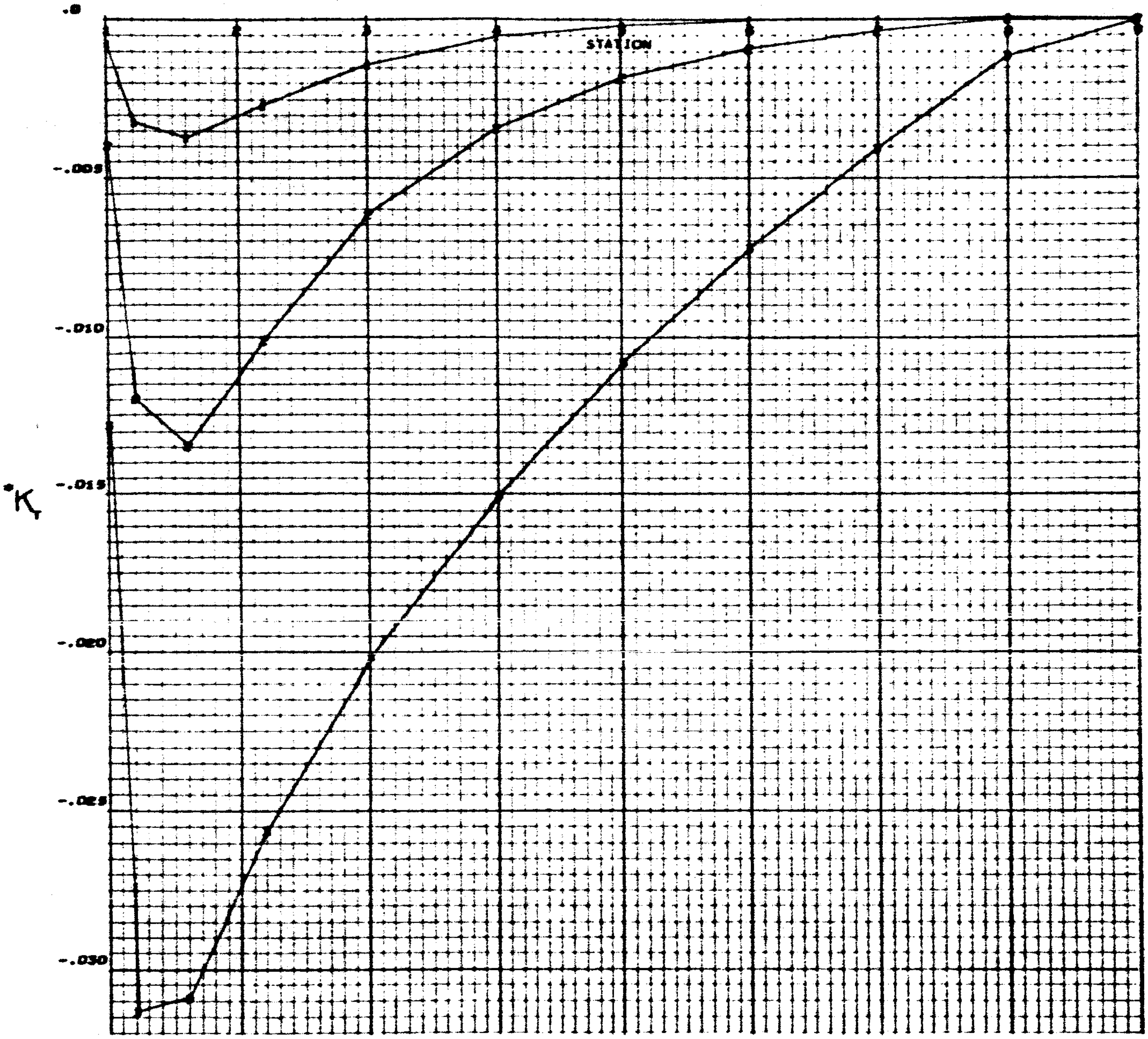
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

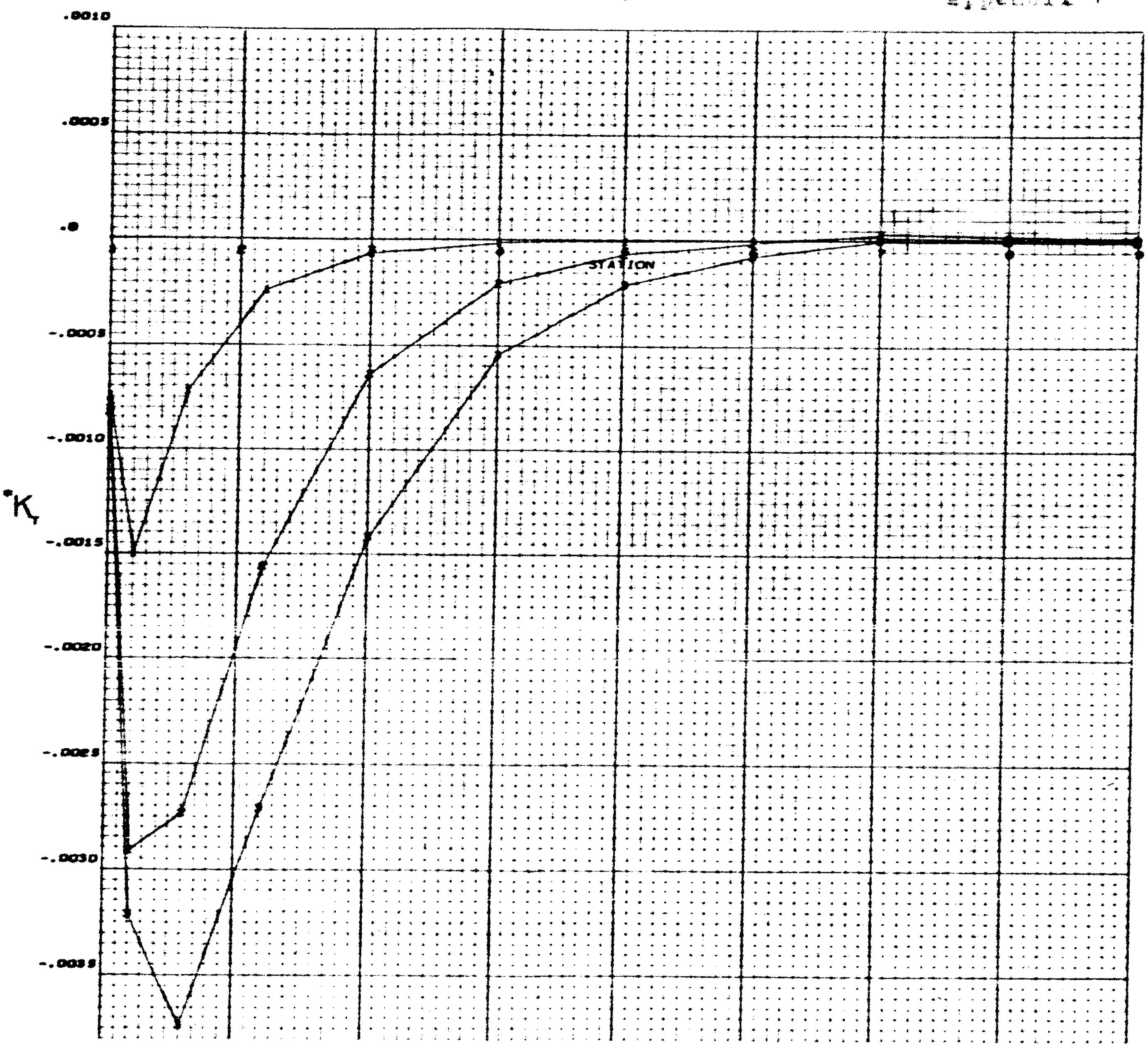
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

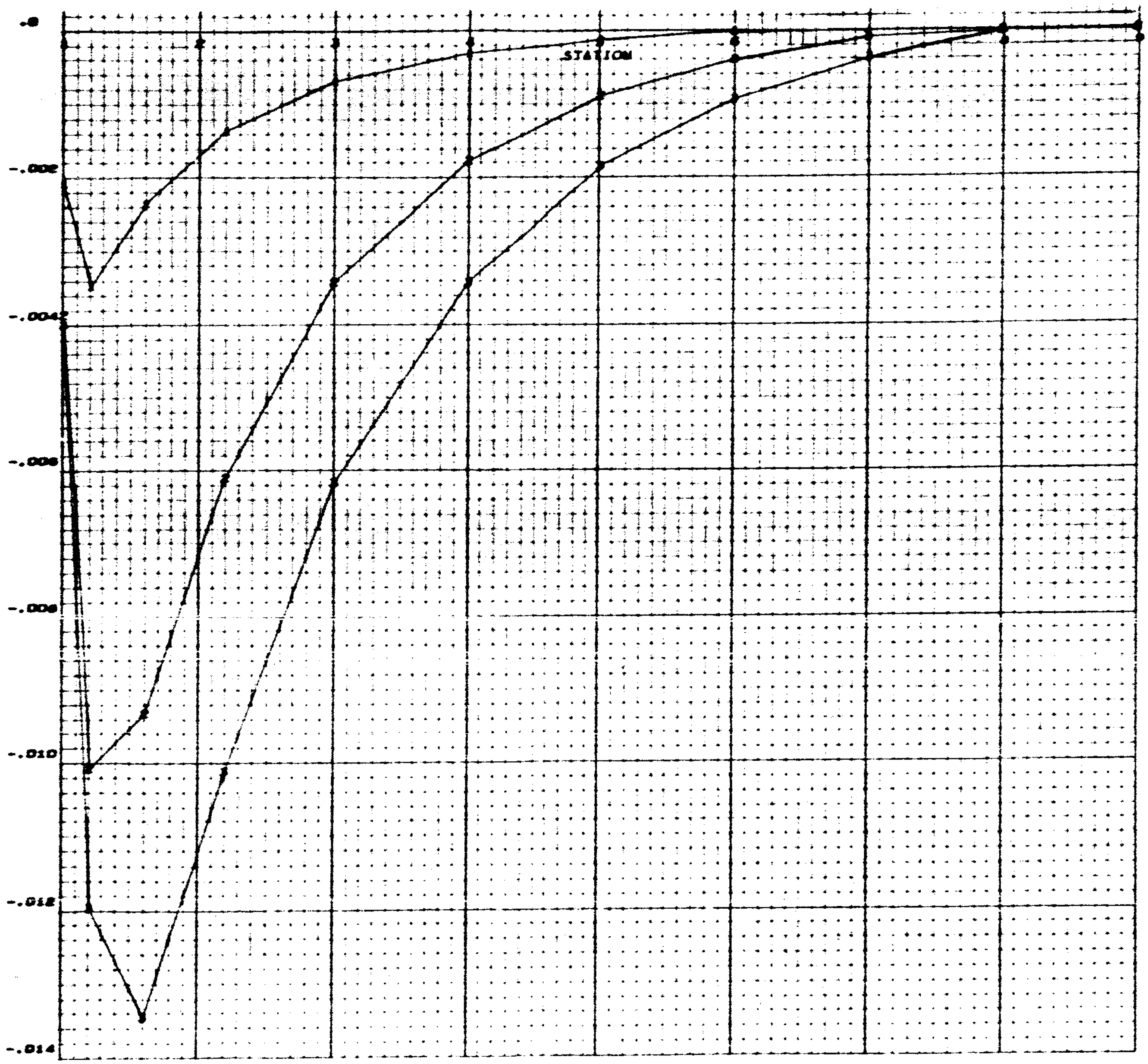
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

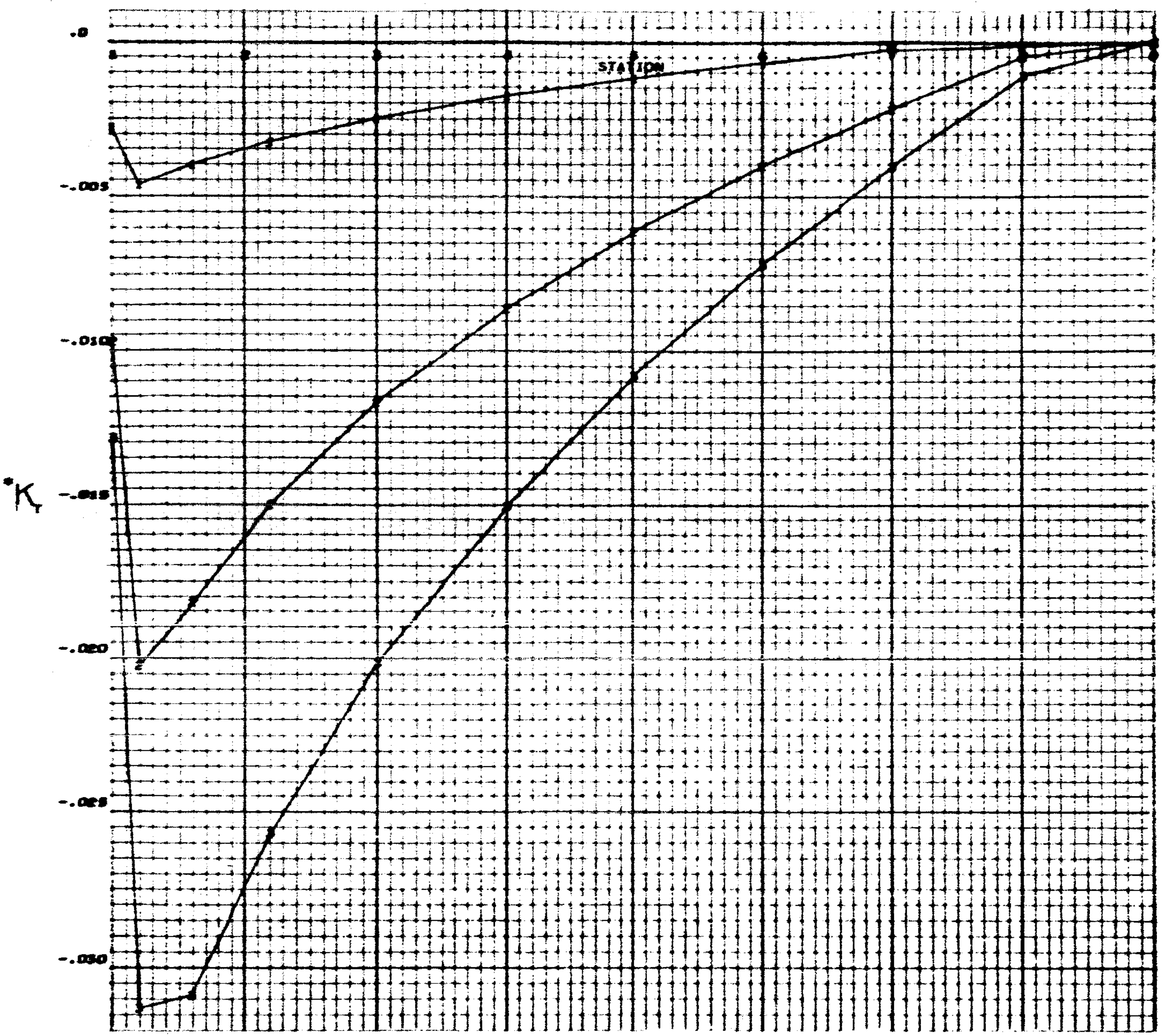
UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

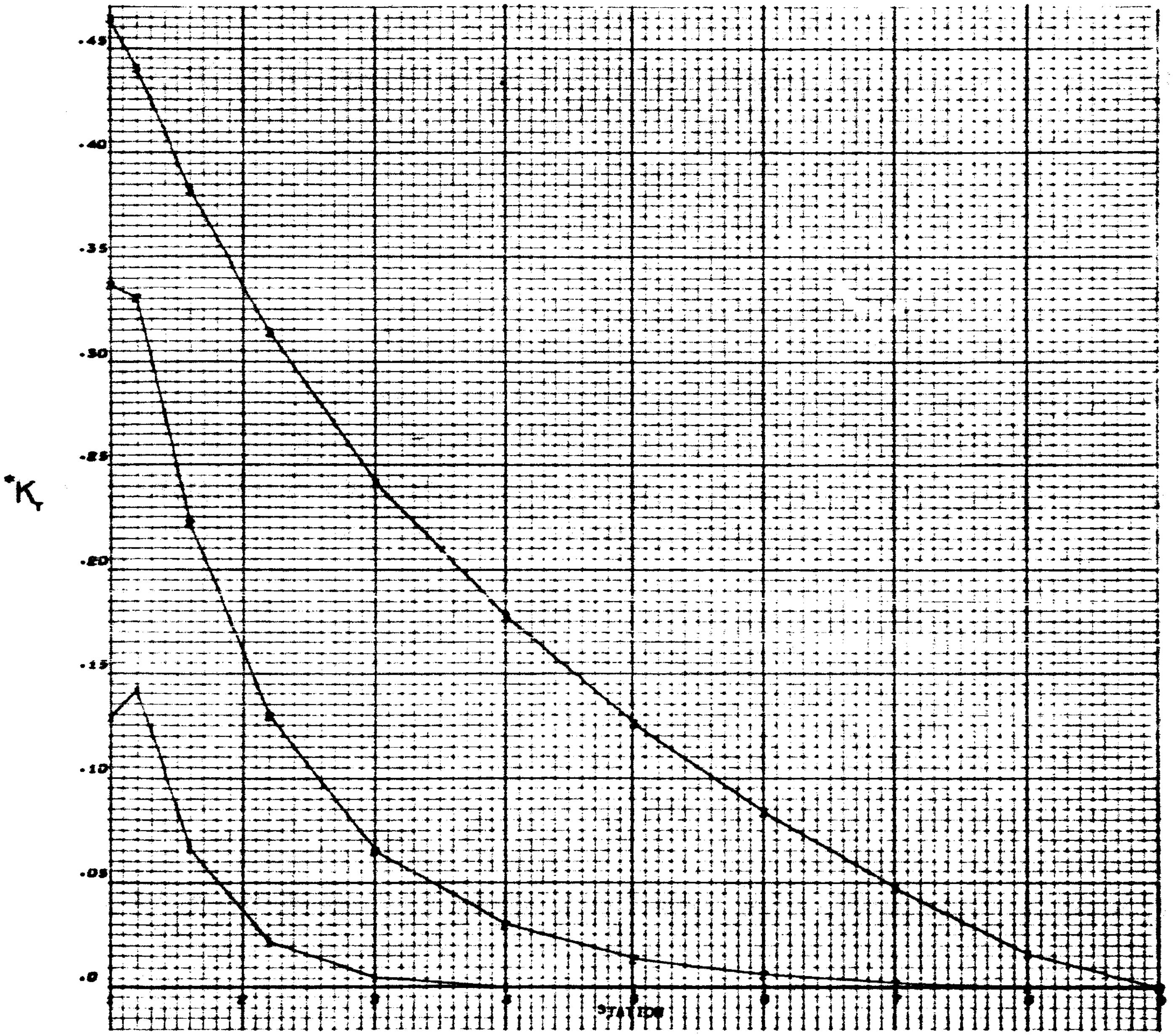
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T R

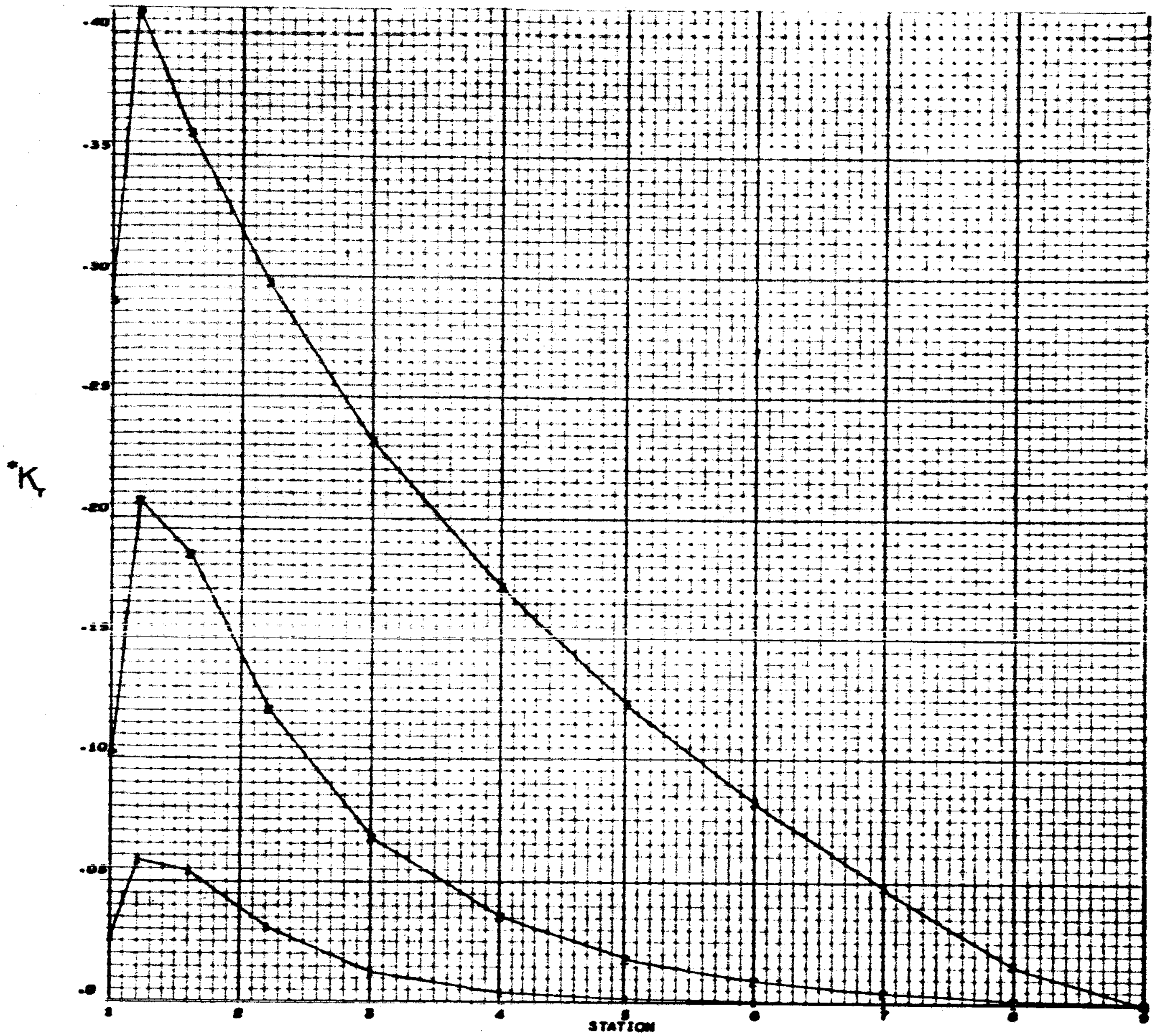
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

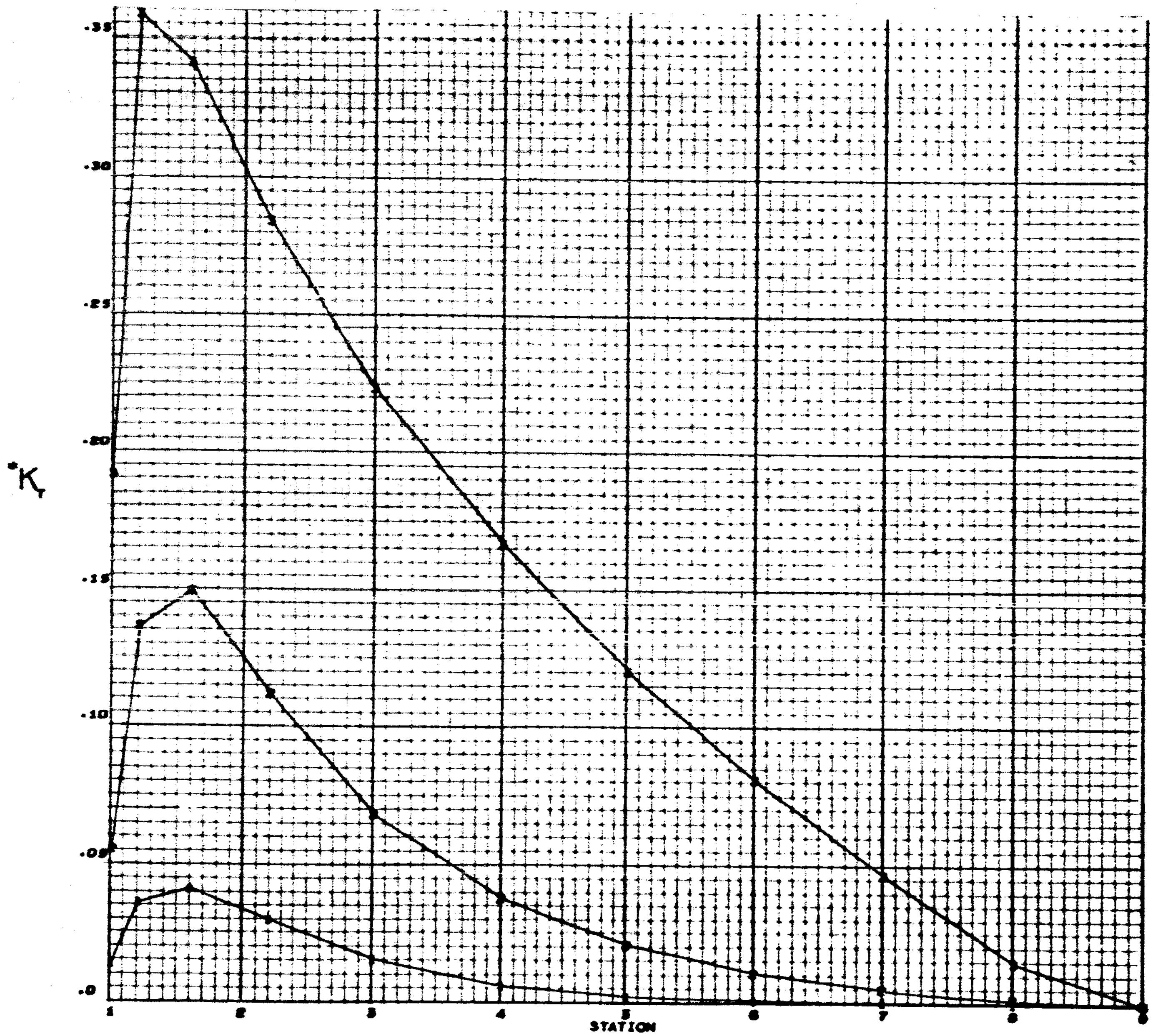
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

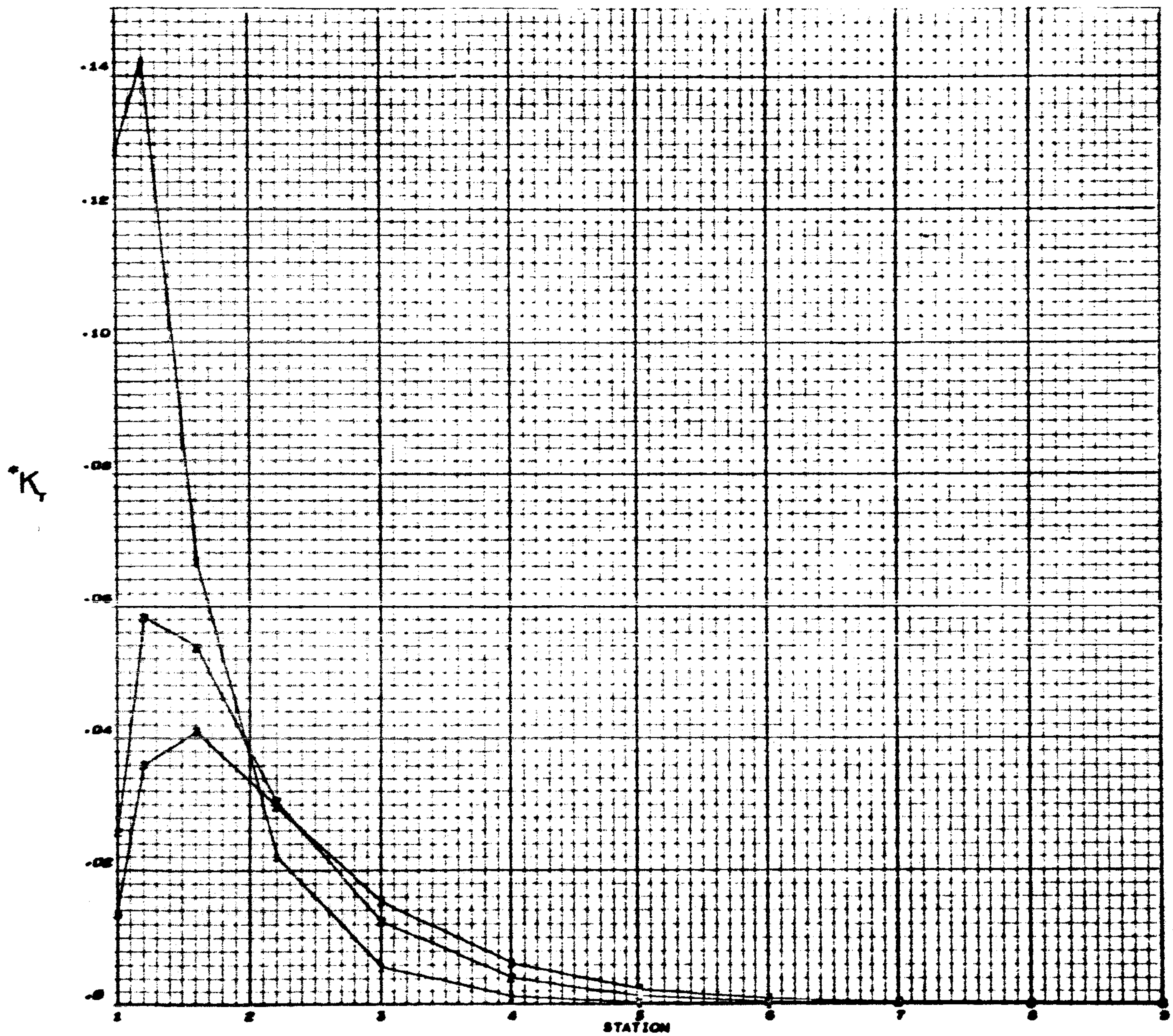
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EA
1	0.02
2	0.20
3	2.00

*NOTE. INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

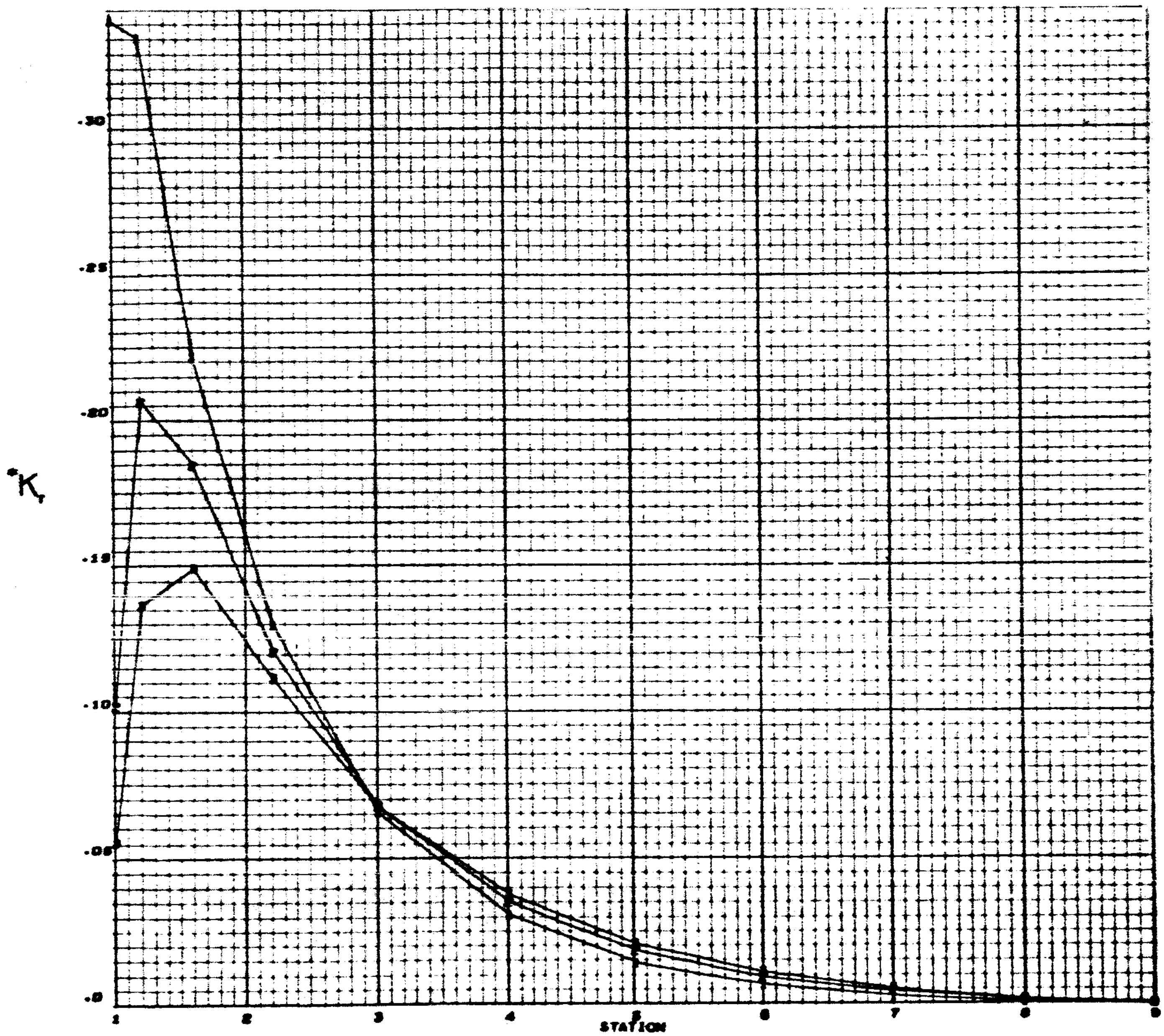
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

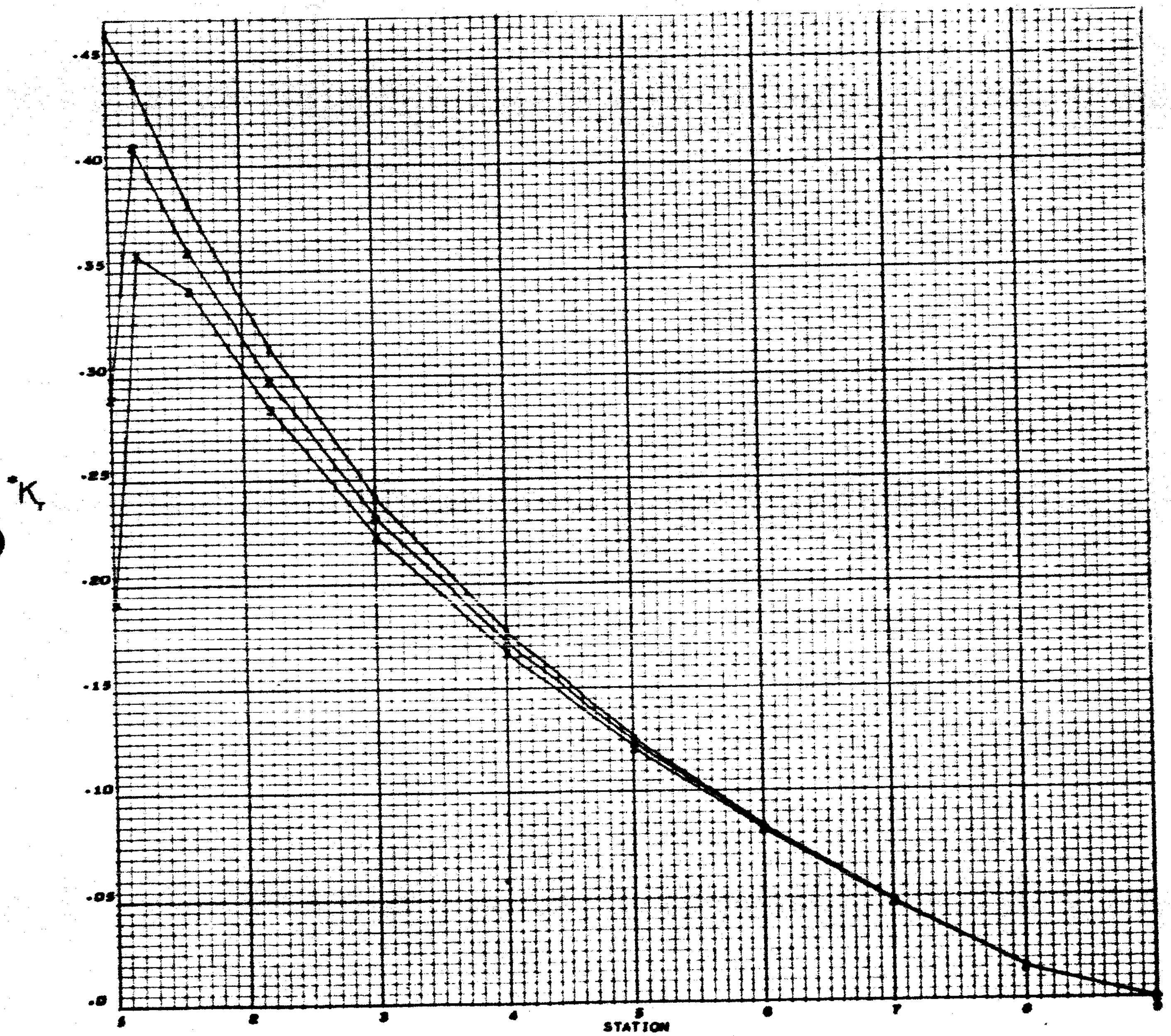


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

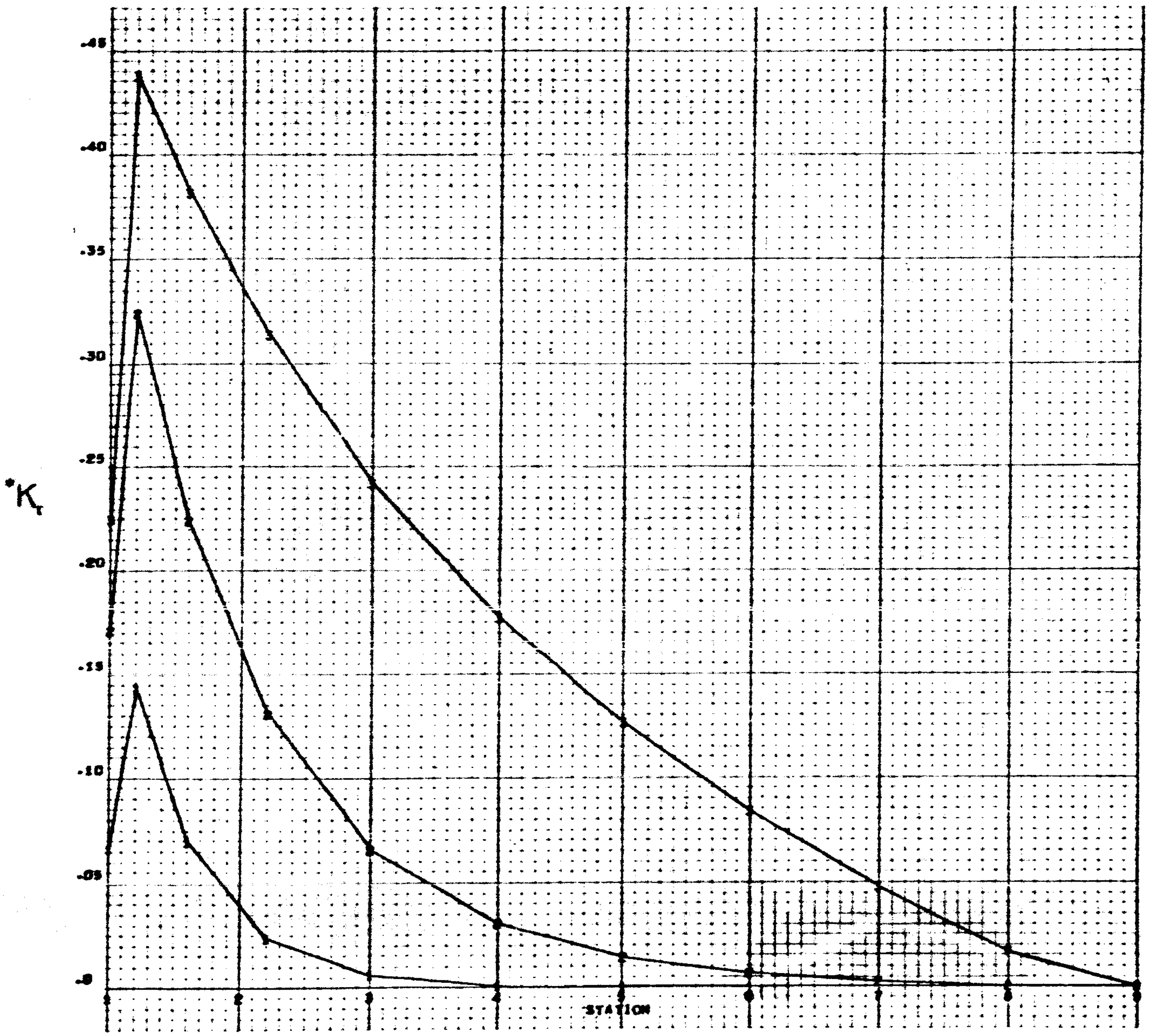
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

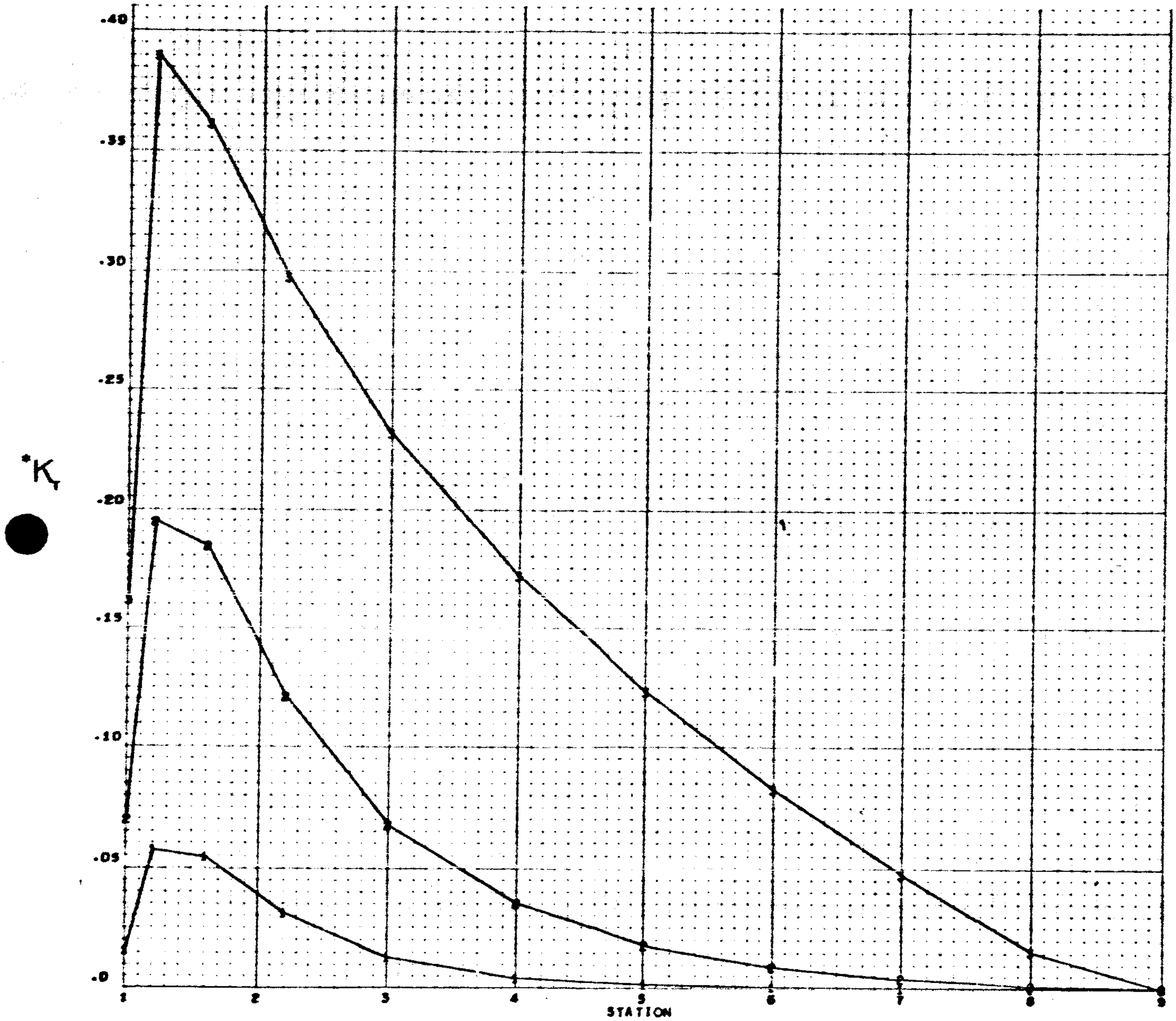
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

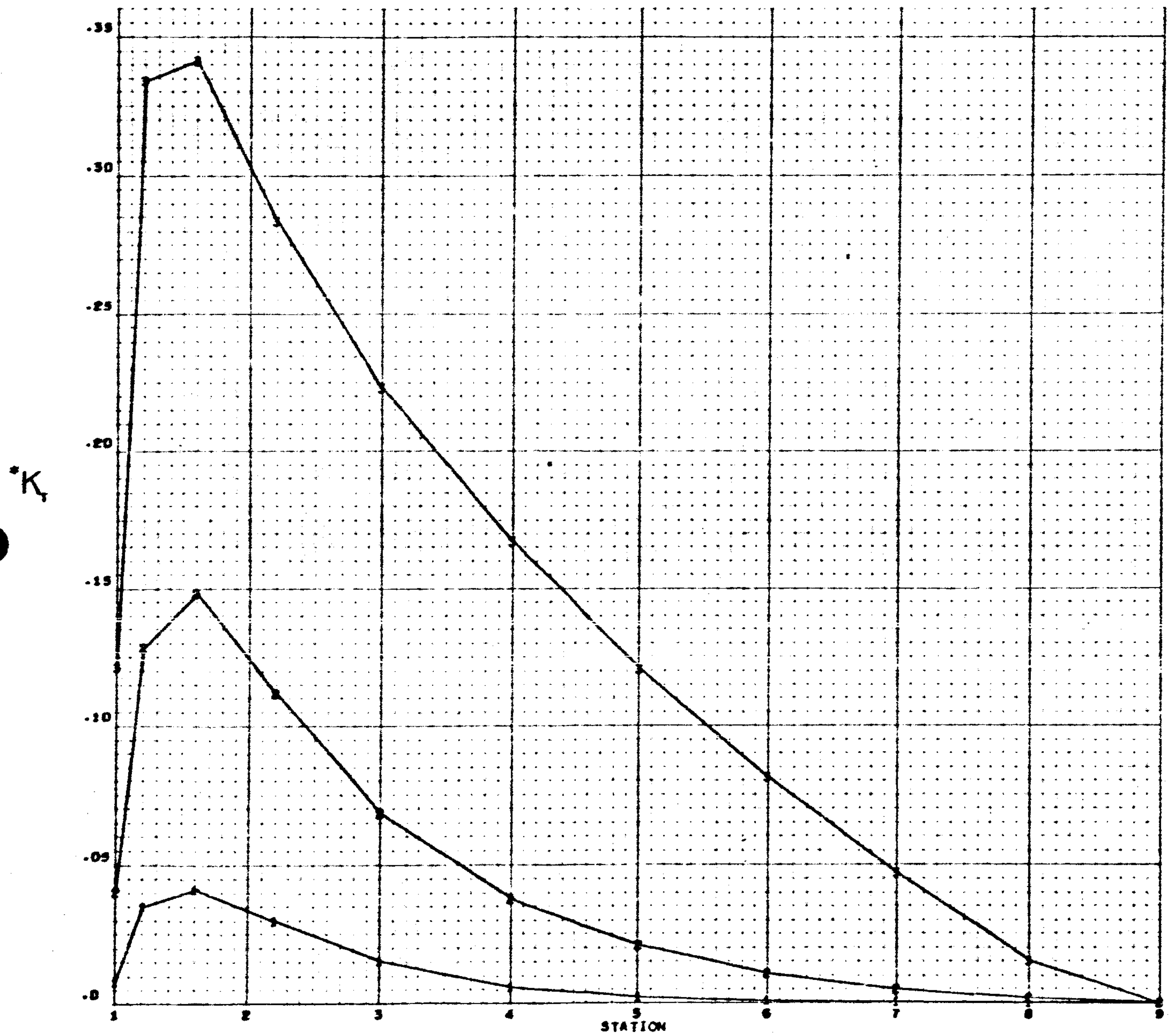
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

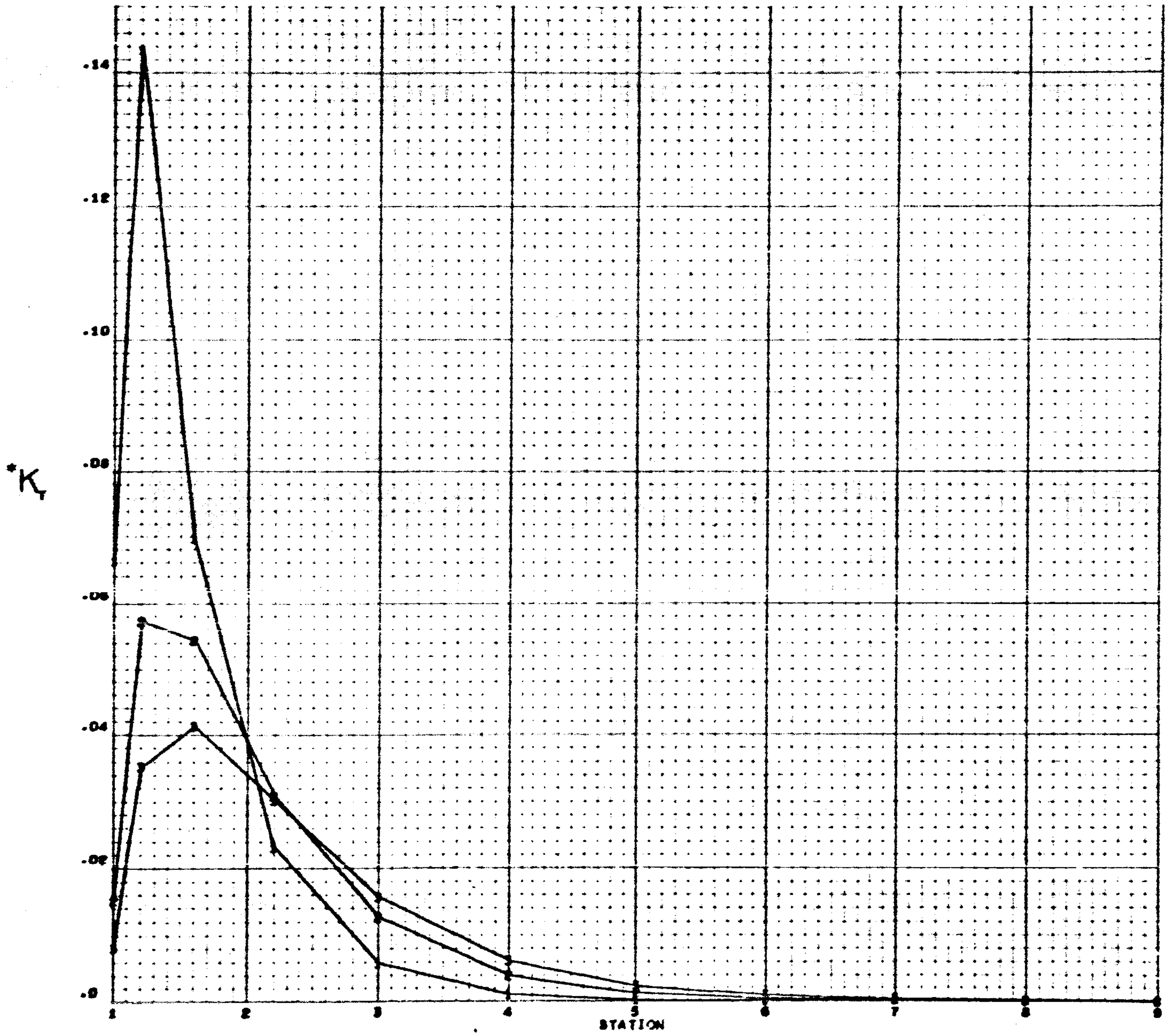
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

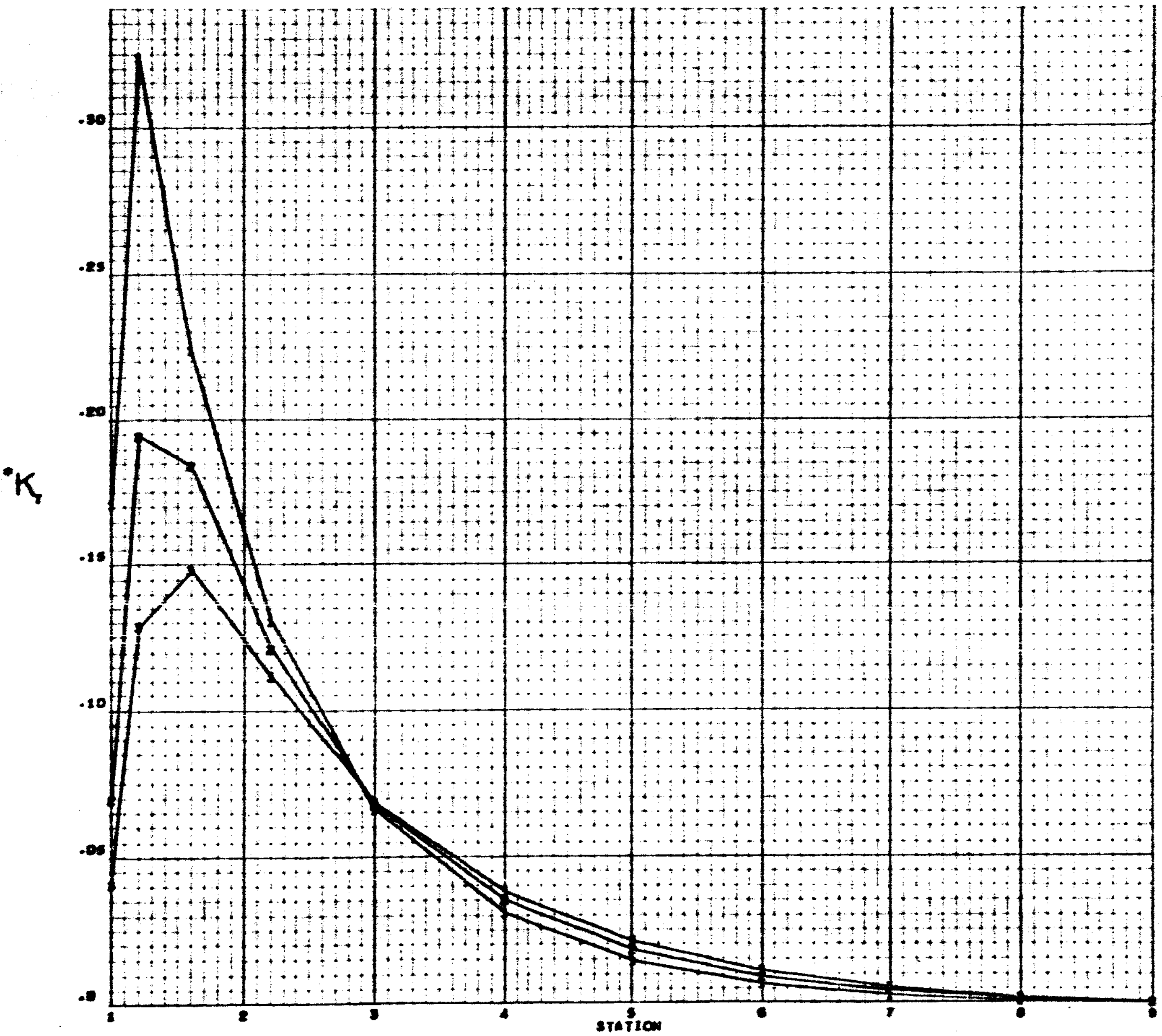
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

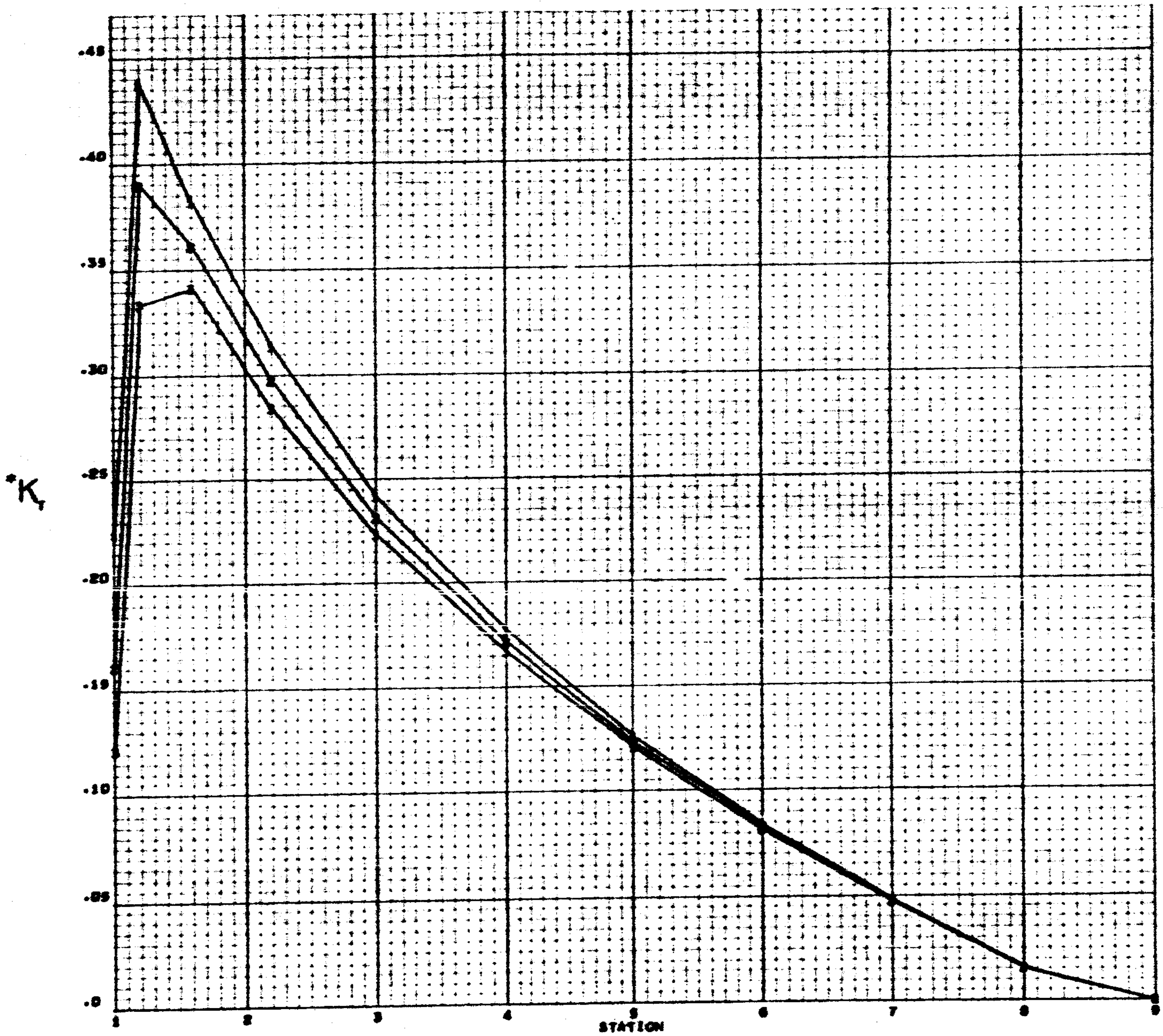
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

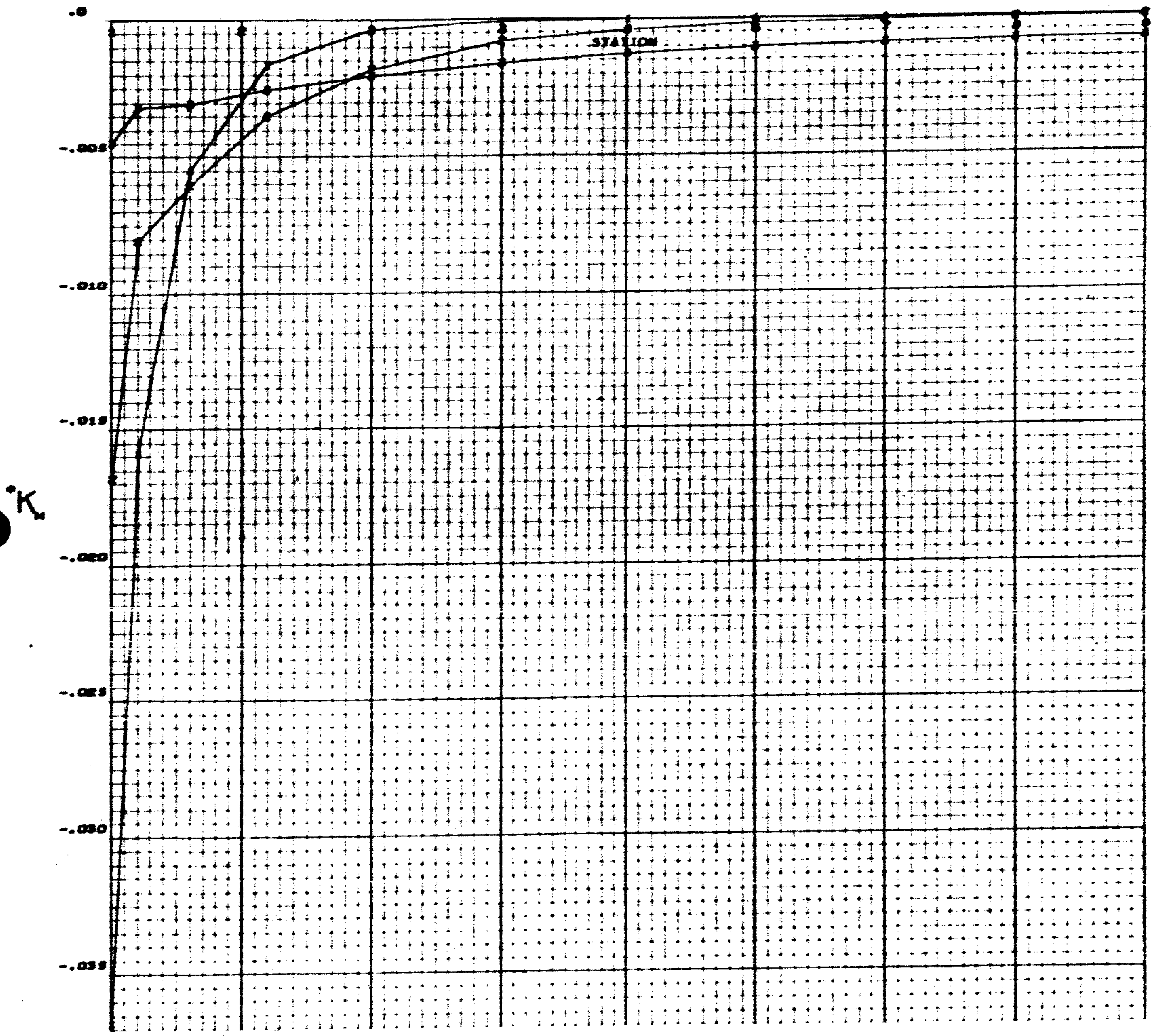
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

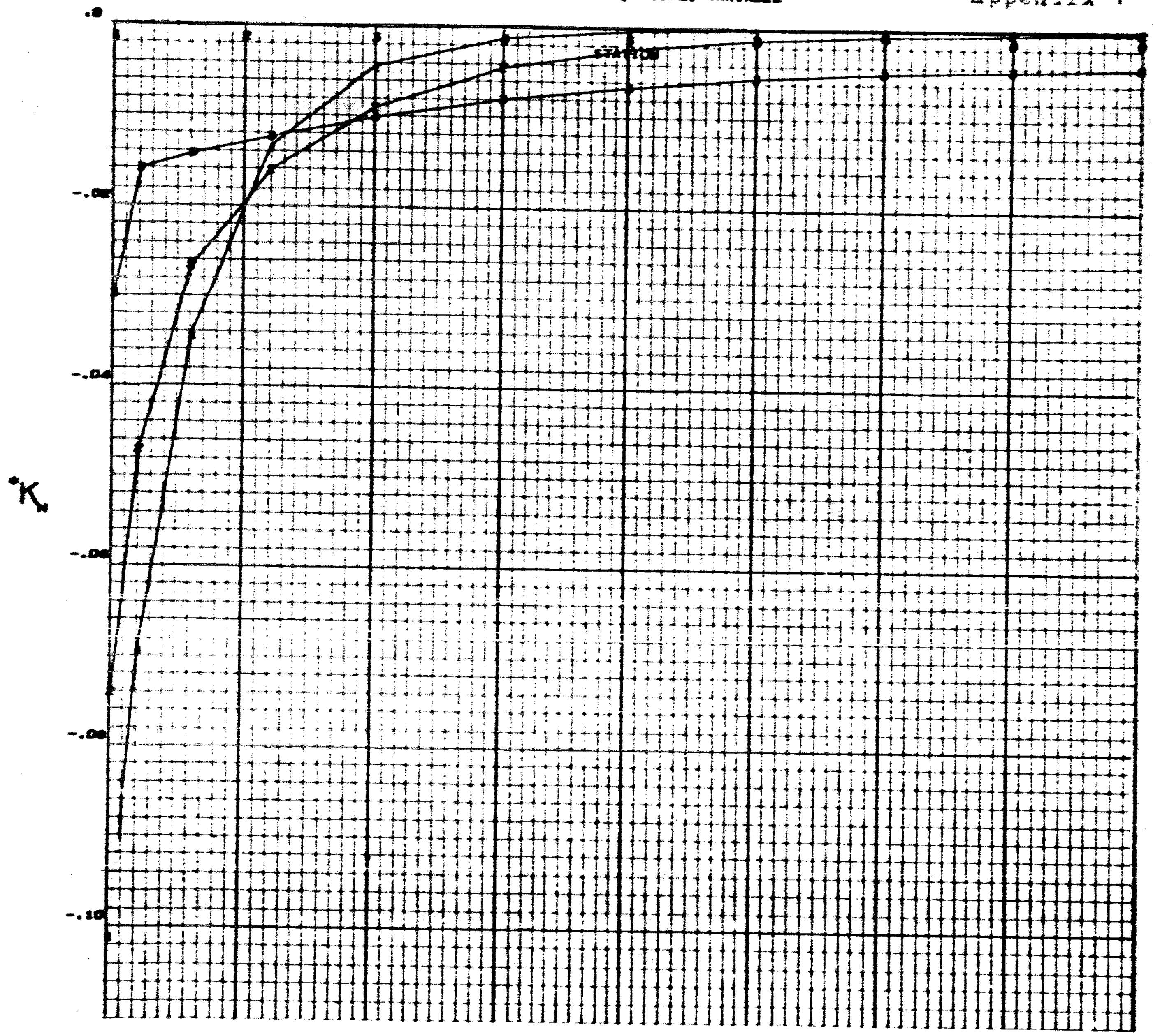
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

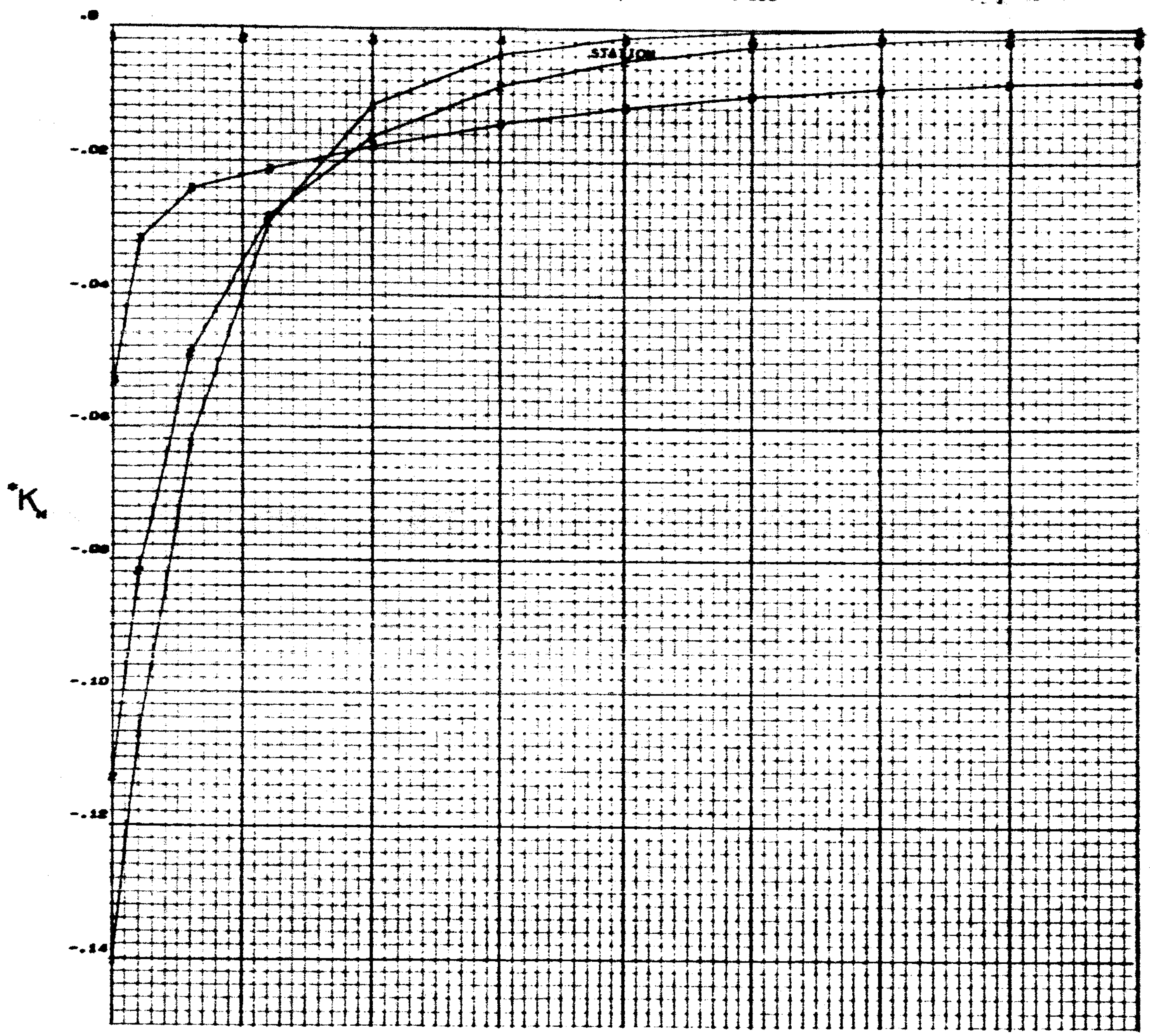
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

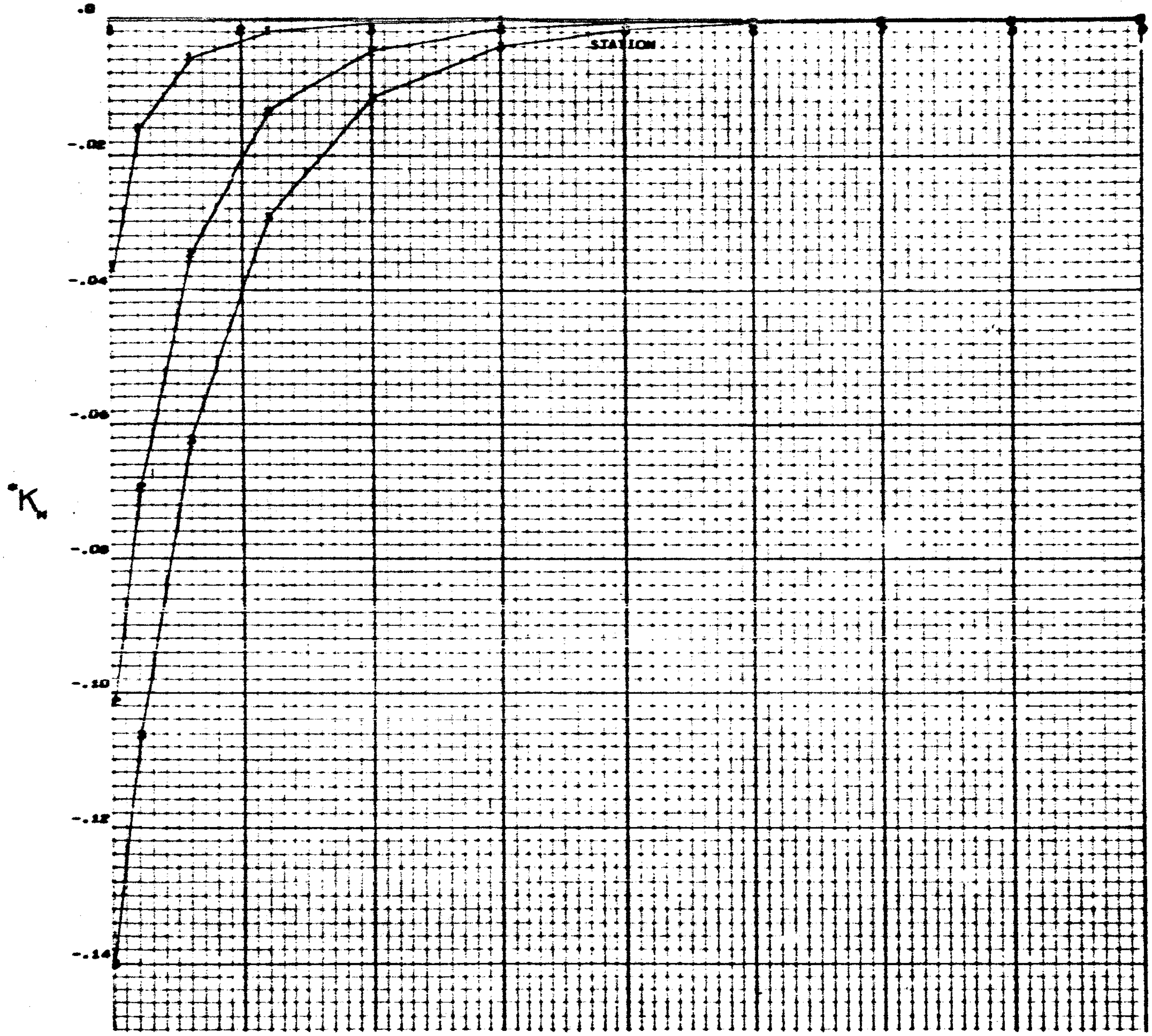
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

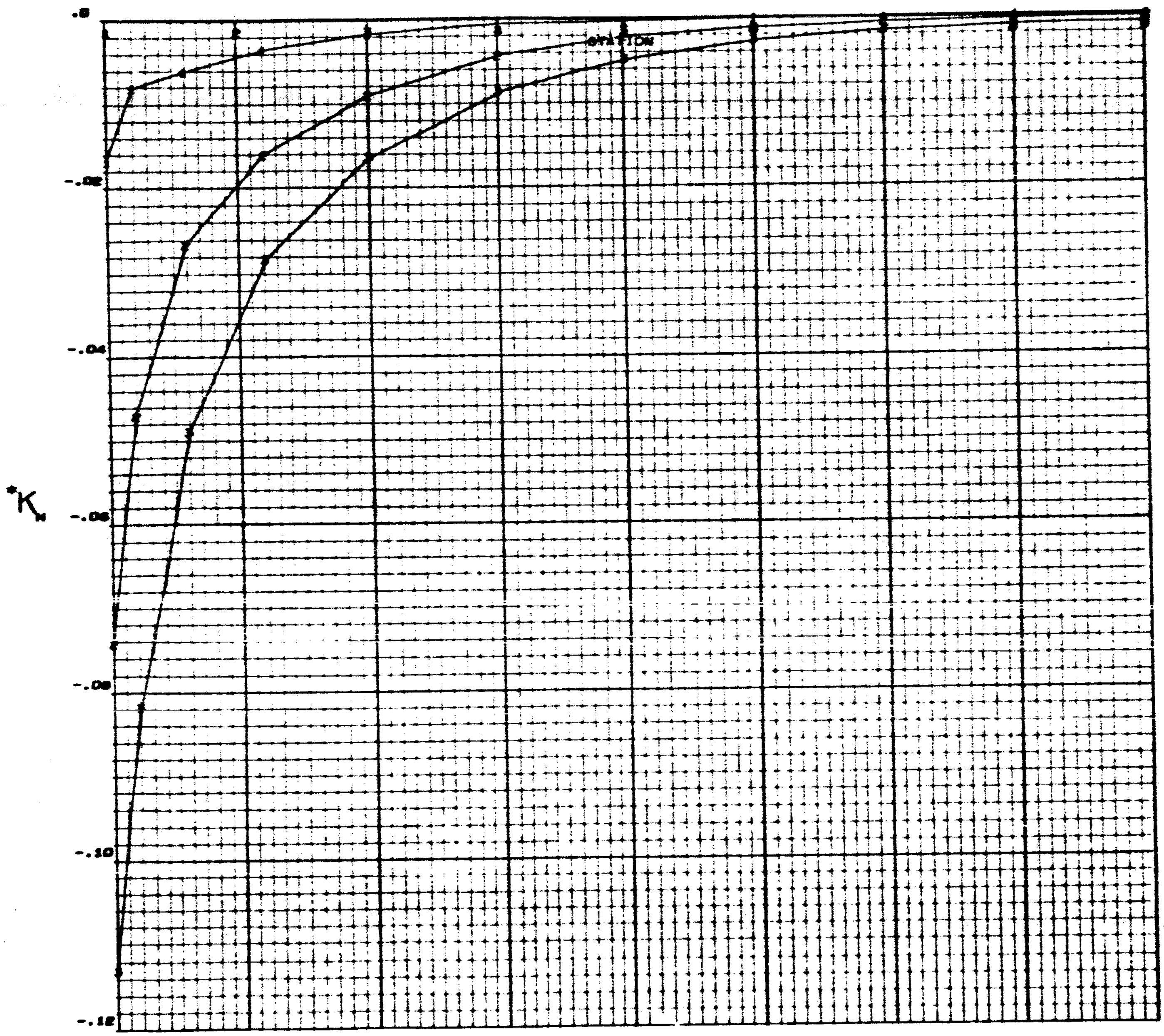


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

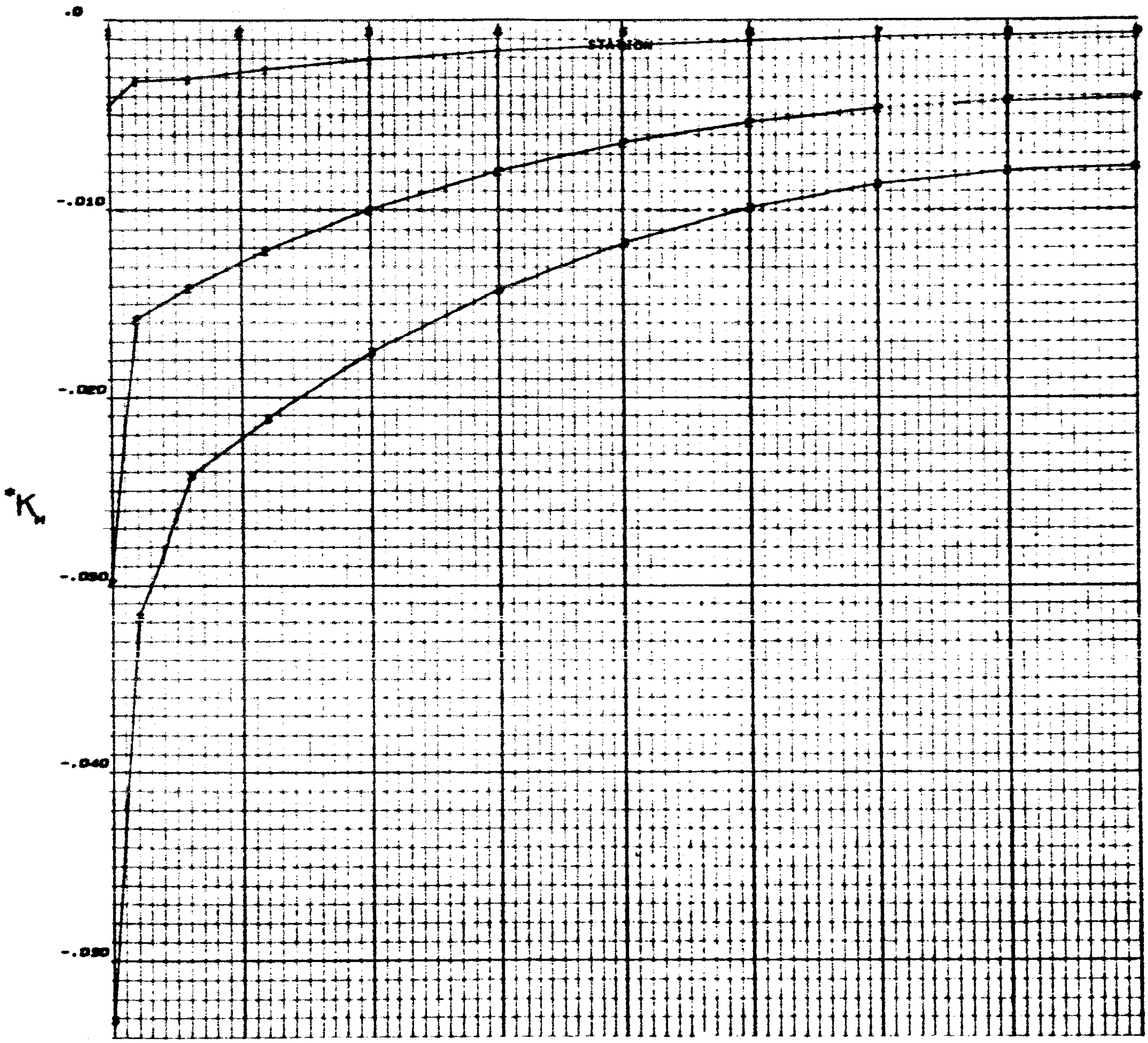
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

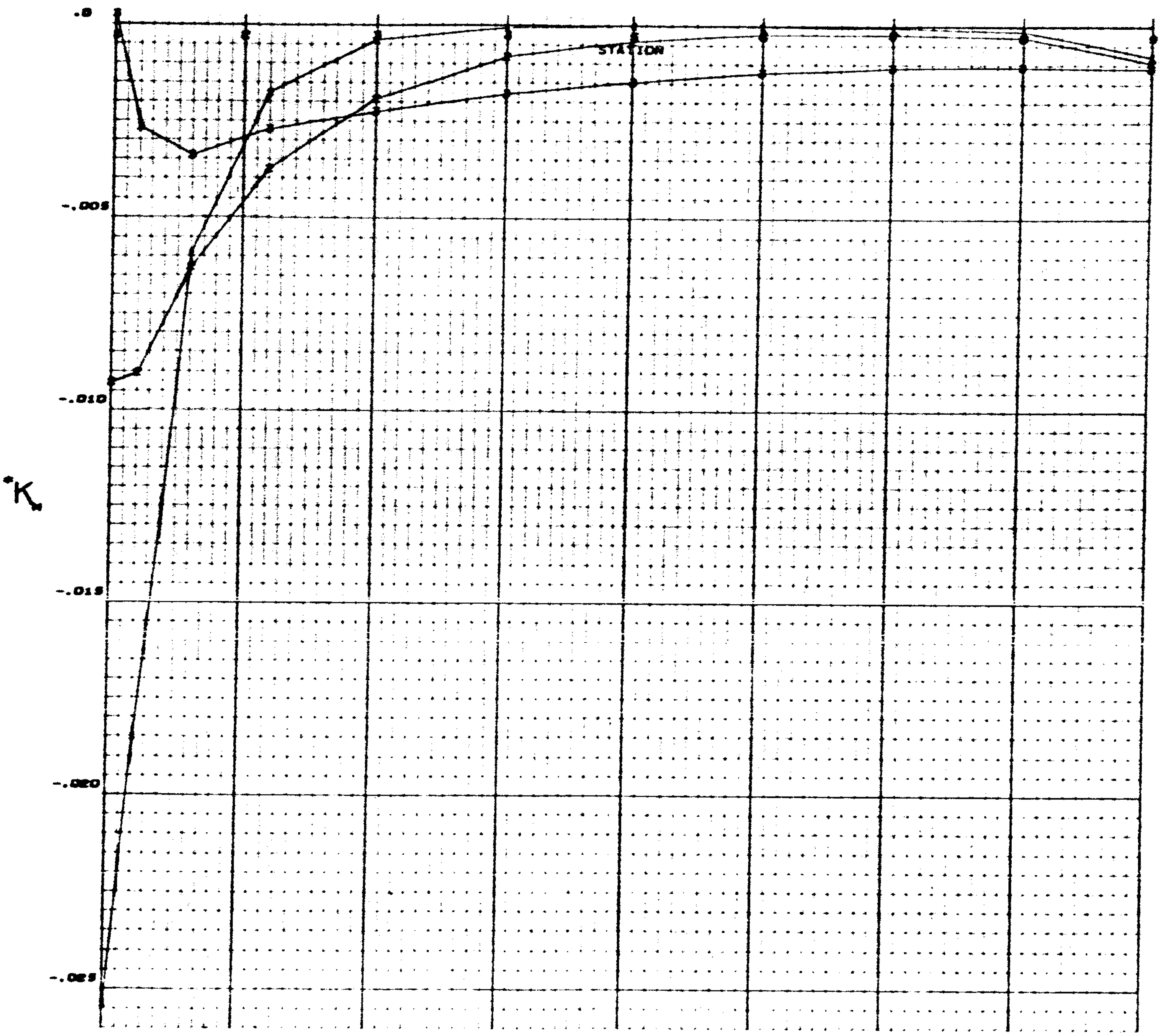


CURVE	C/R
1	0.01
2	0.02
3	0.05

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE

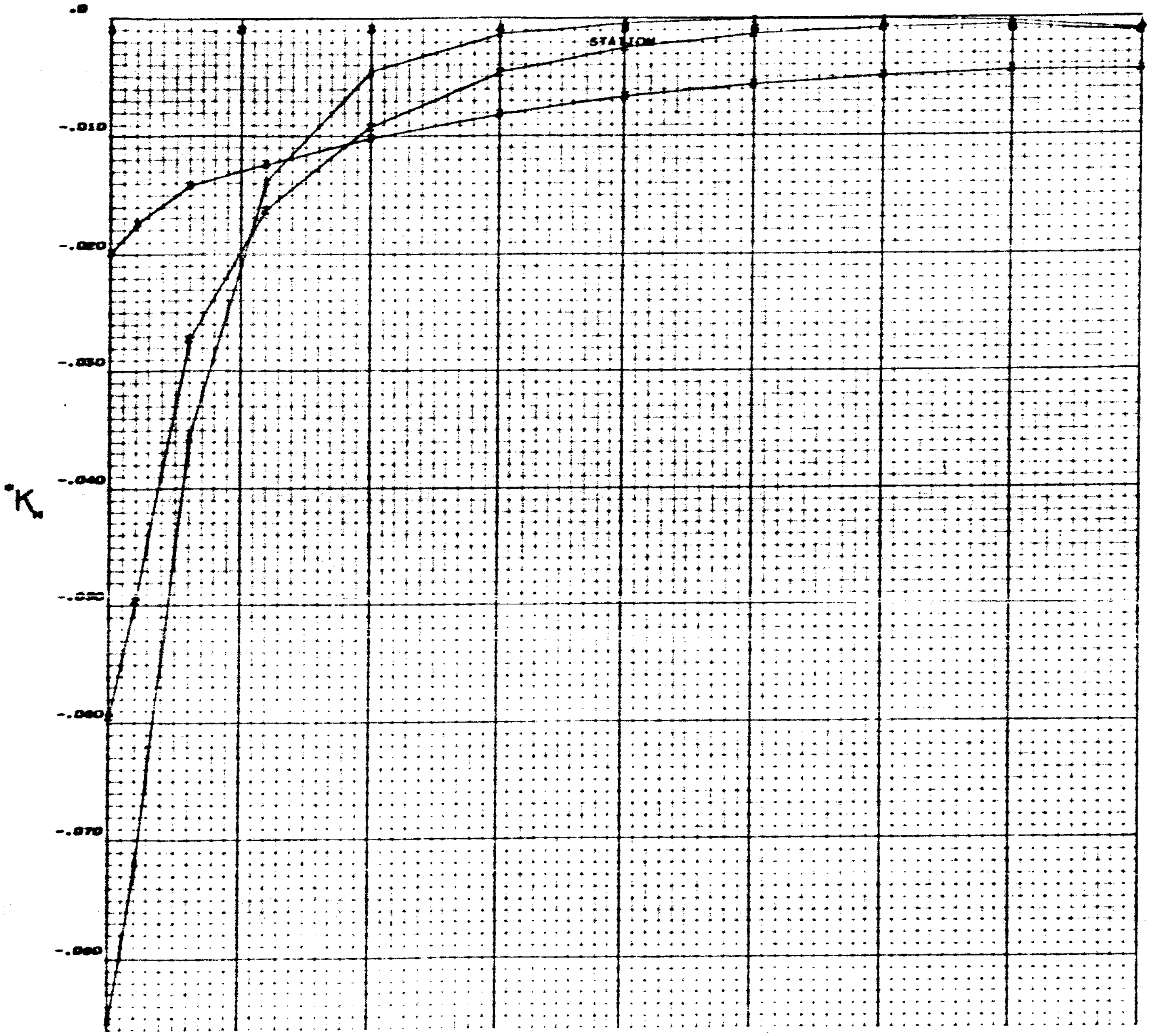


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE

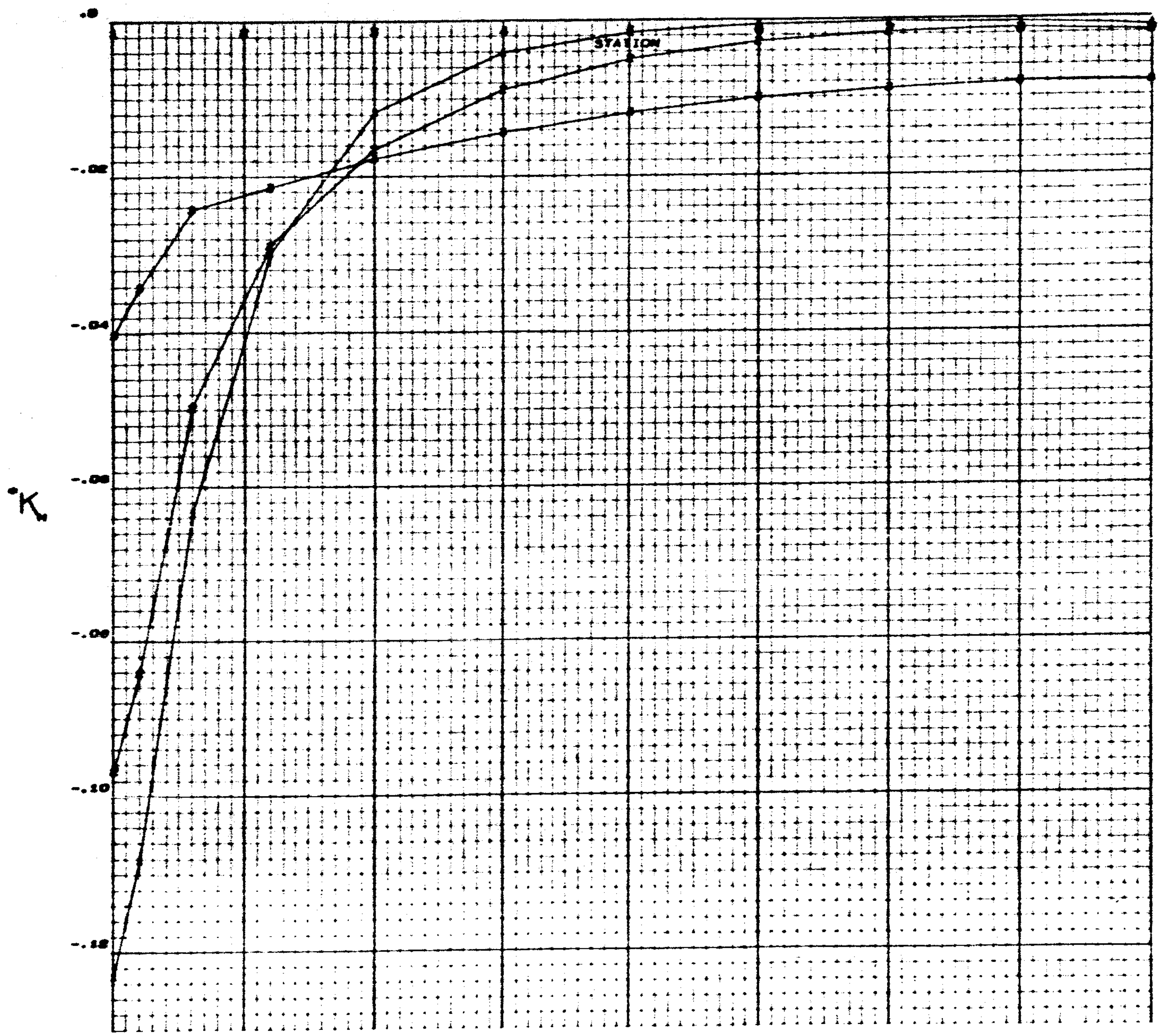


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
M. INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

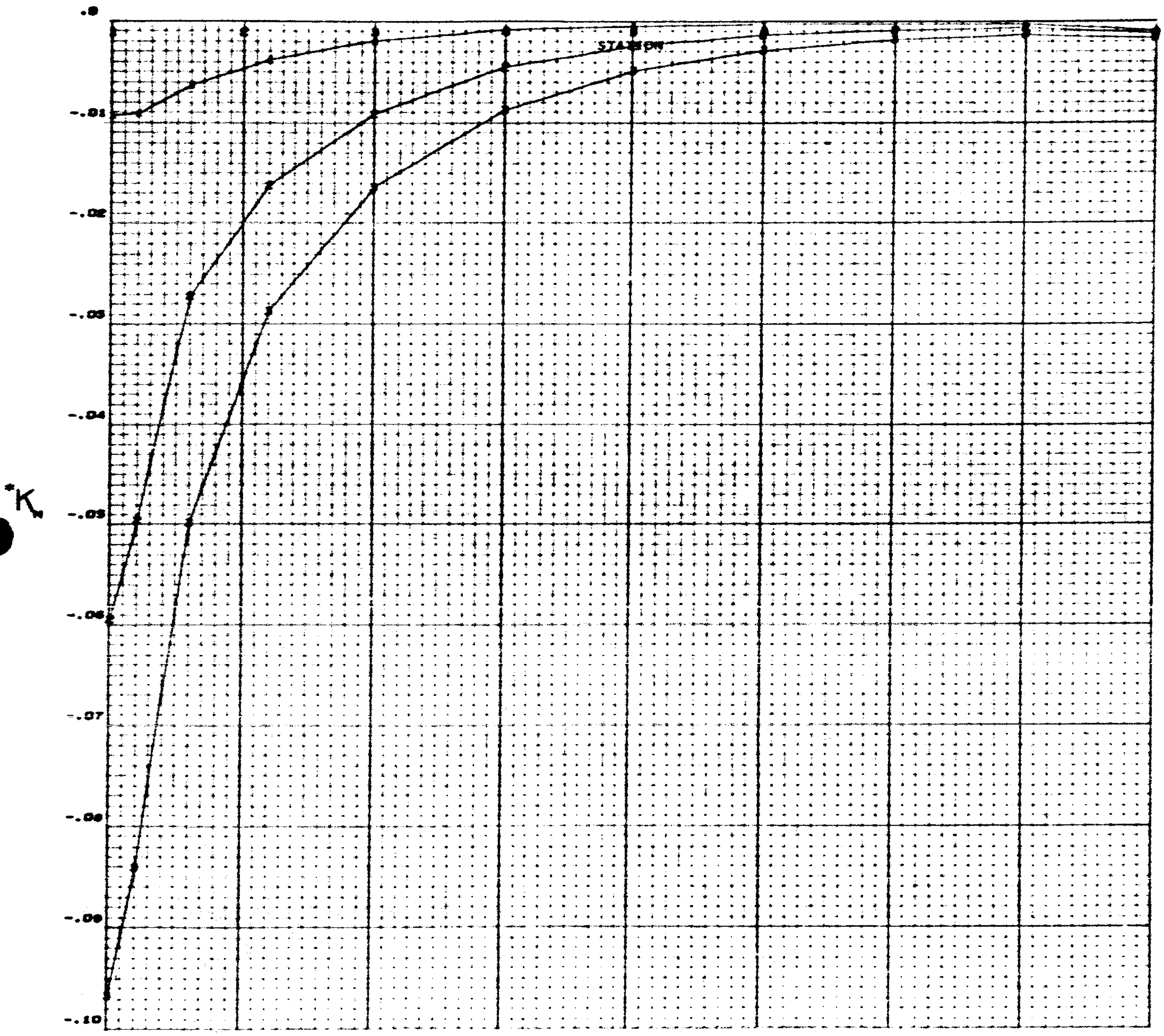
*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS. $M = K_M R$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS. $M = K_M R$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

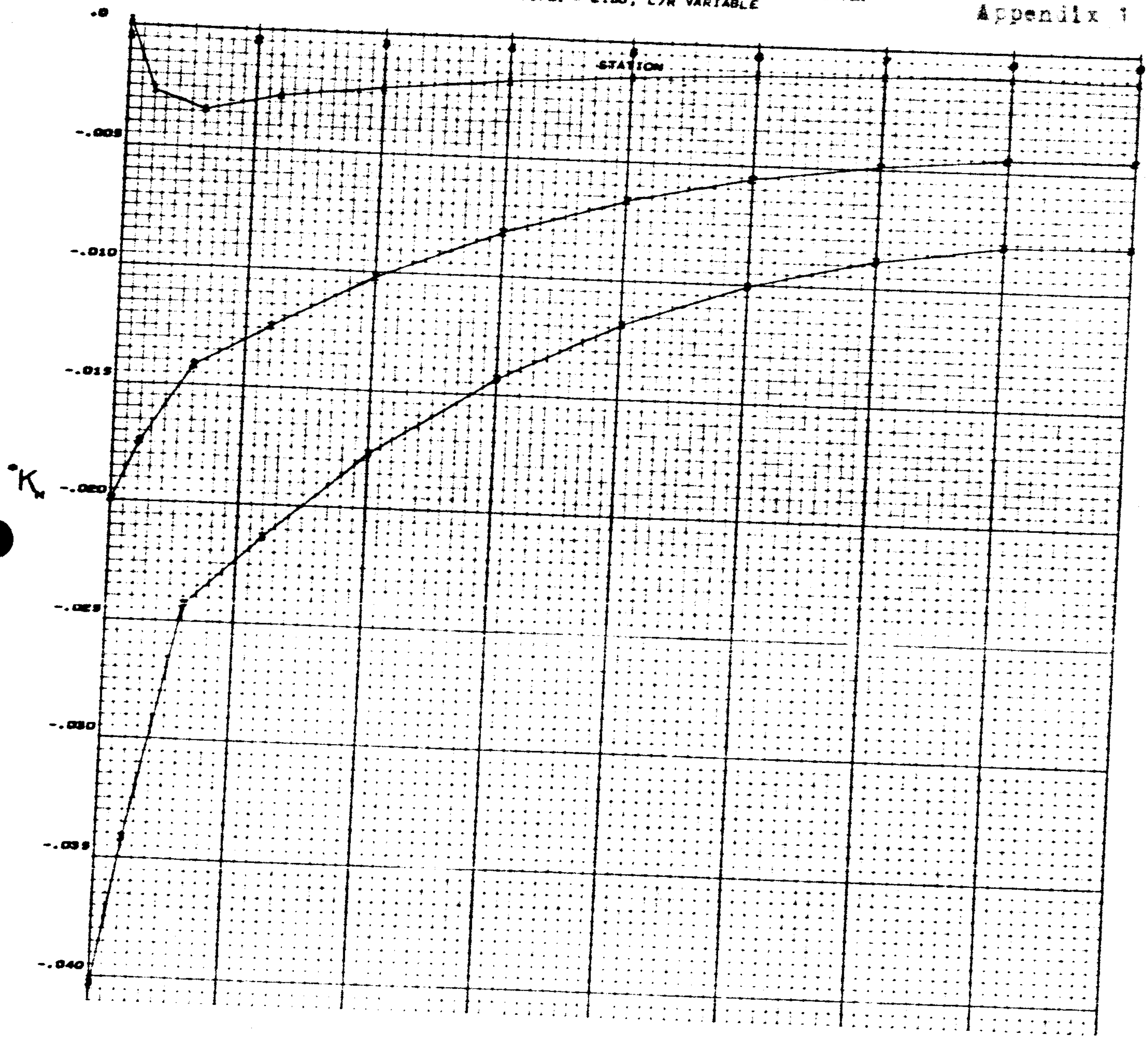


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

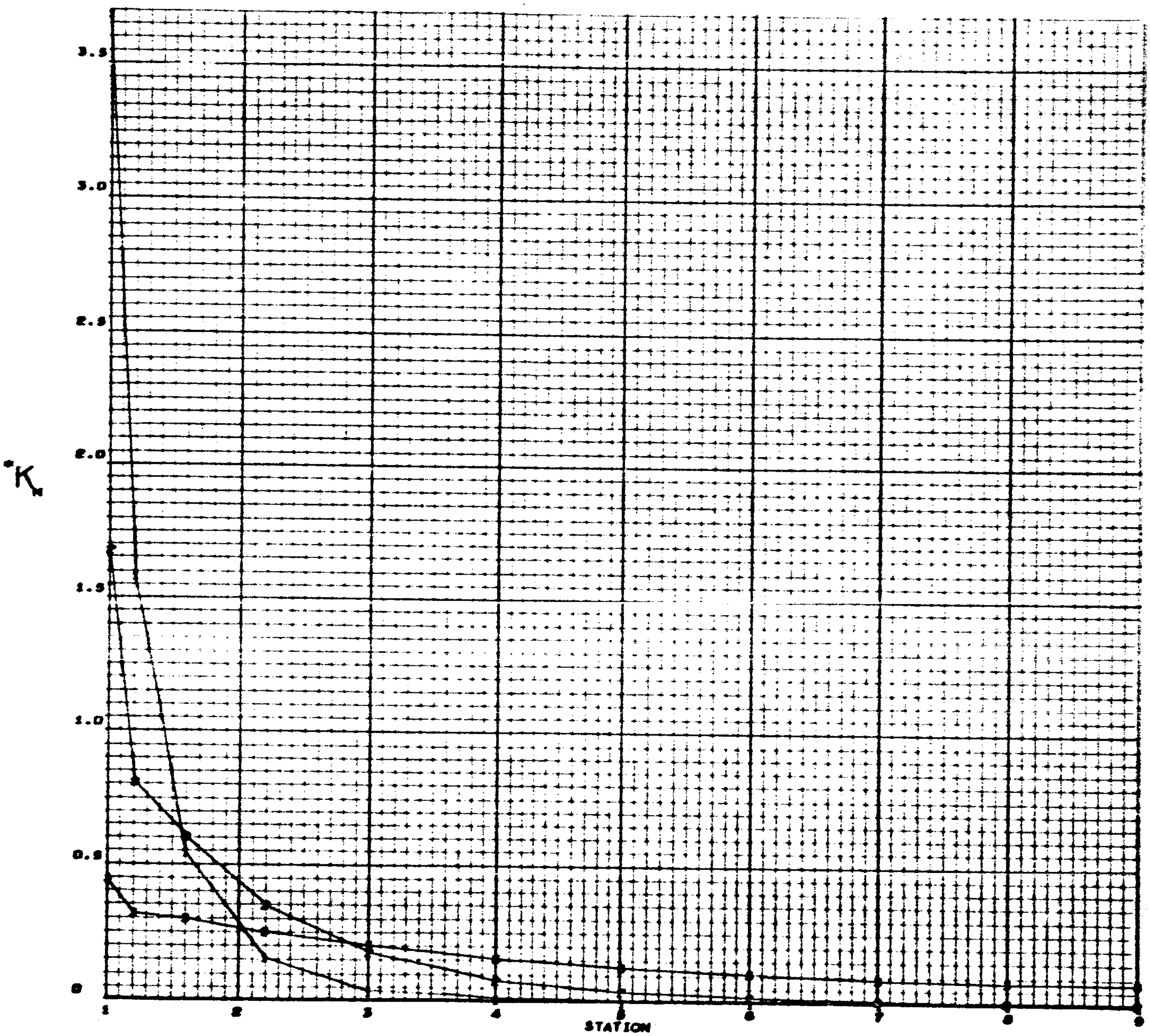
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

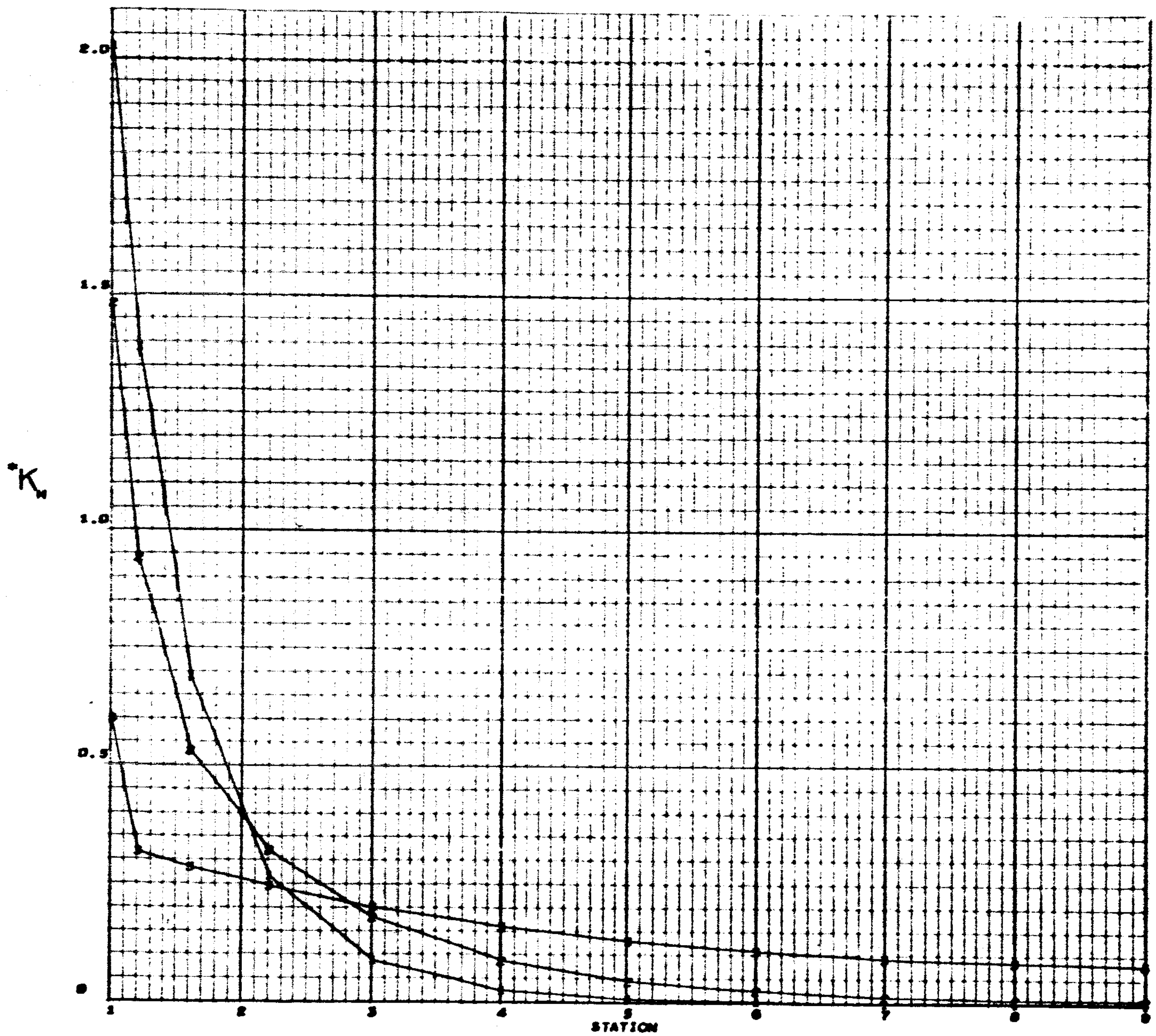
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

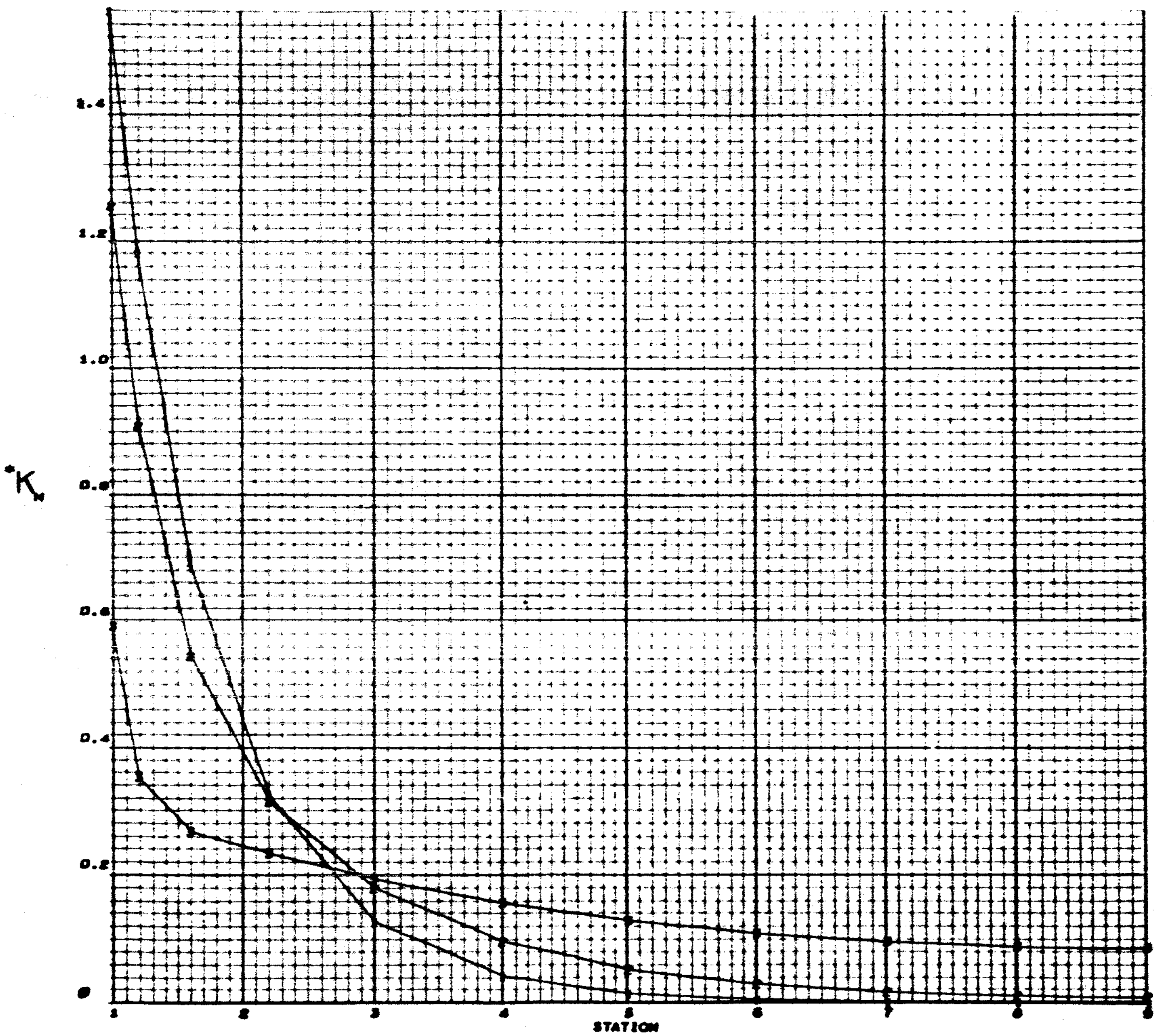
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.08
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

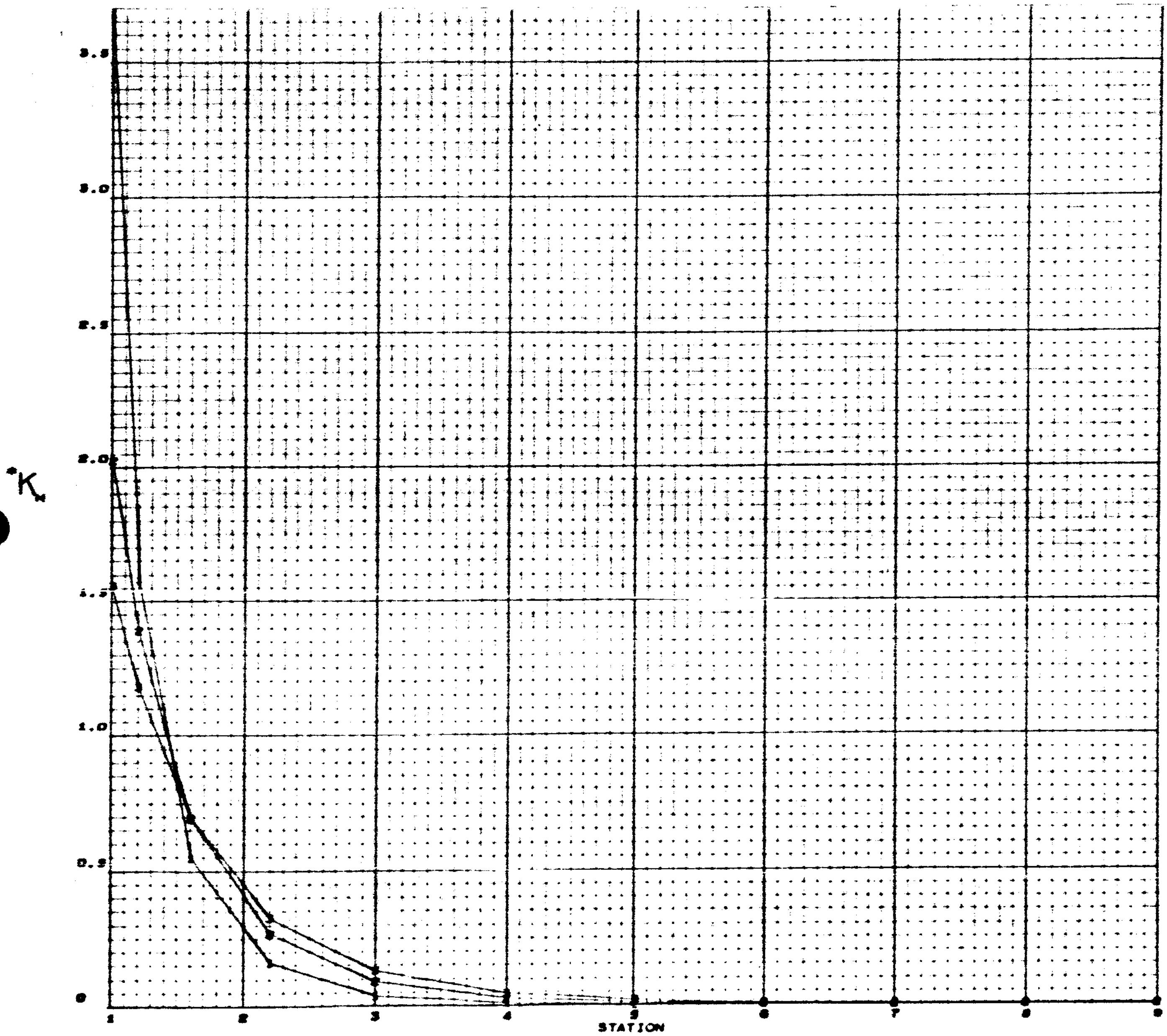
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_N$

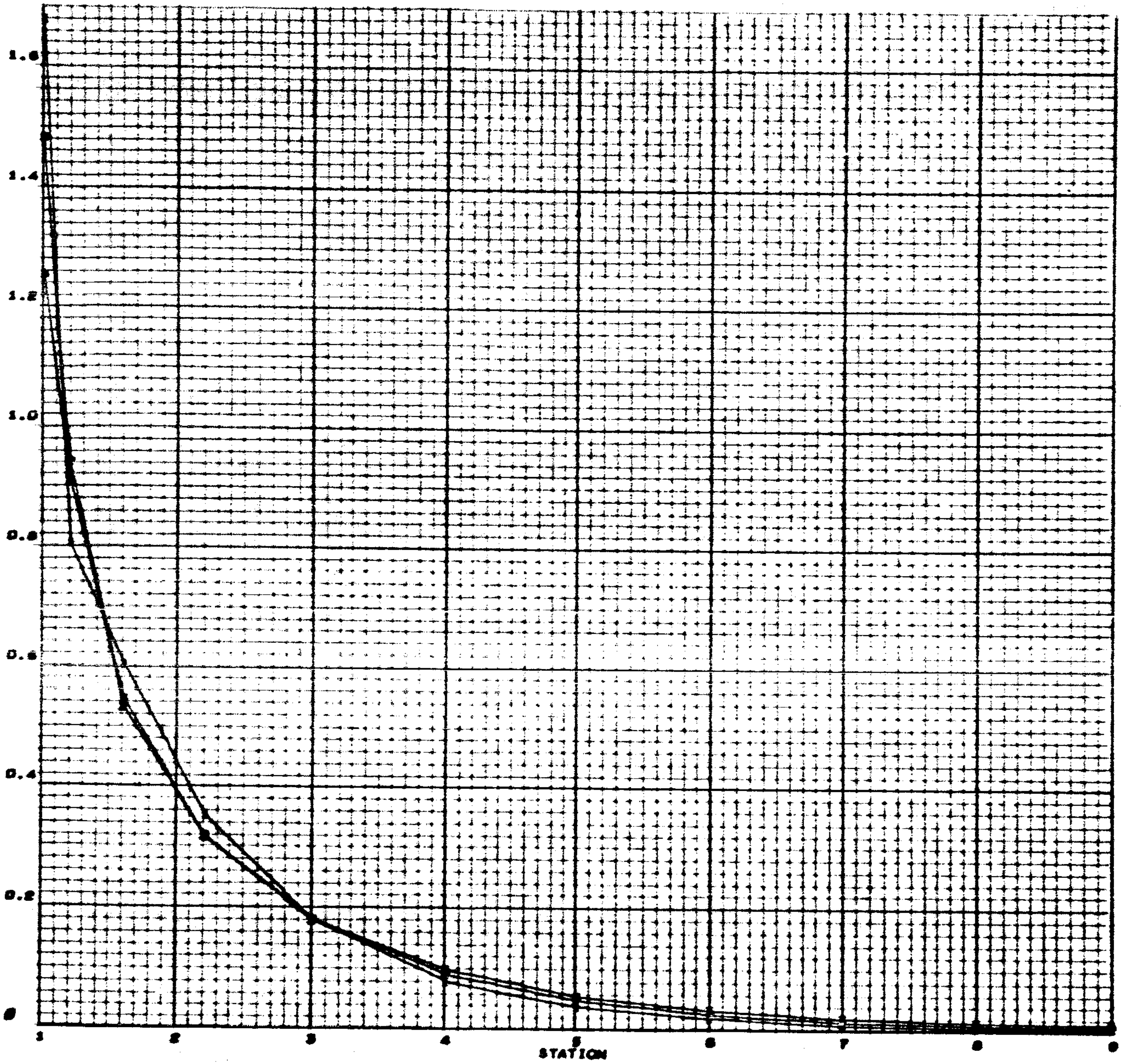
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

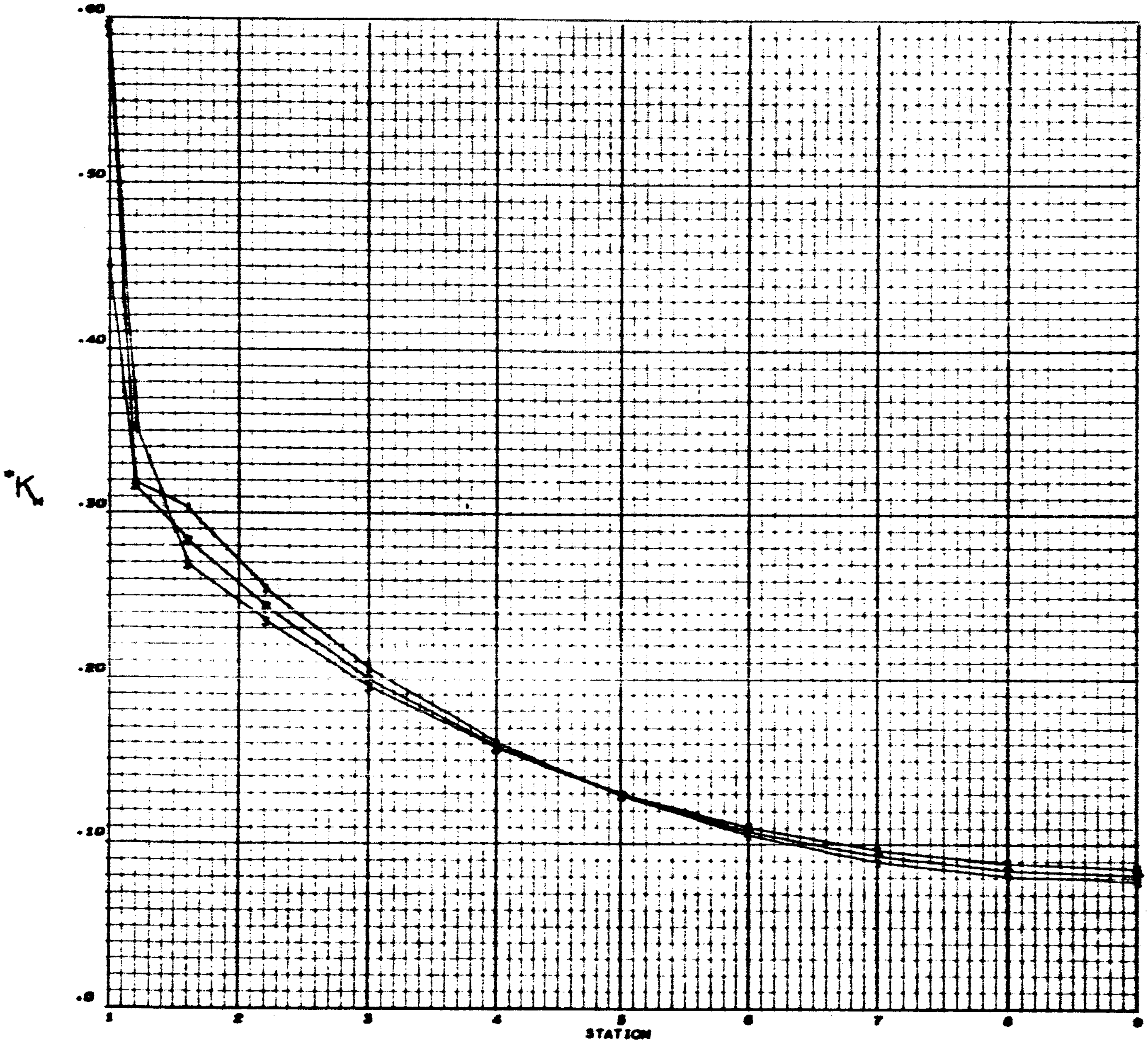
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

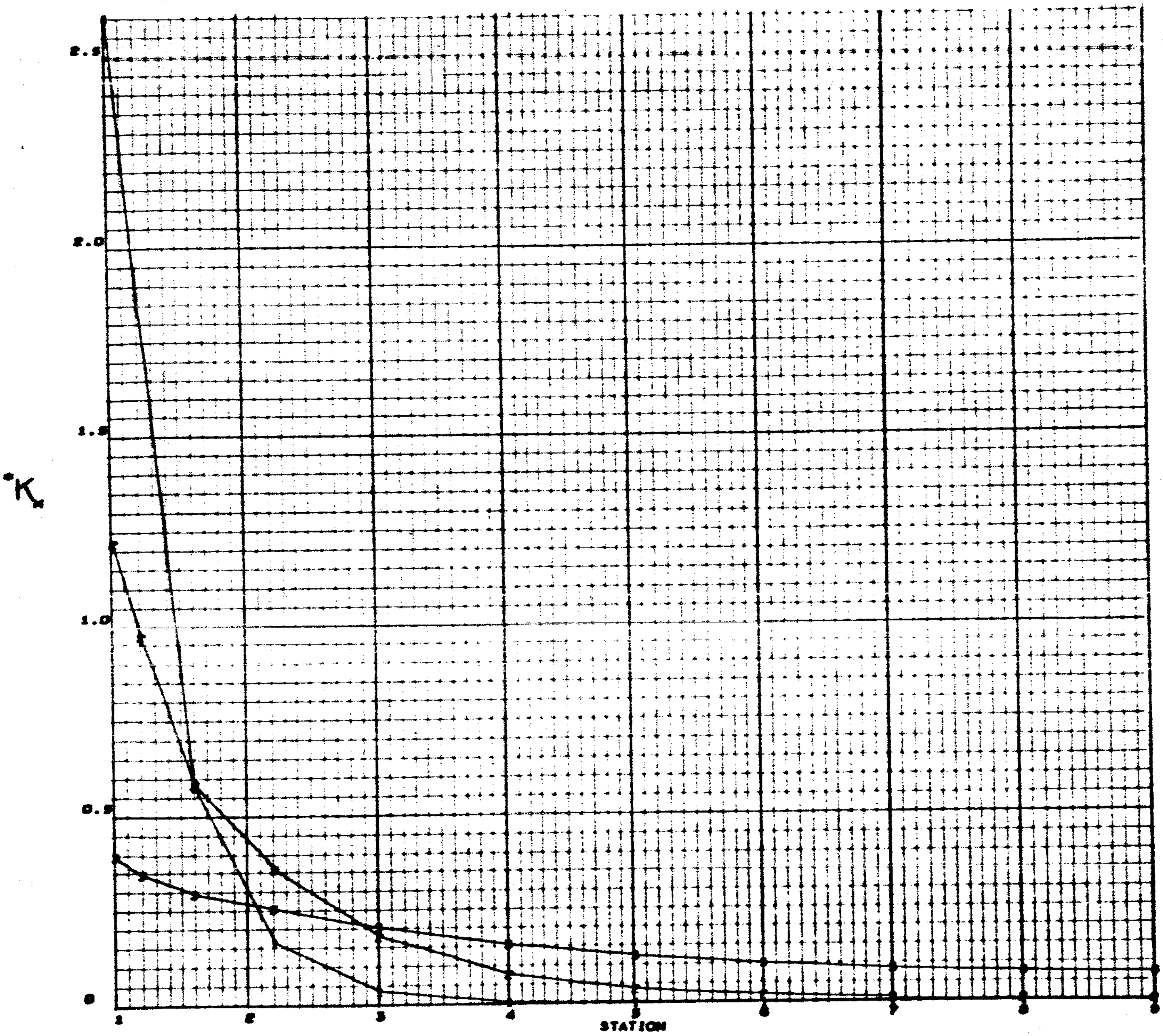


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

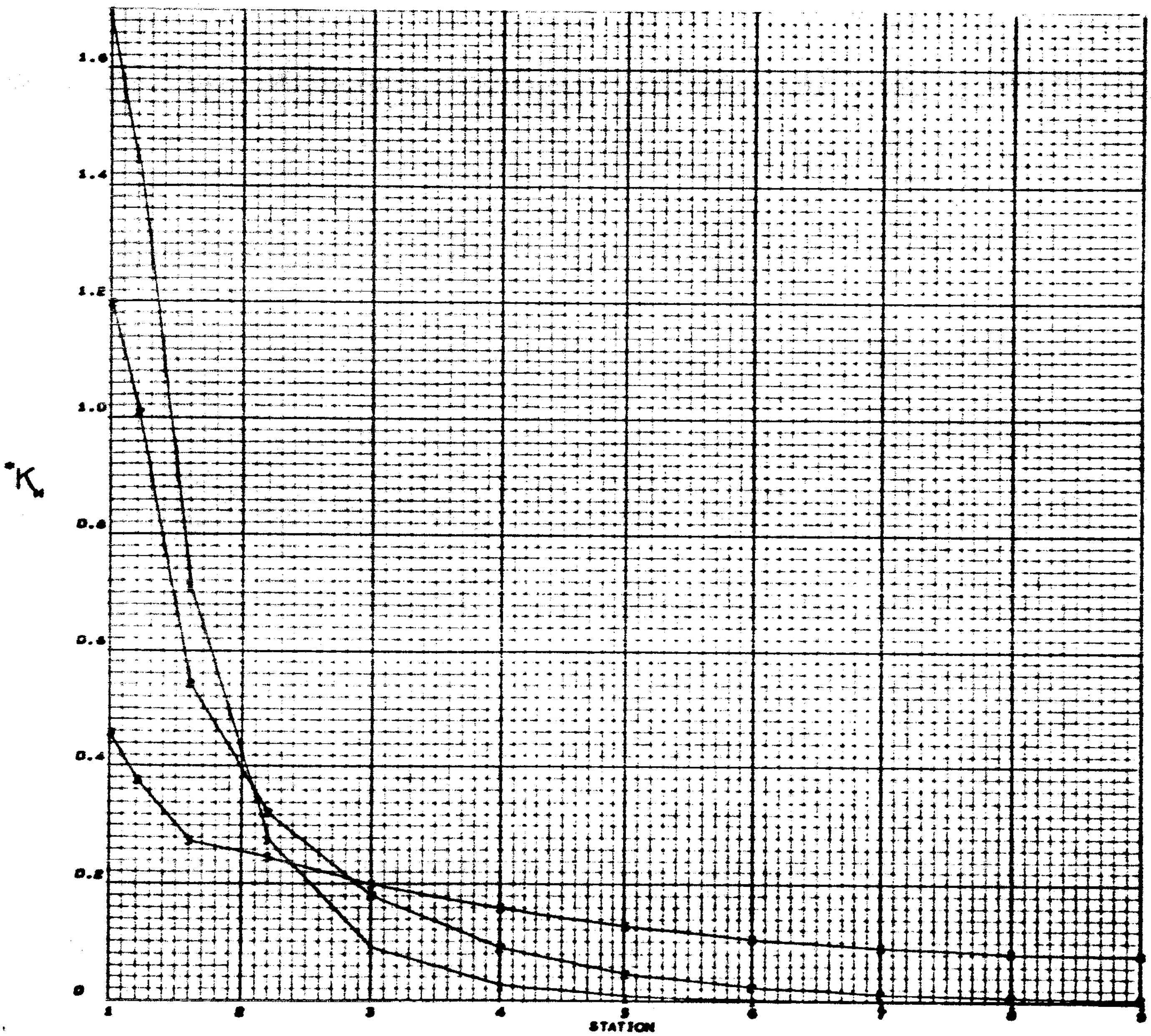
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

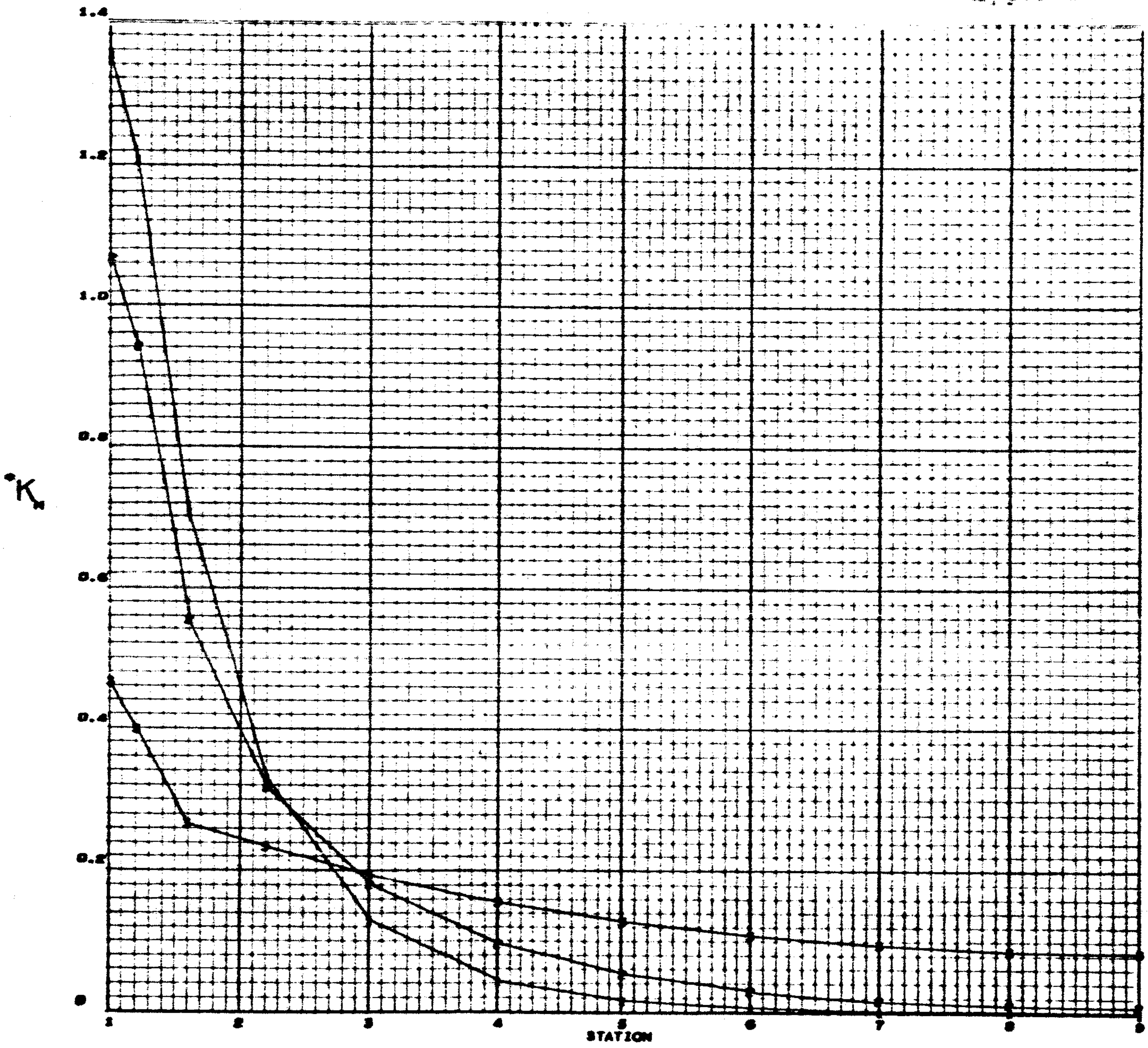
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

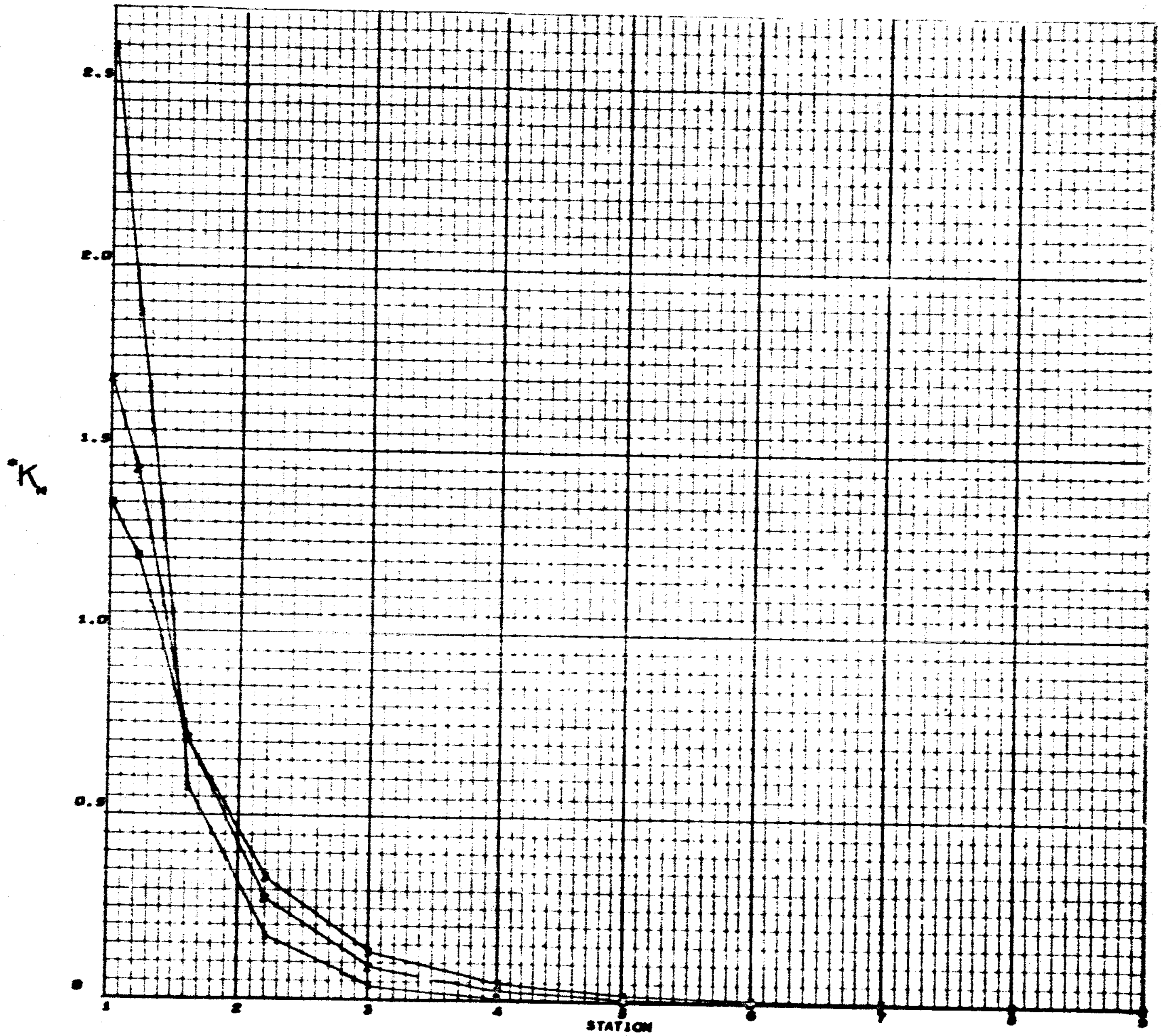
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

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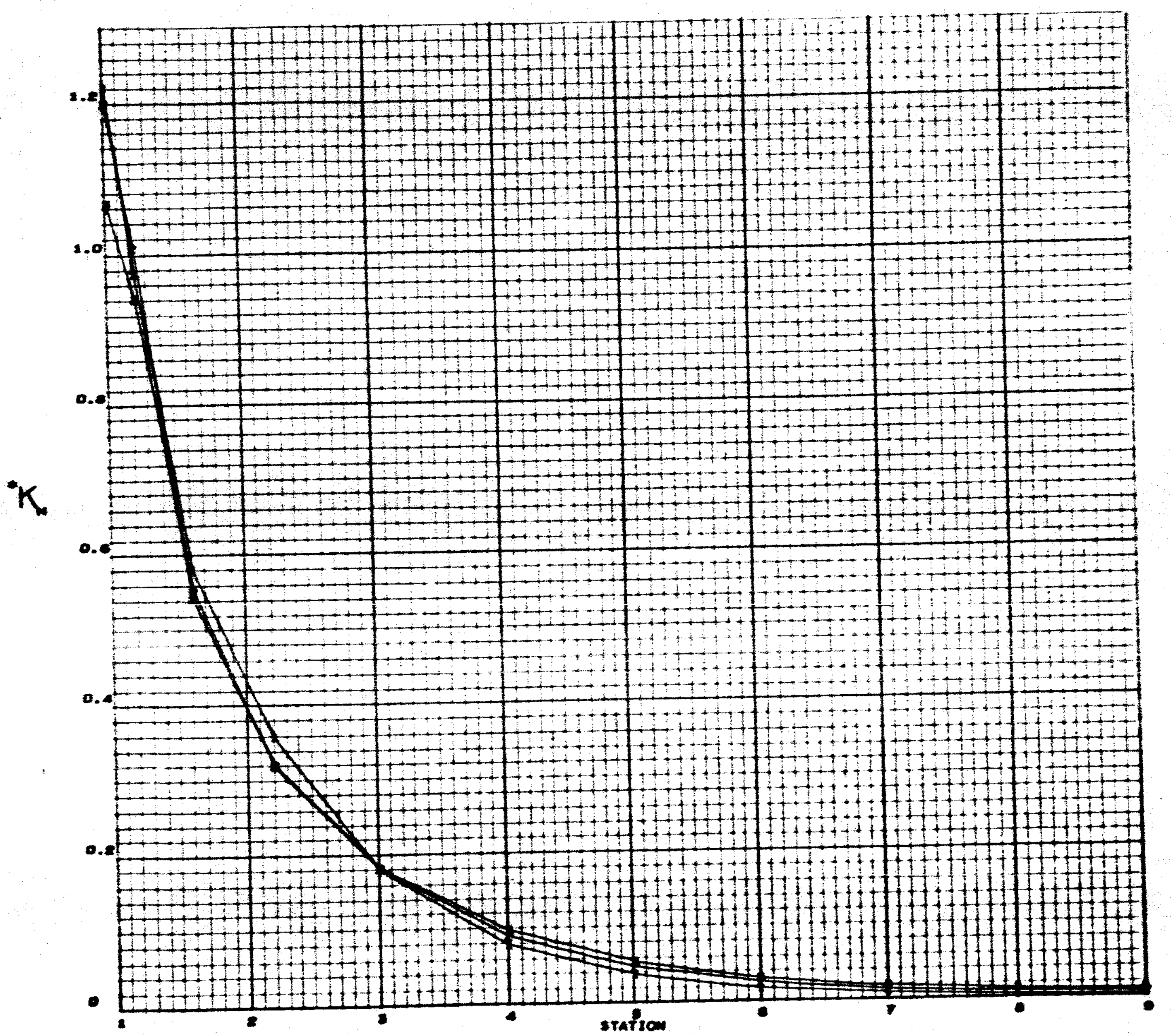
Appendix 1

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

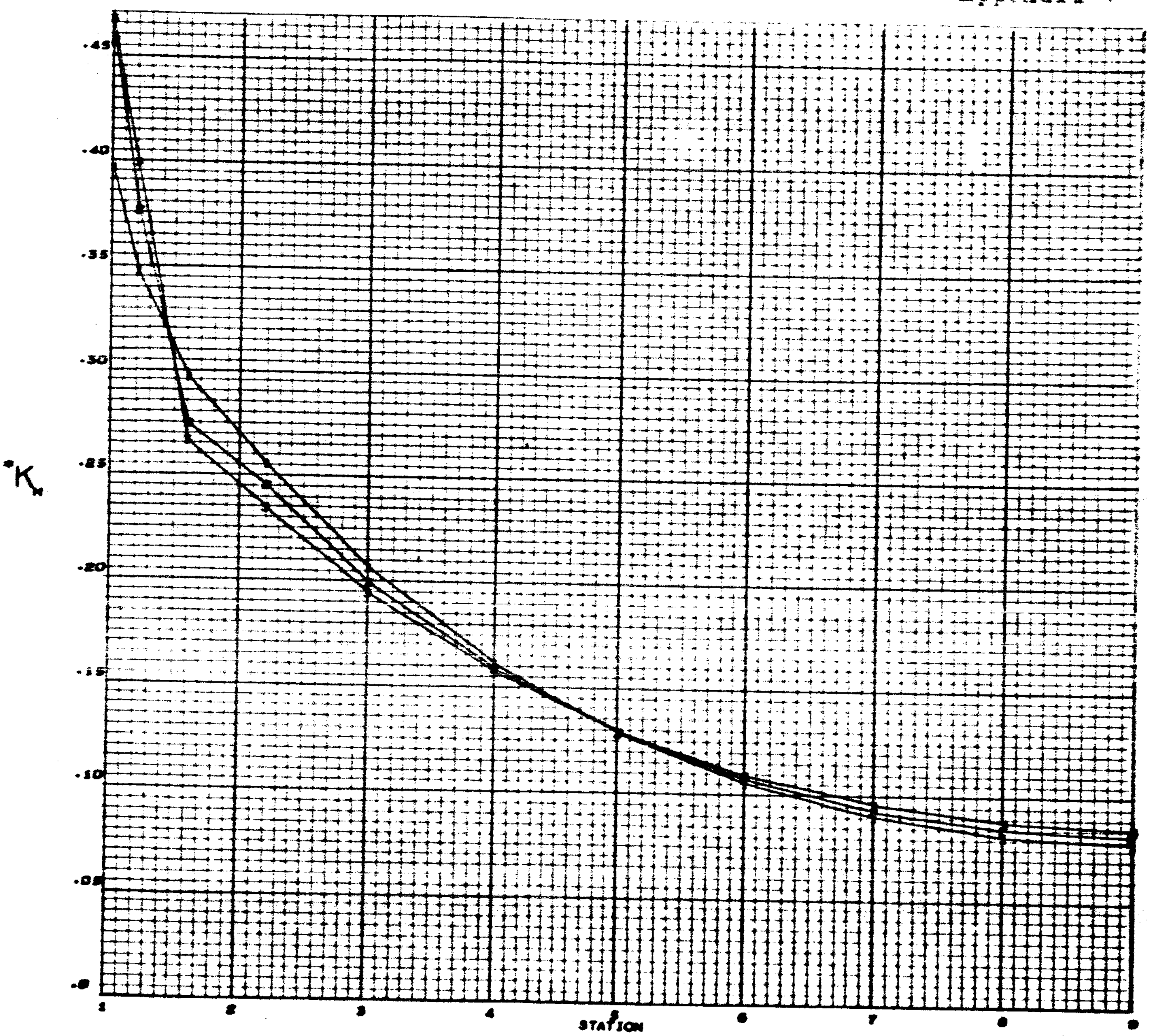
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.0[illegible]
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

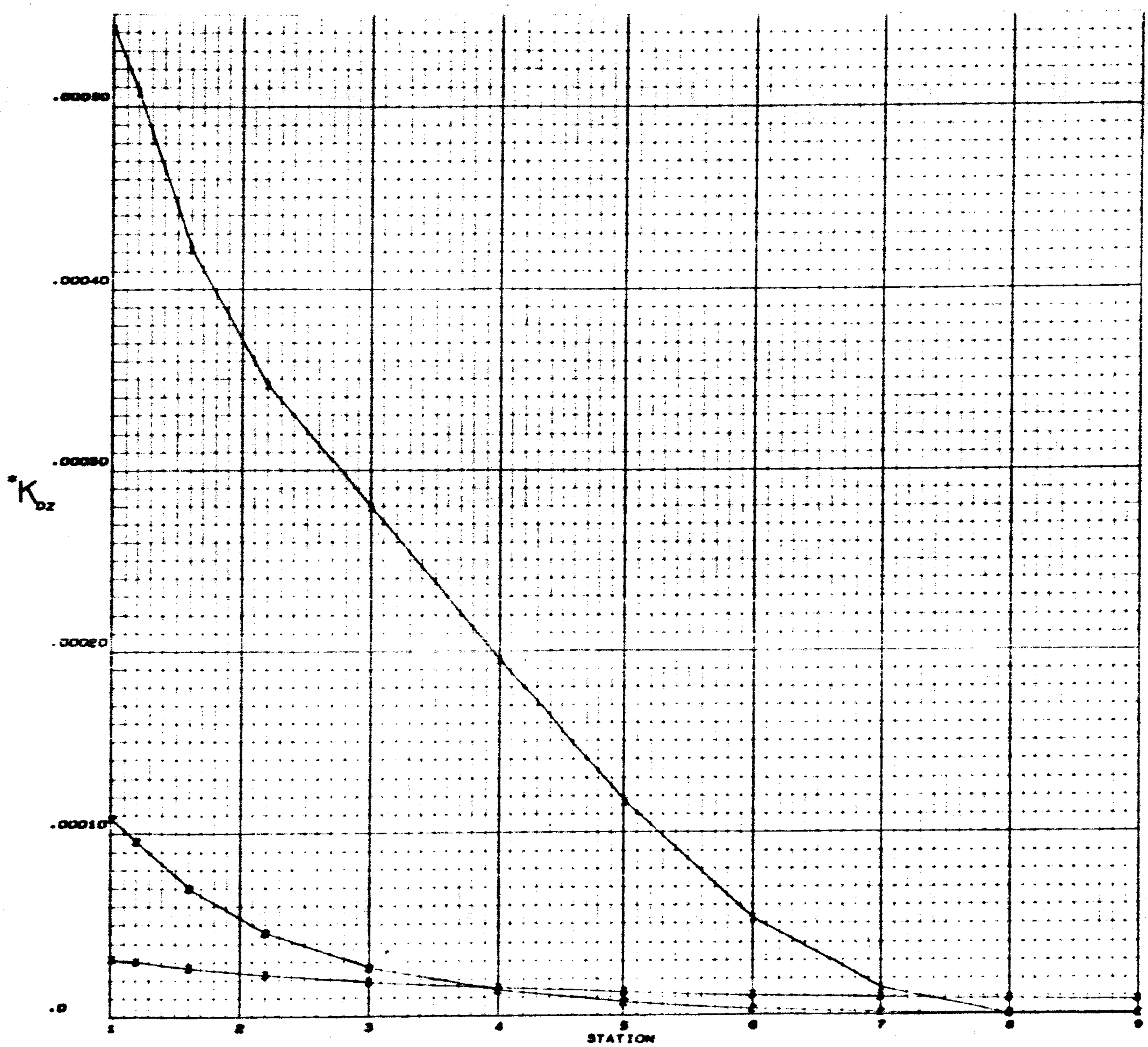
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

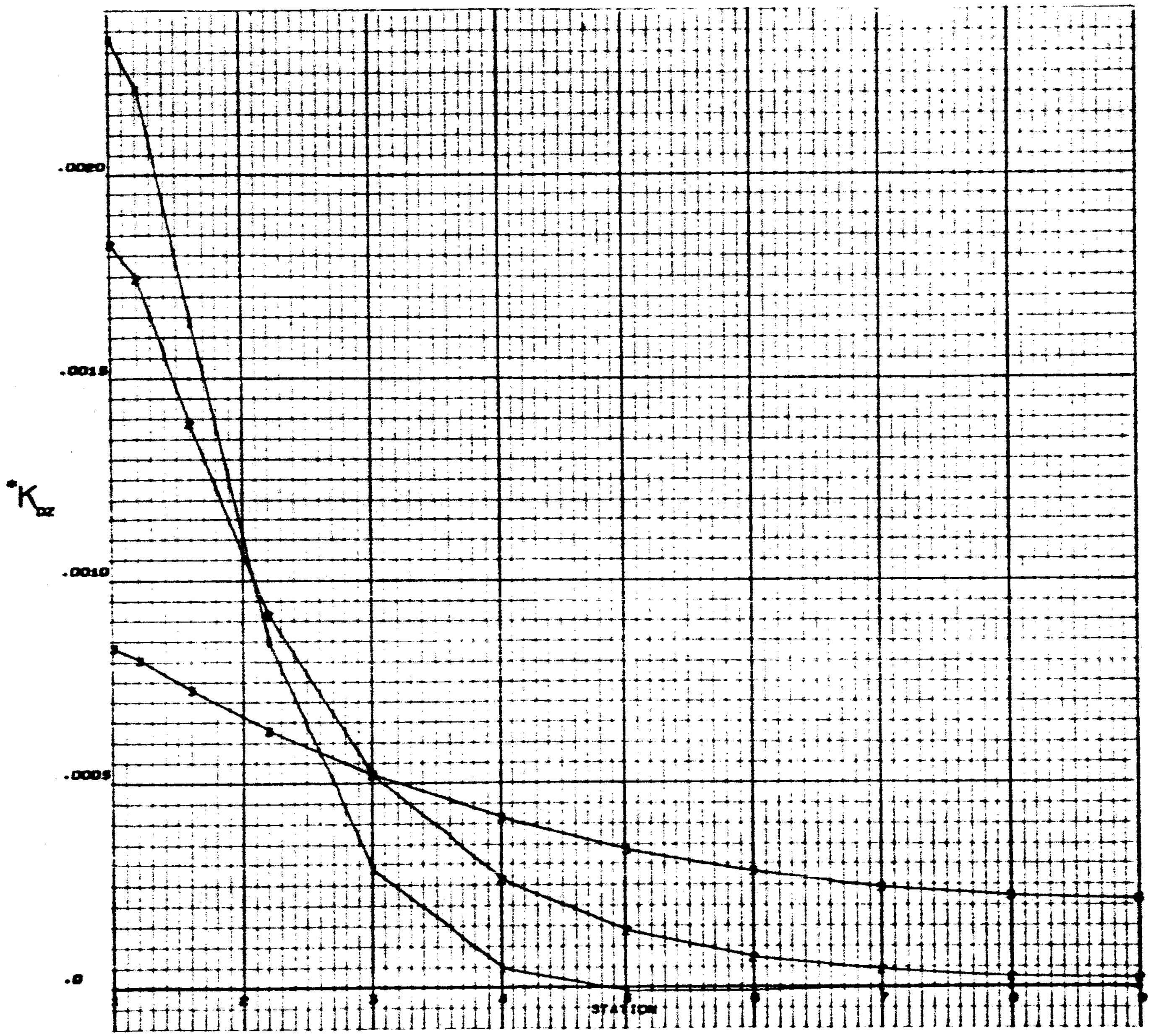
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

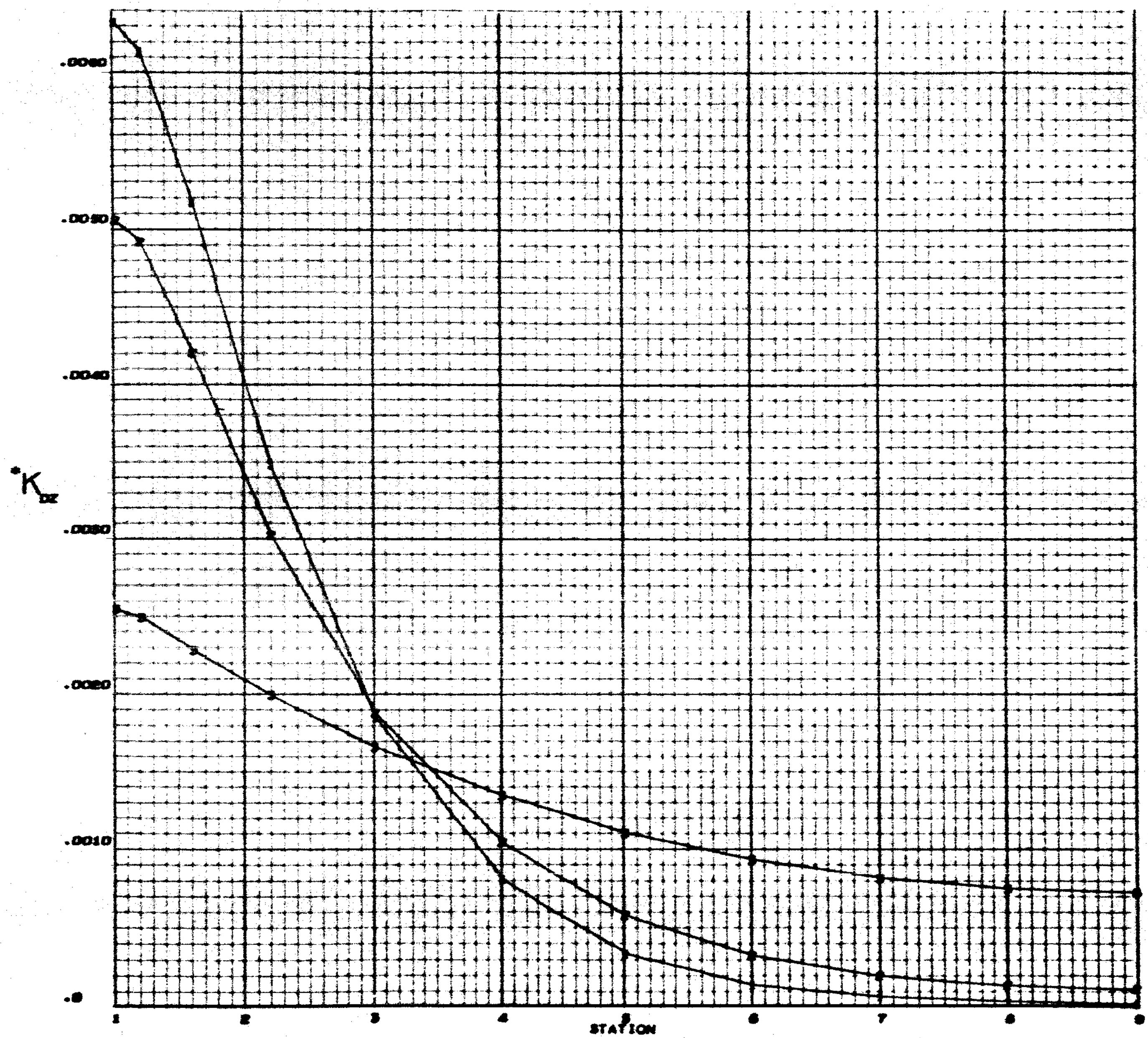
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE

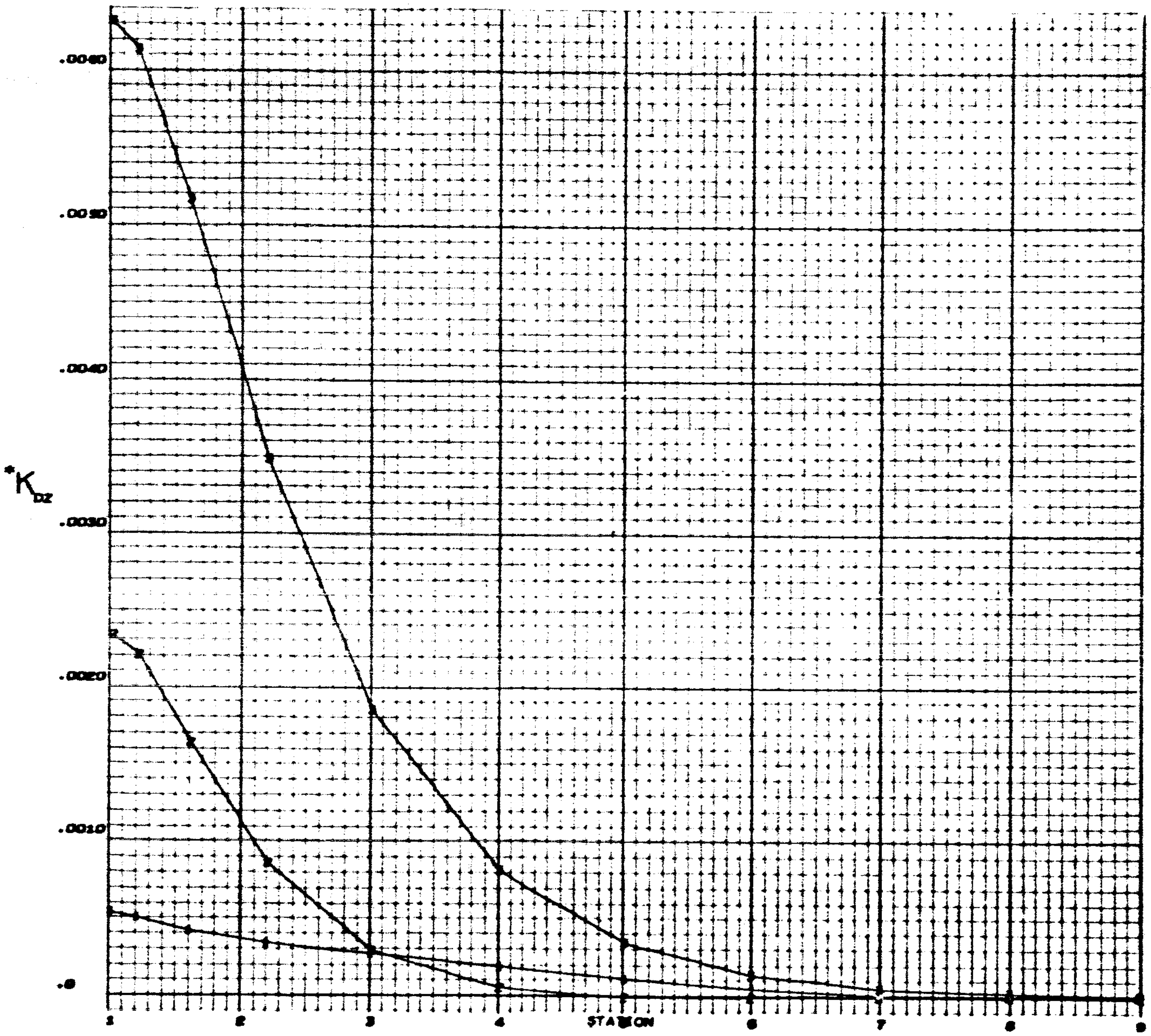


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_z = K_{DZ}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

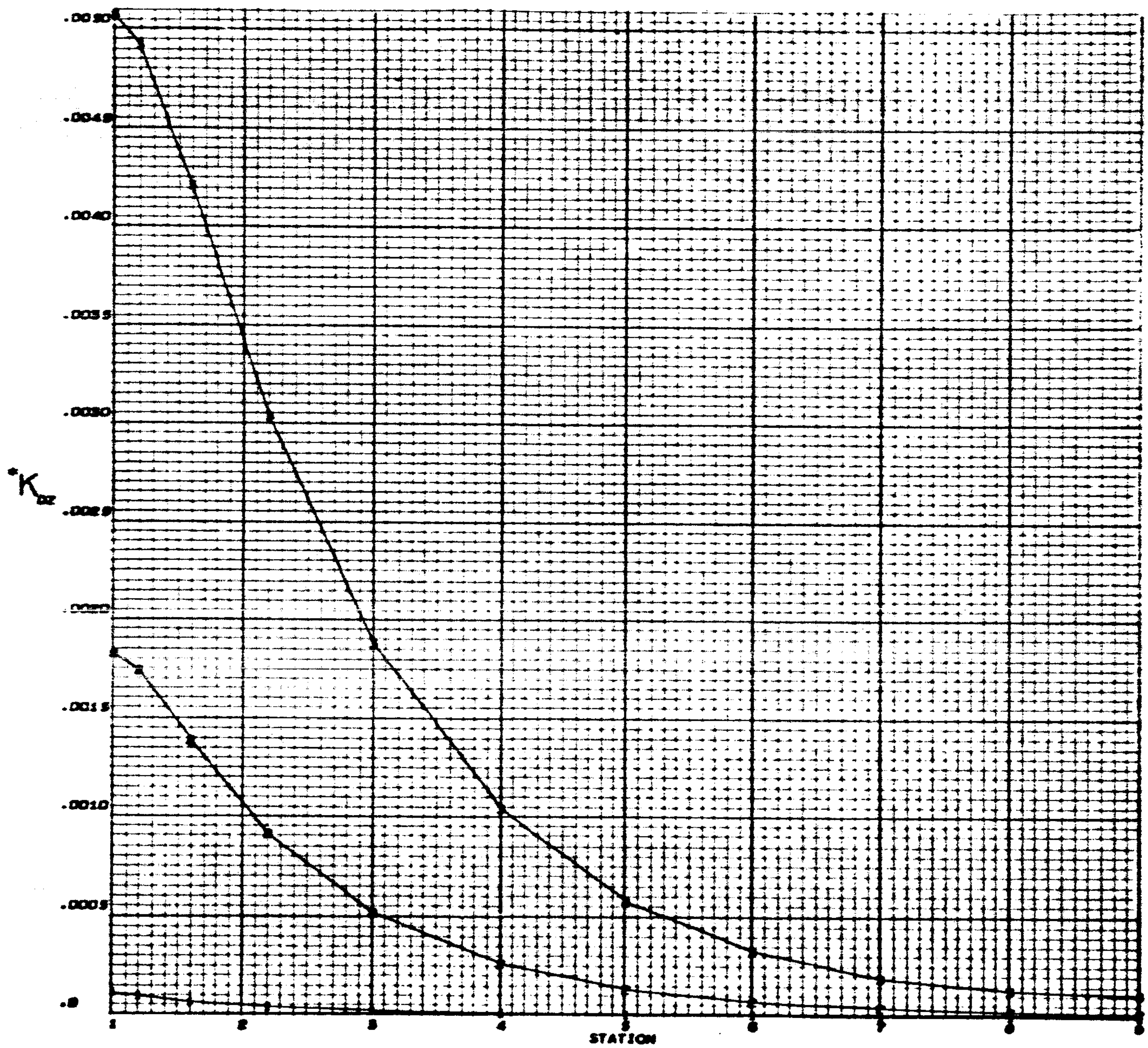
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

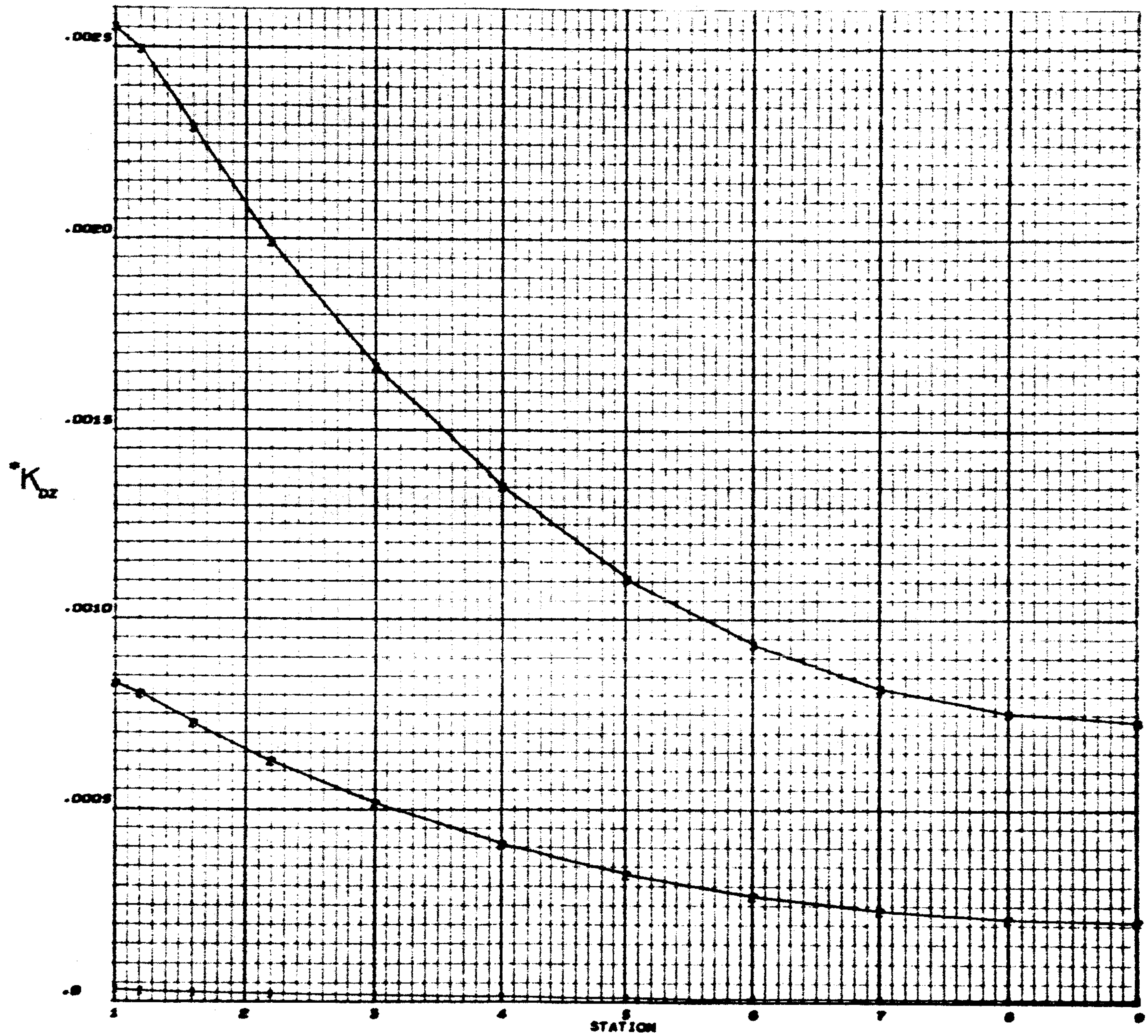
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.50

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

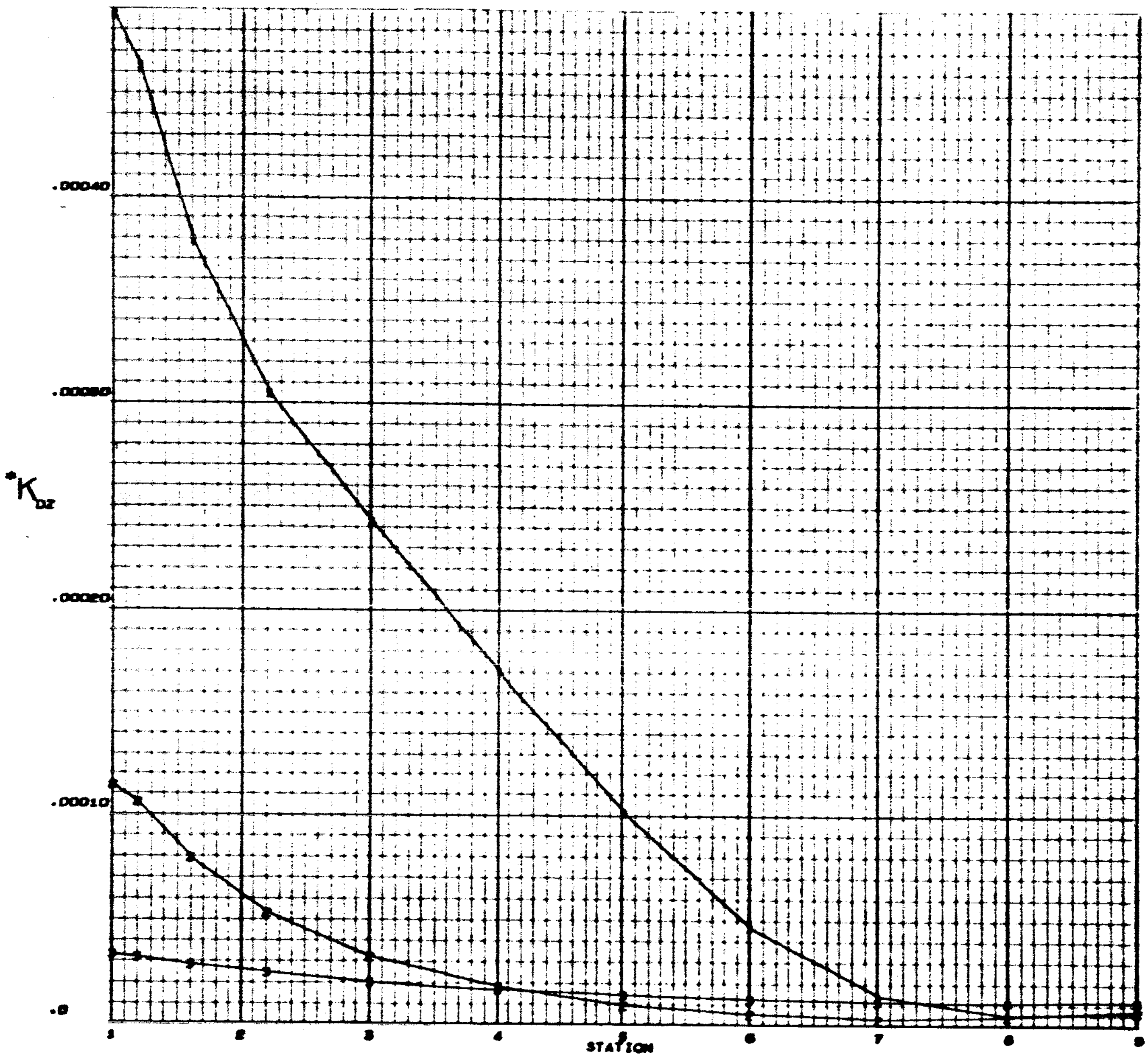


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

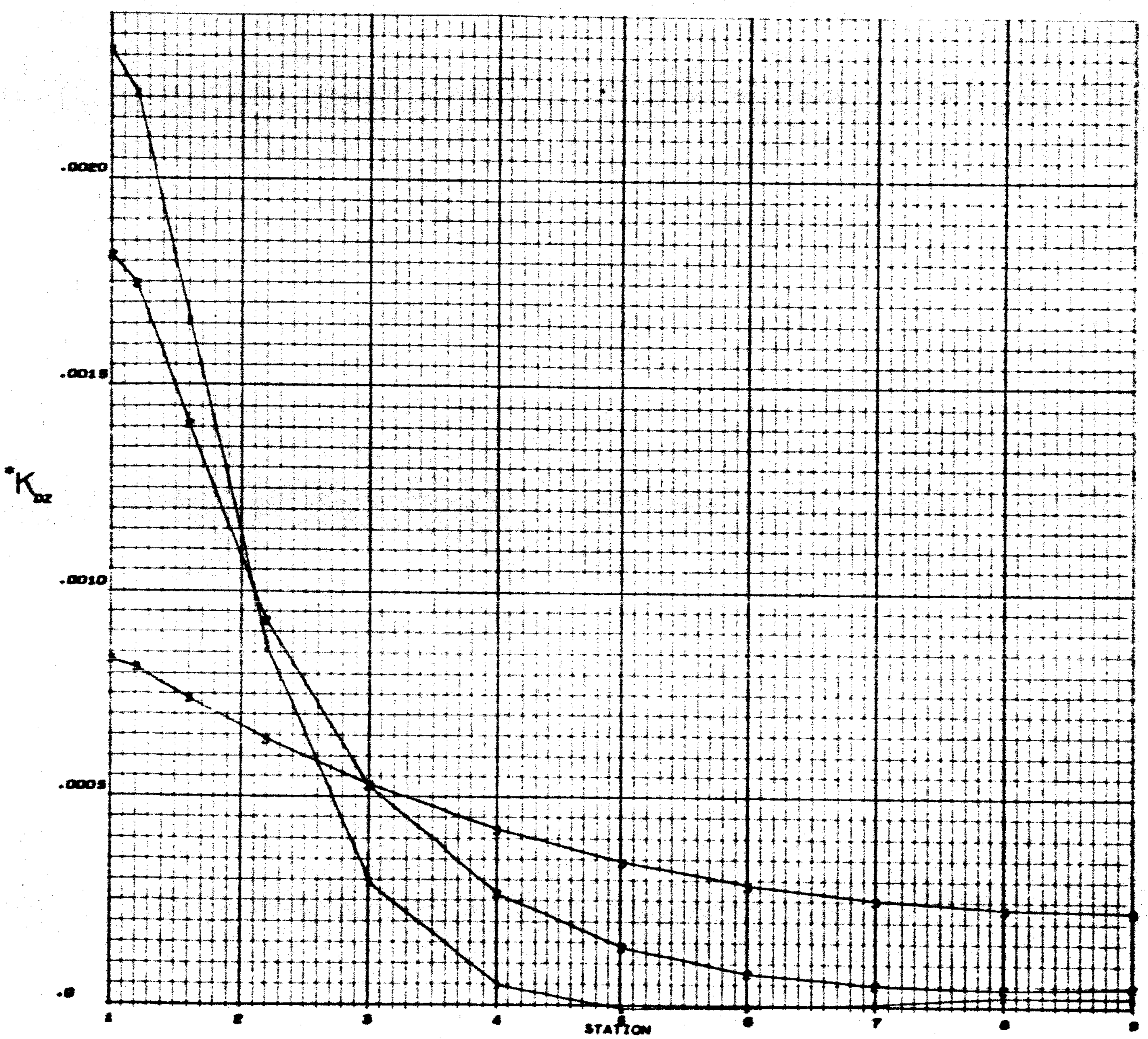
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

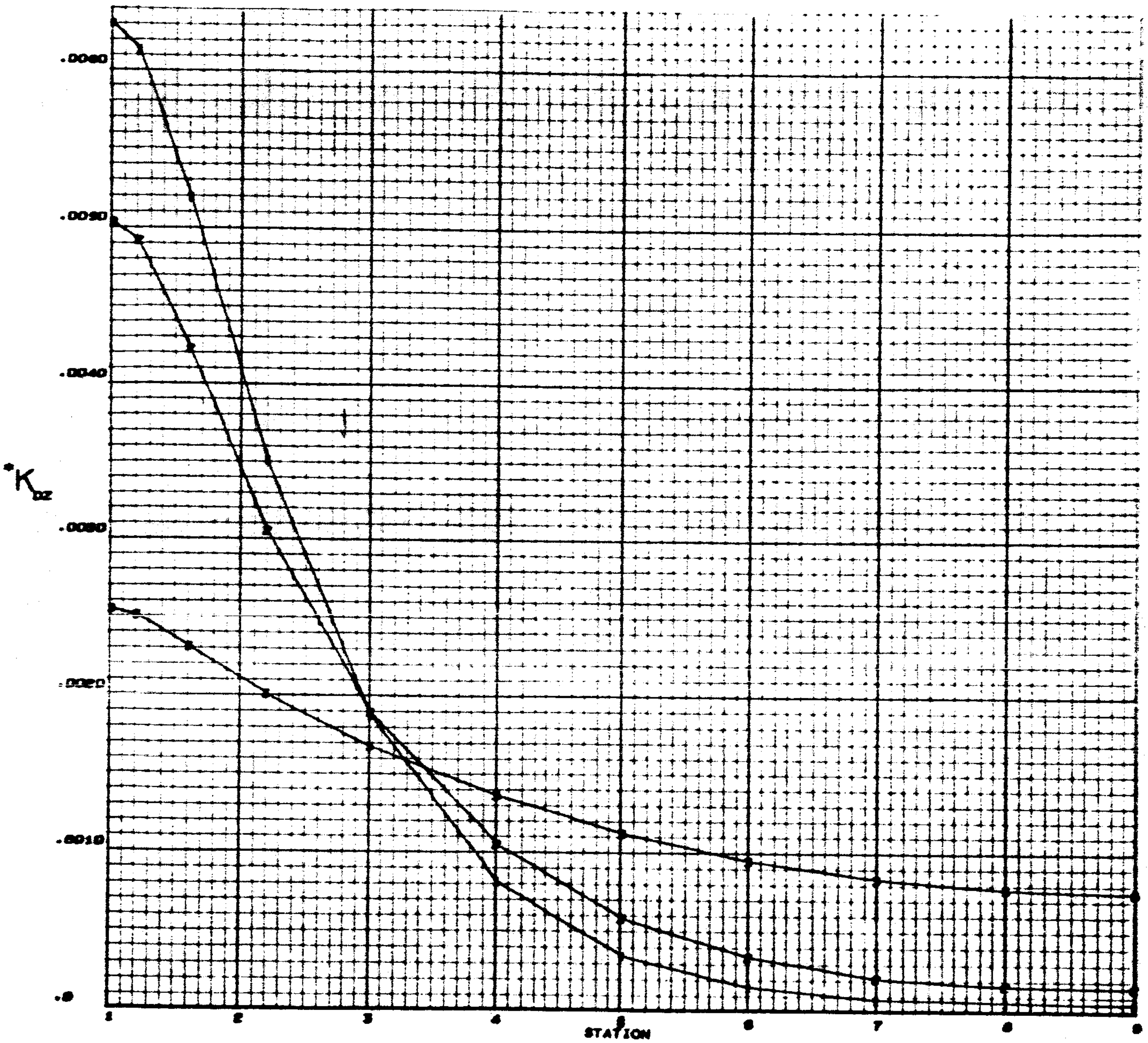
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

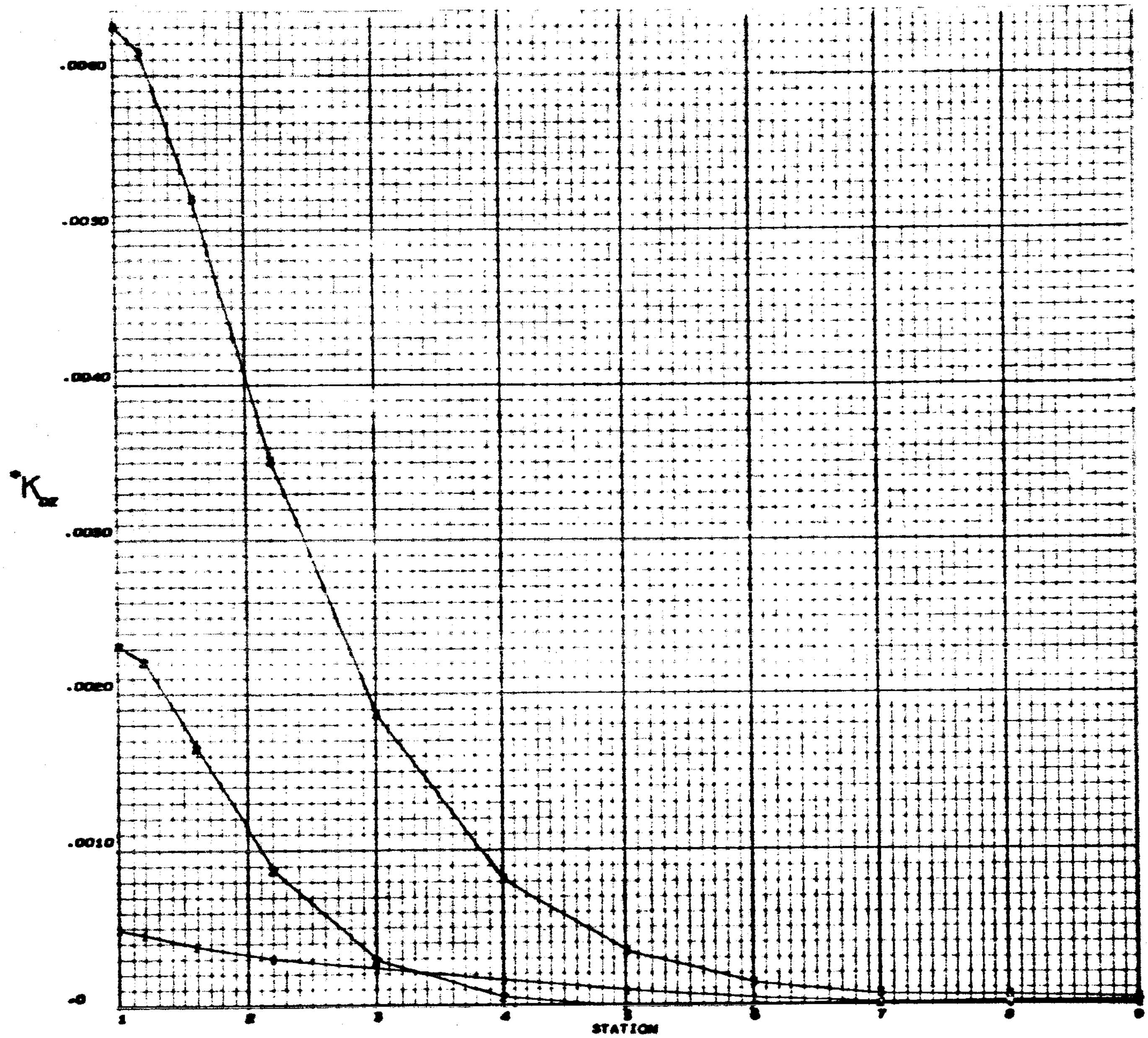
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

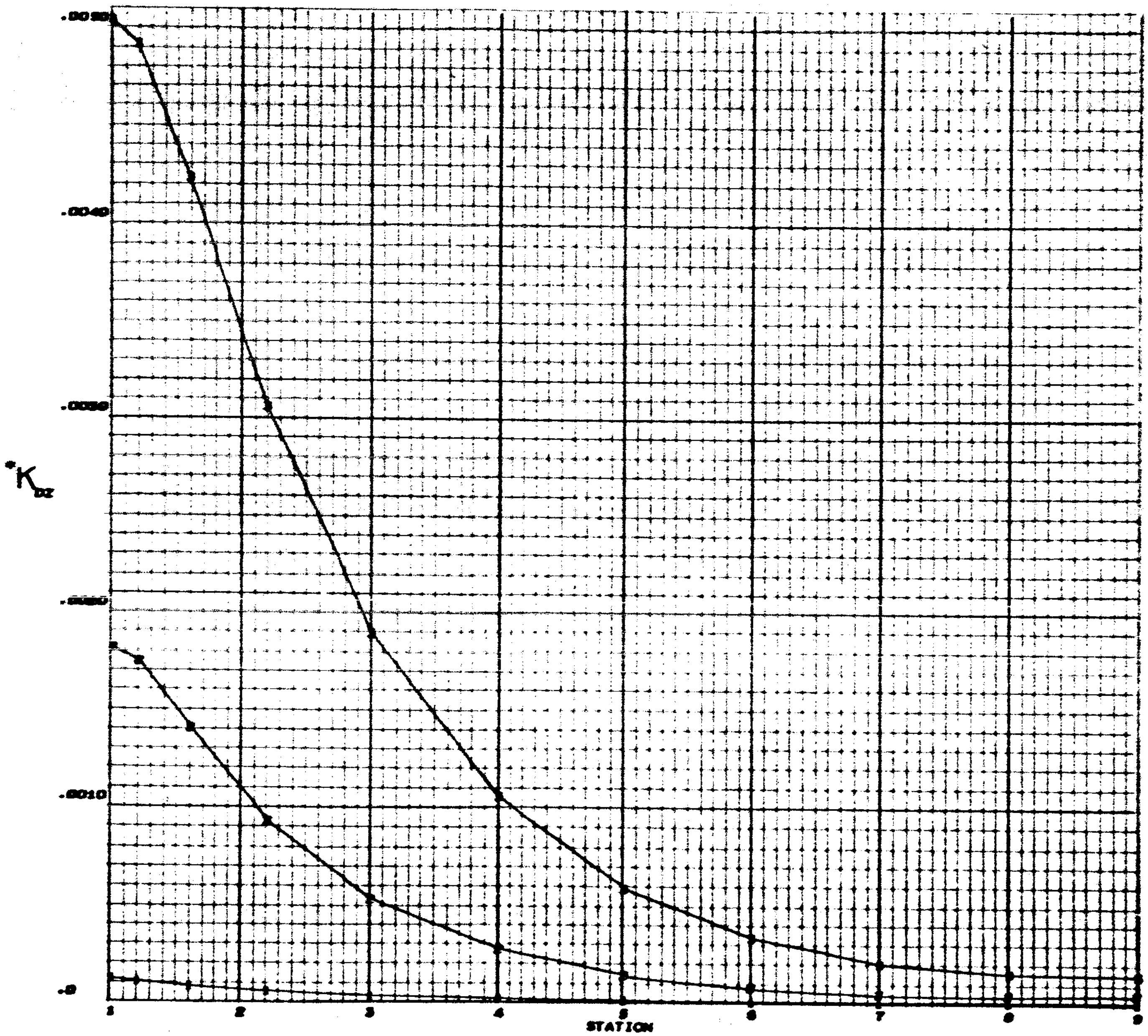
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

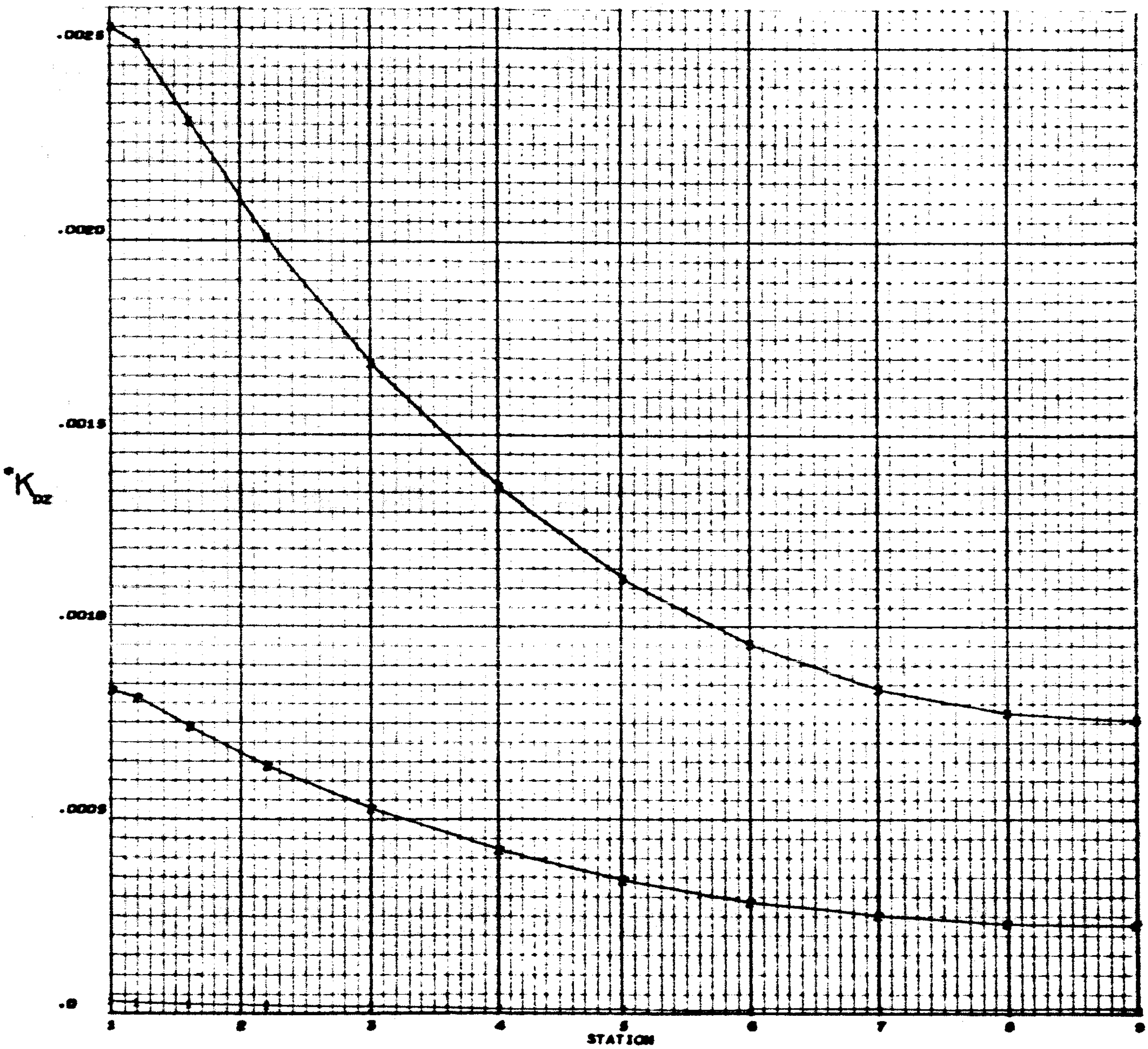
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

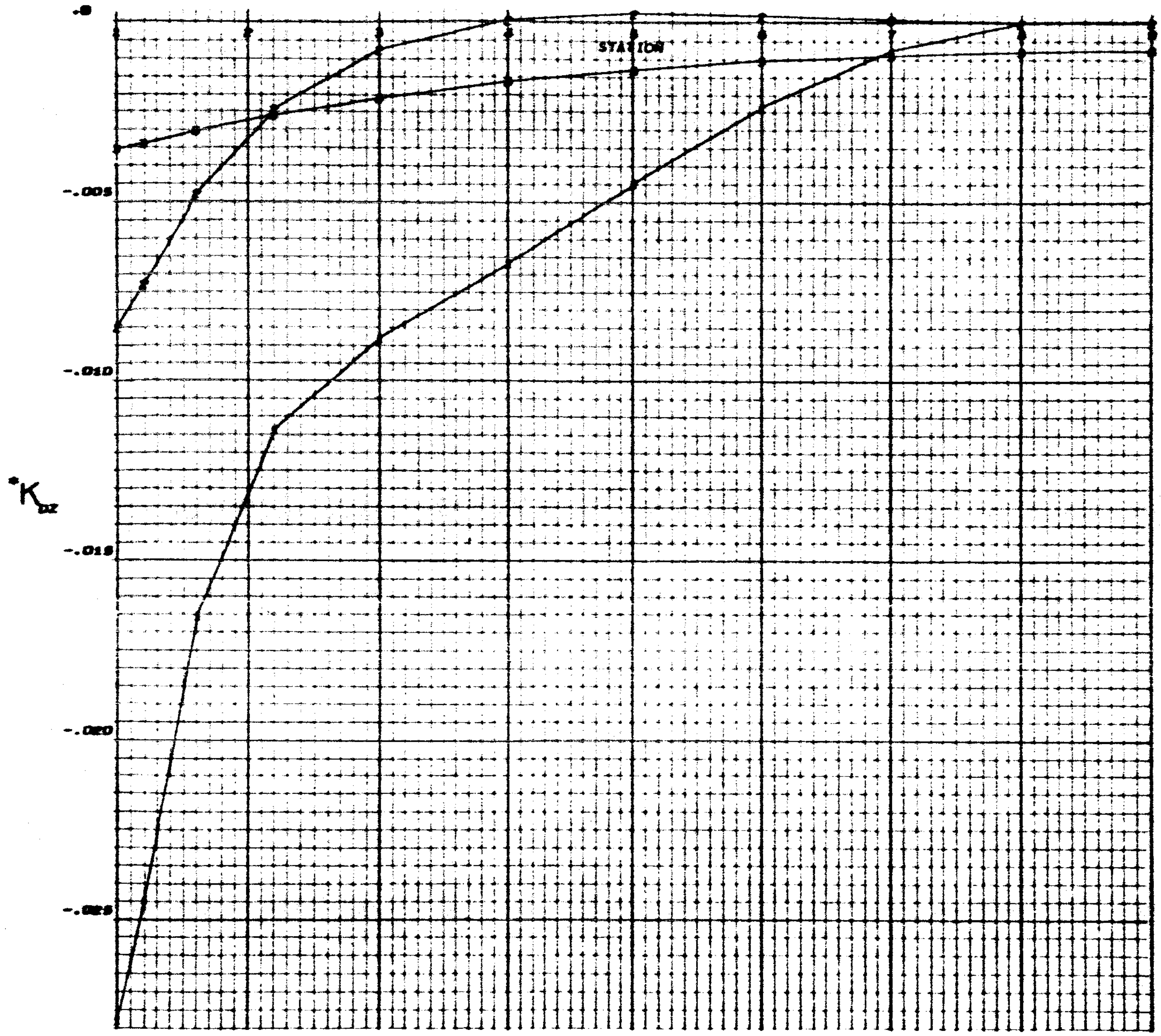
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

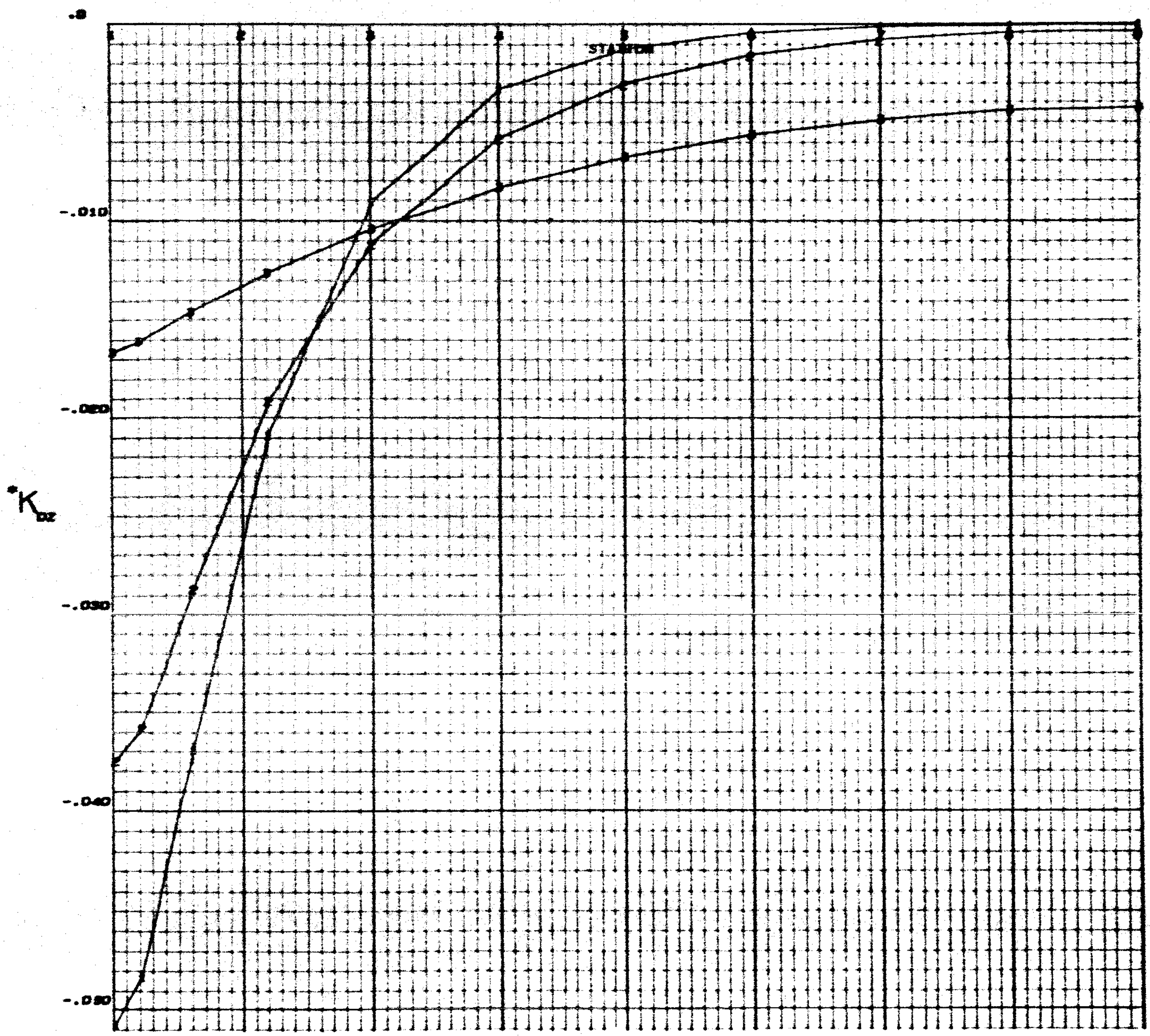
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_z = K_{Dz}(R^2/EI)$

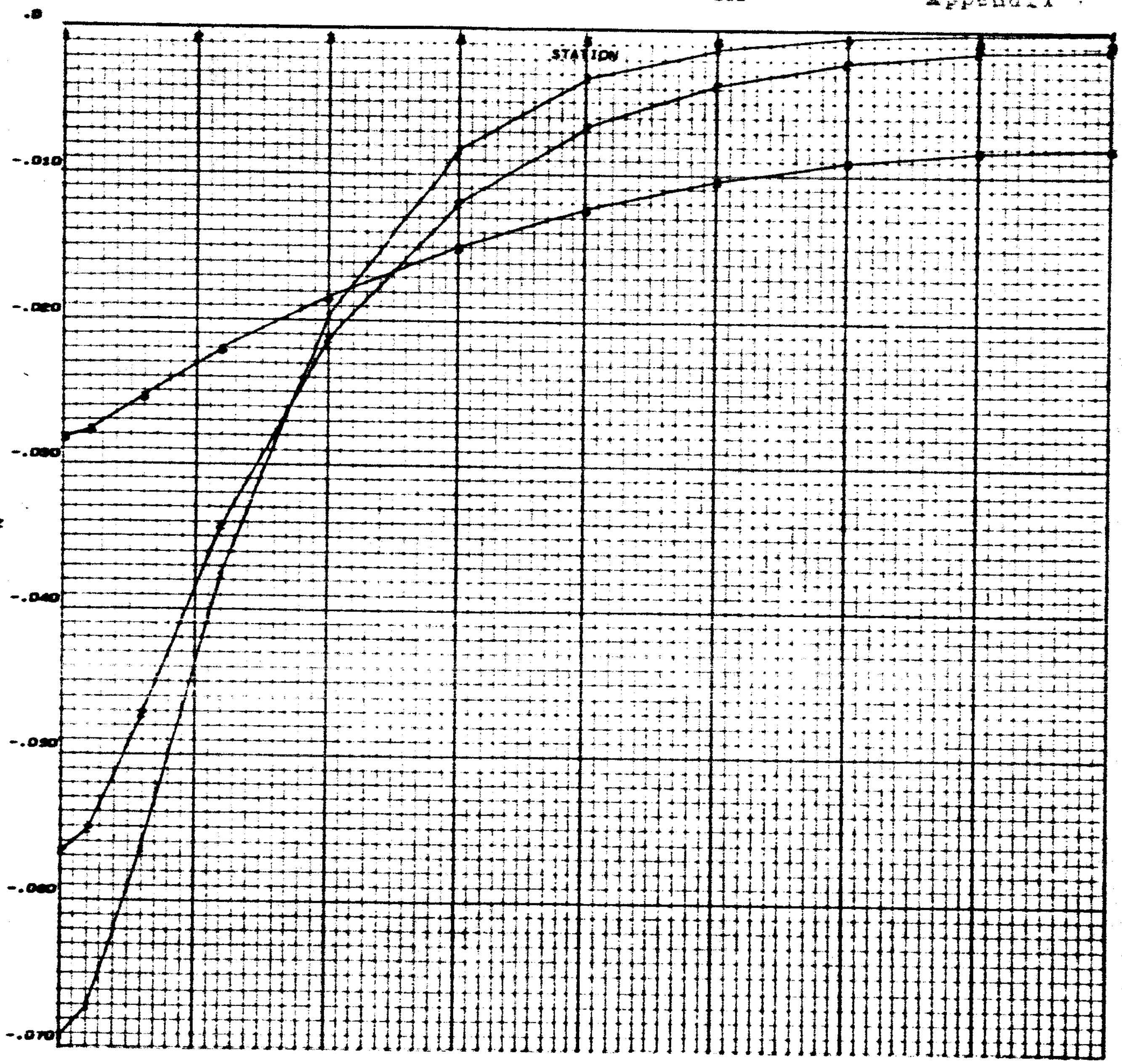
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

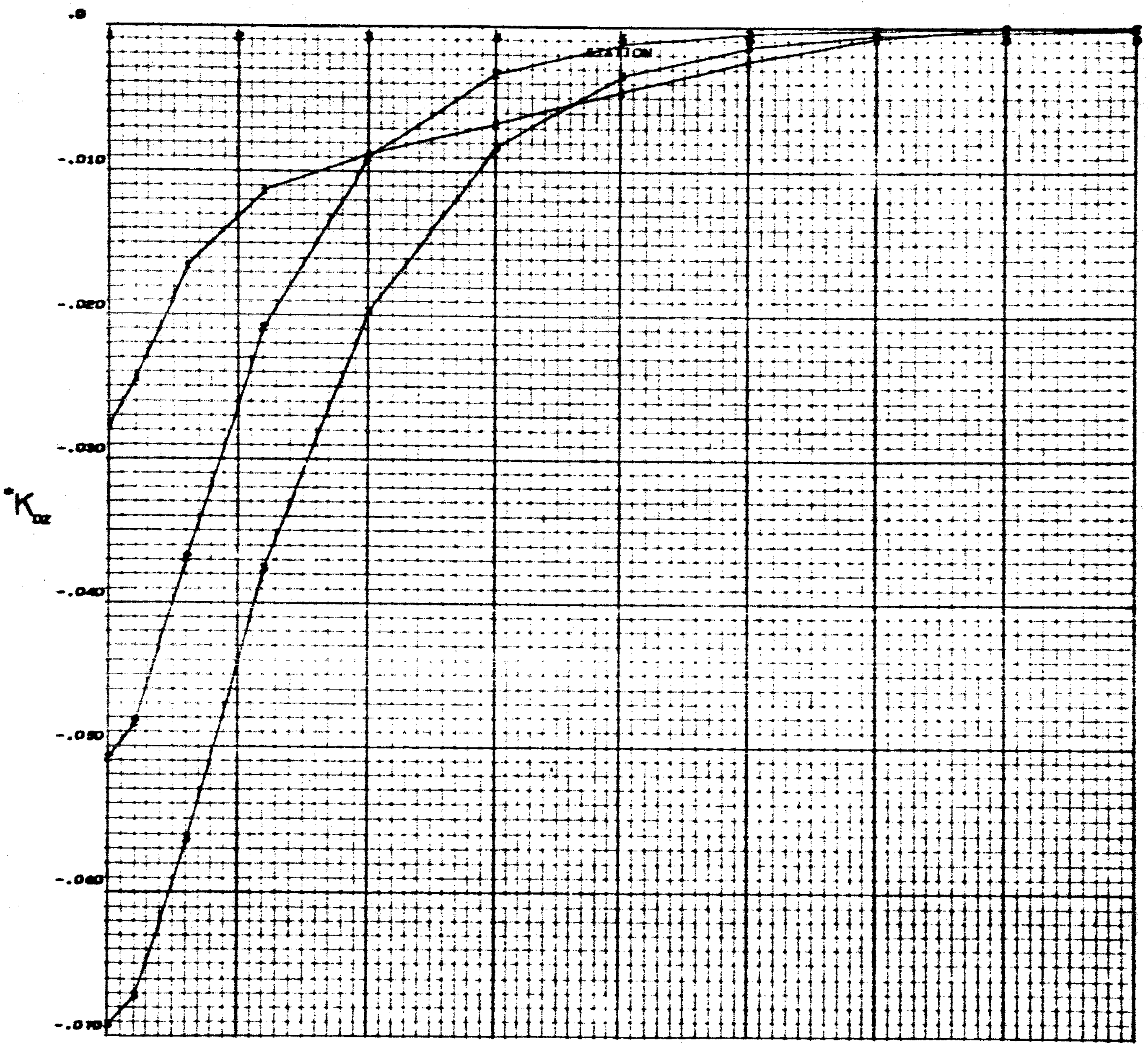
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.08, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE - NORMAL DEFLECTION, $D_z = K_{DZ}(R^2/EI)$

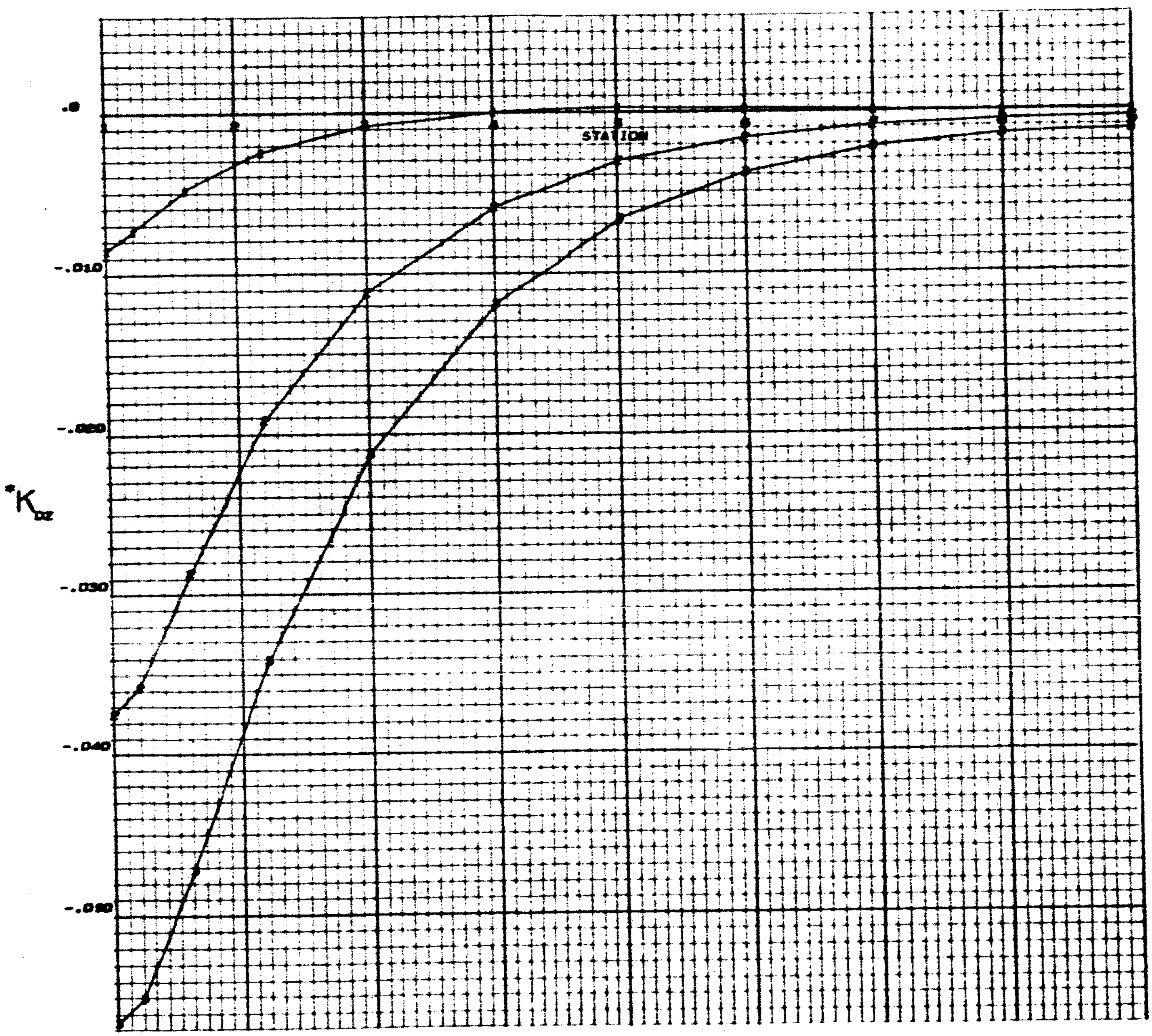
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

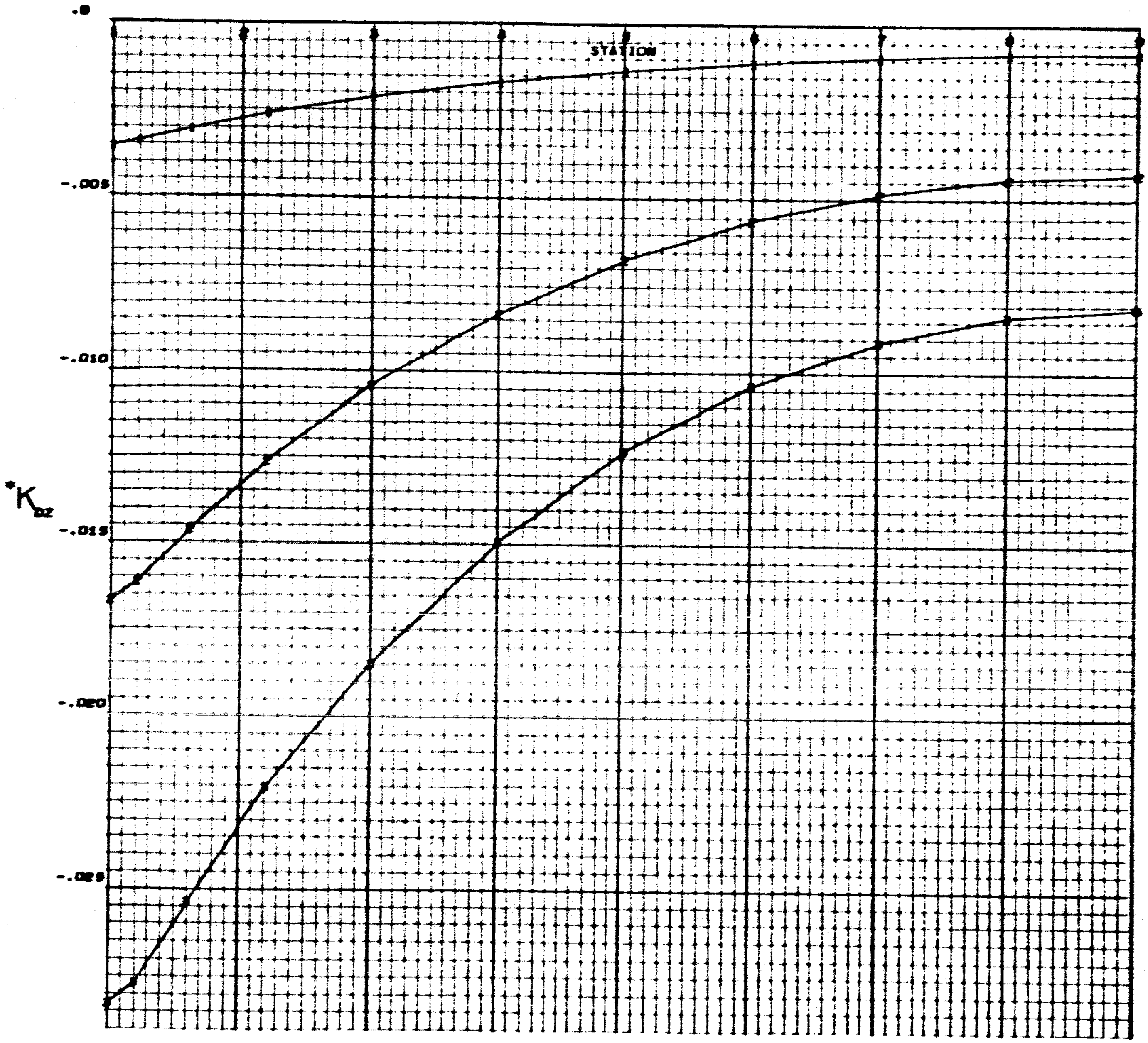
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

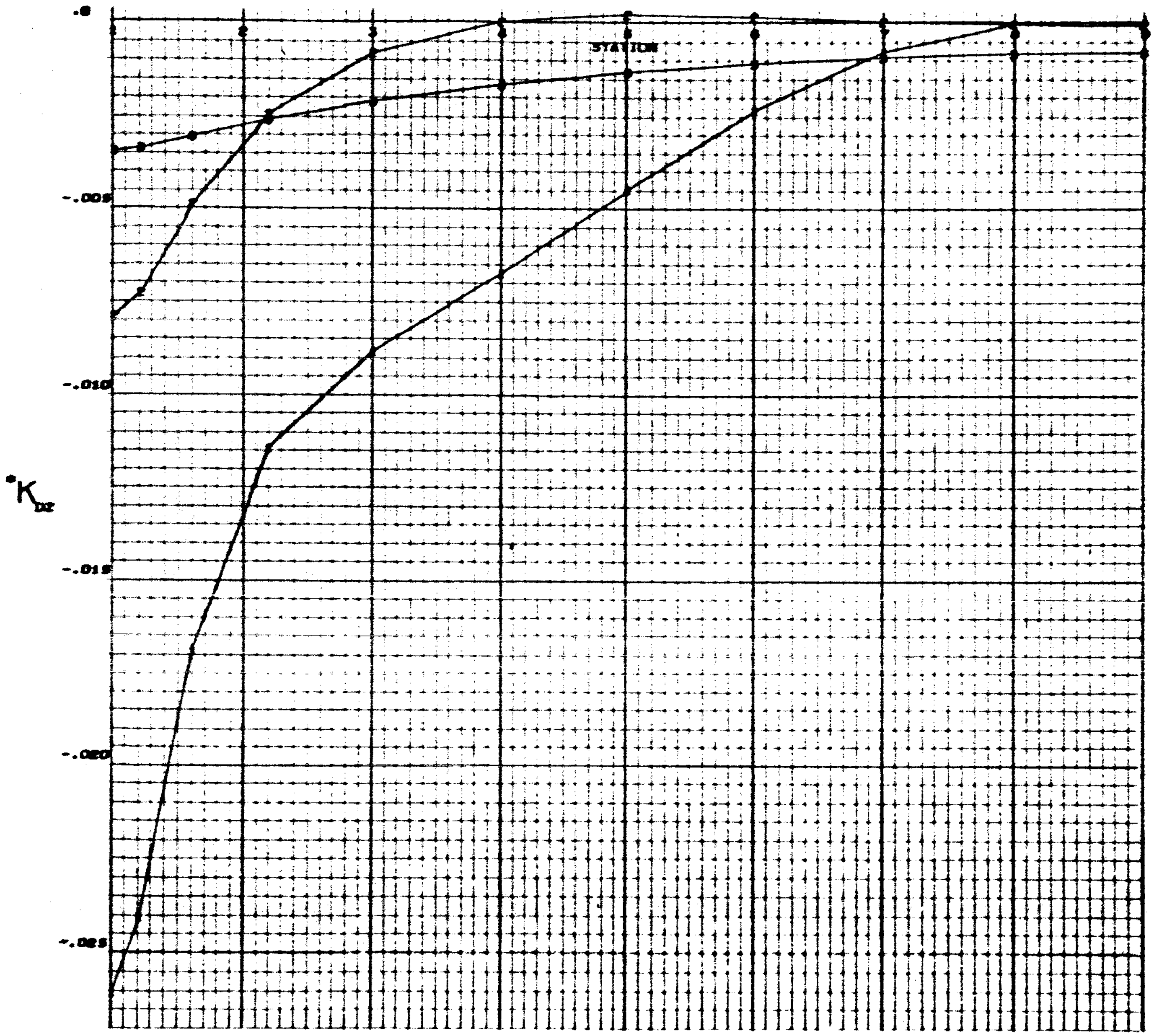
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.08

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

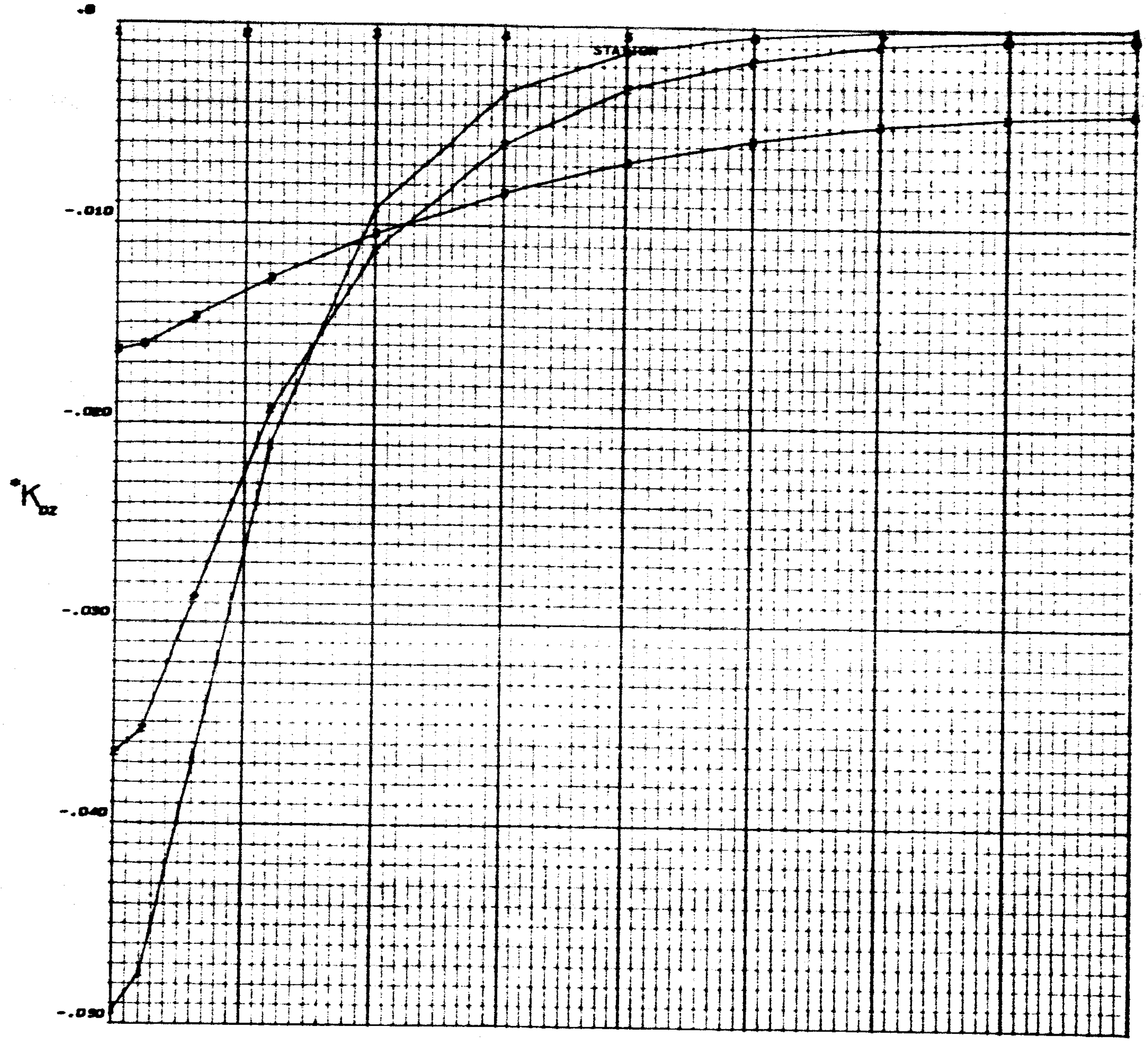
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

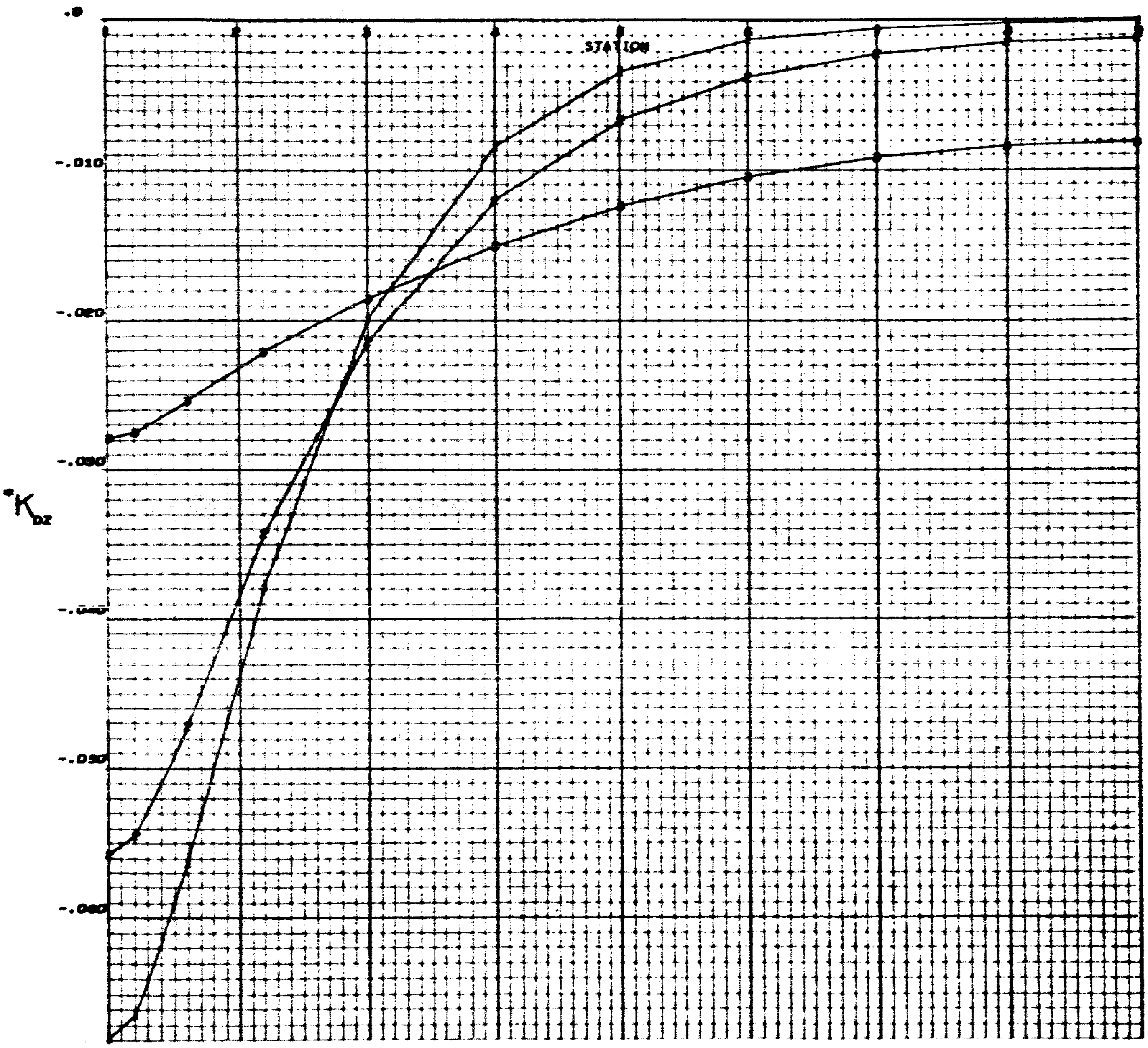
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, D_Z = K_{DZ} (R^2/EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = 0.09, GJ/EI VARIABLE



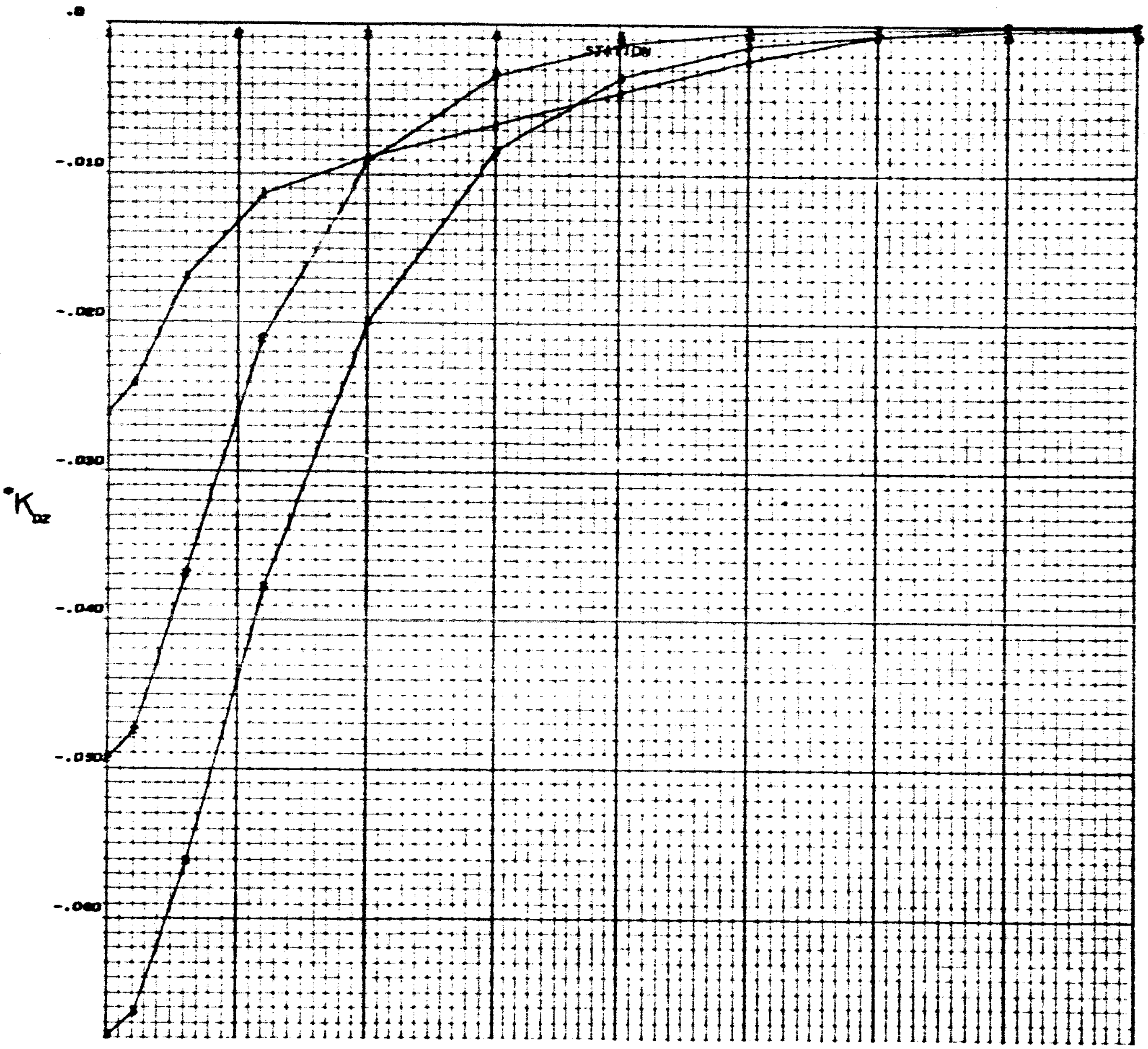
CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

Appendix 1

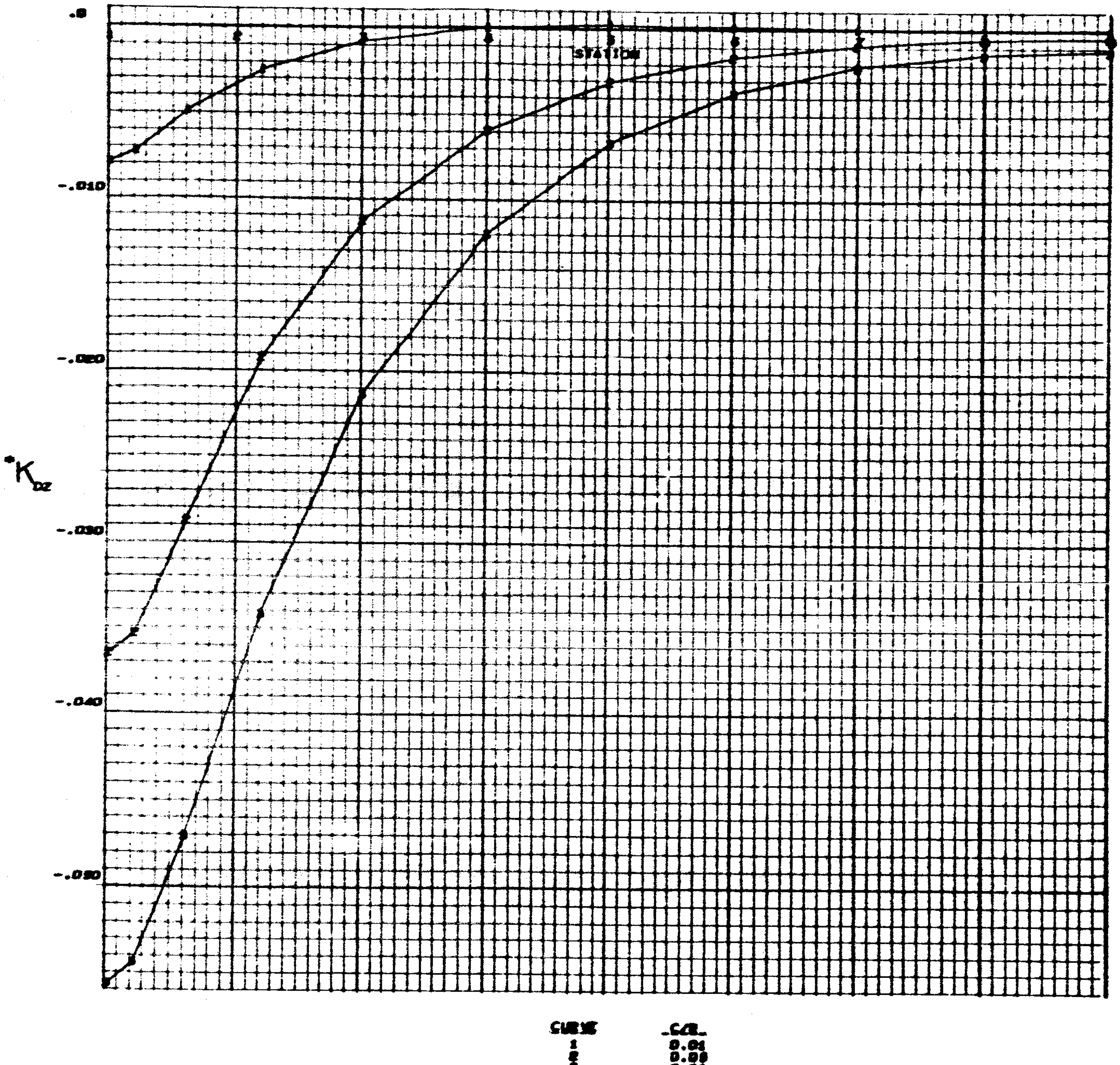
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	[illegible]
3	[illegible]

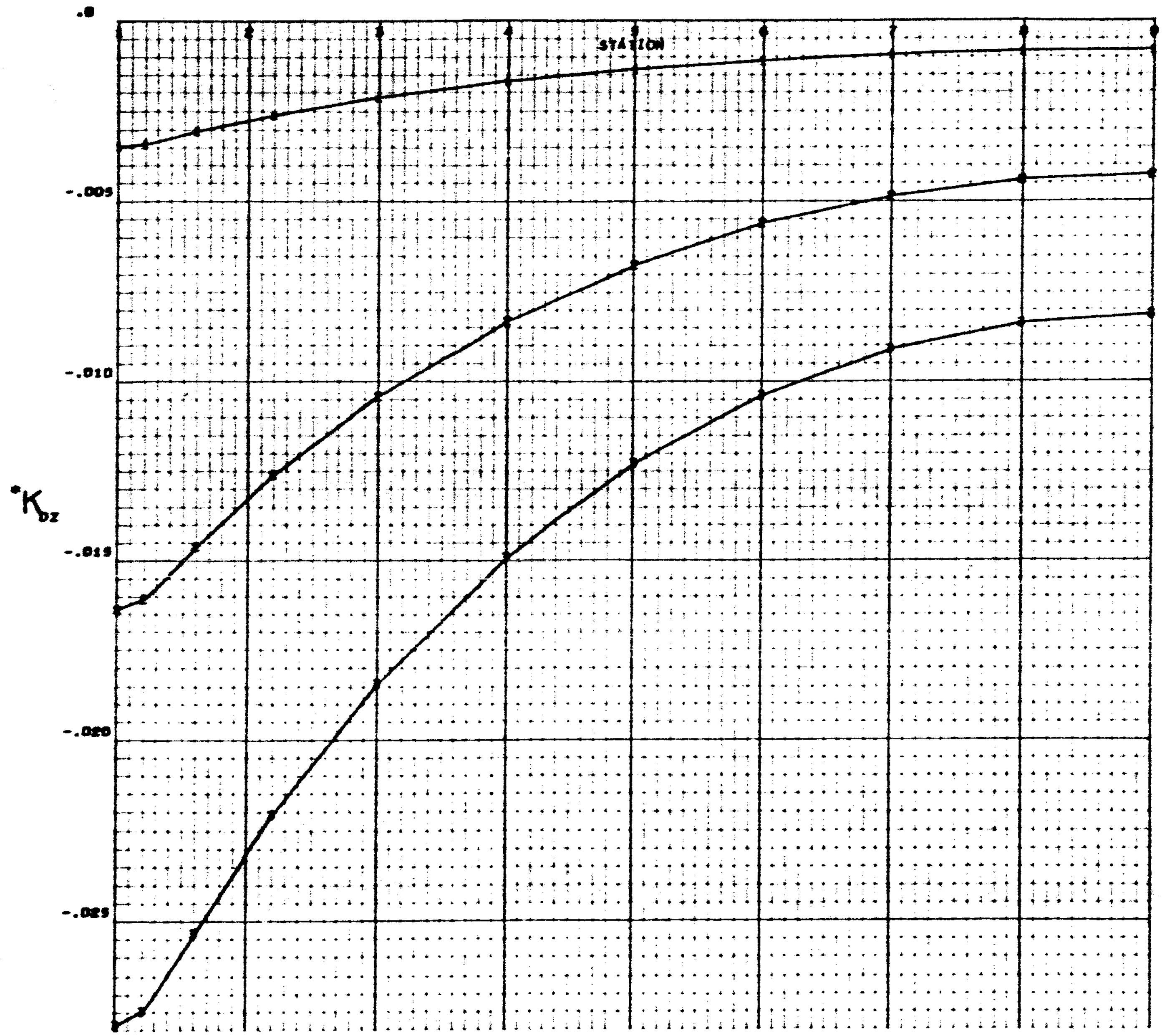
*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

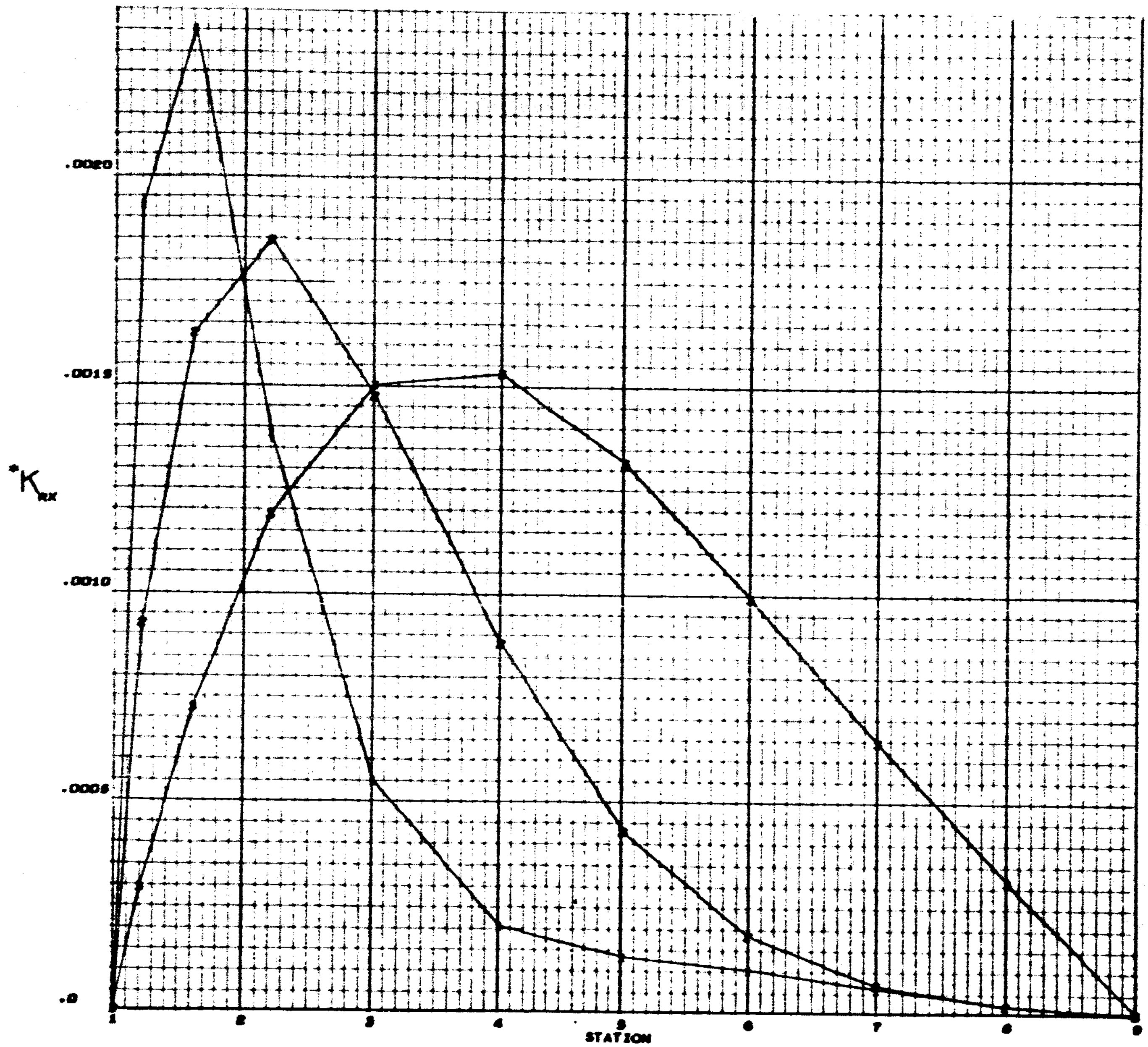
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

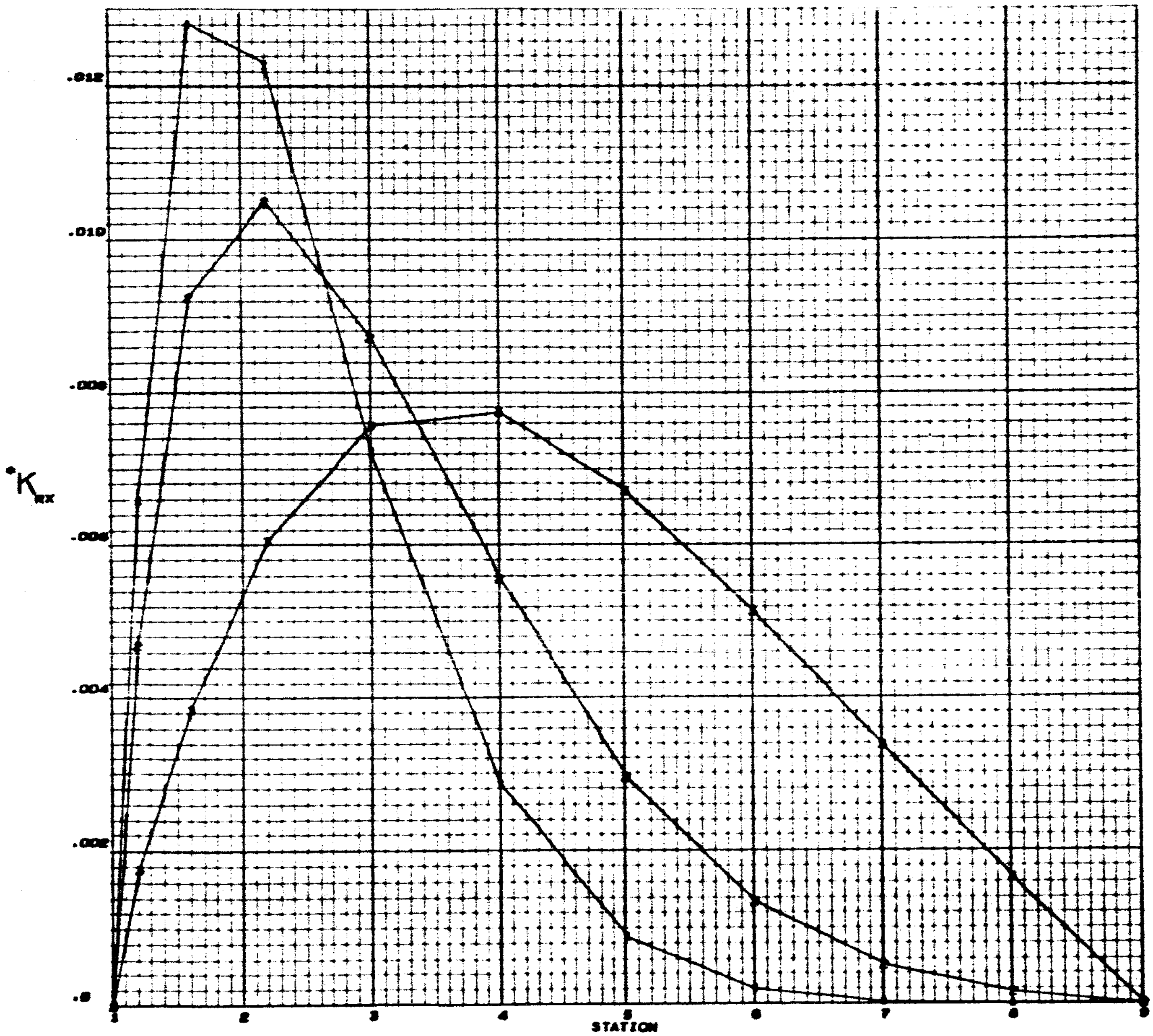
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

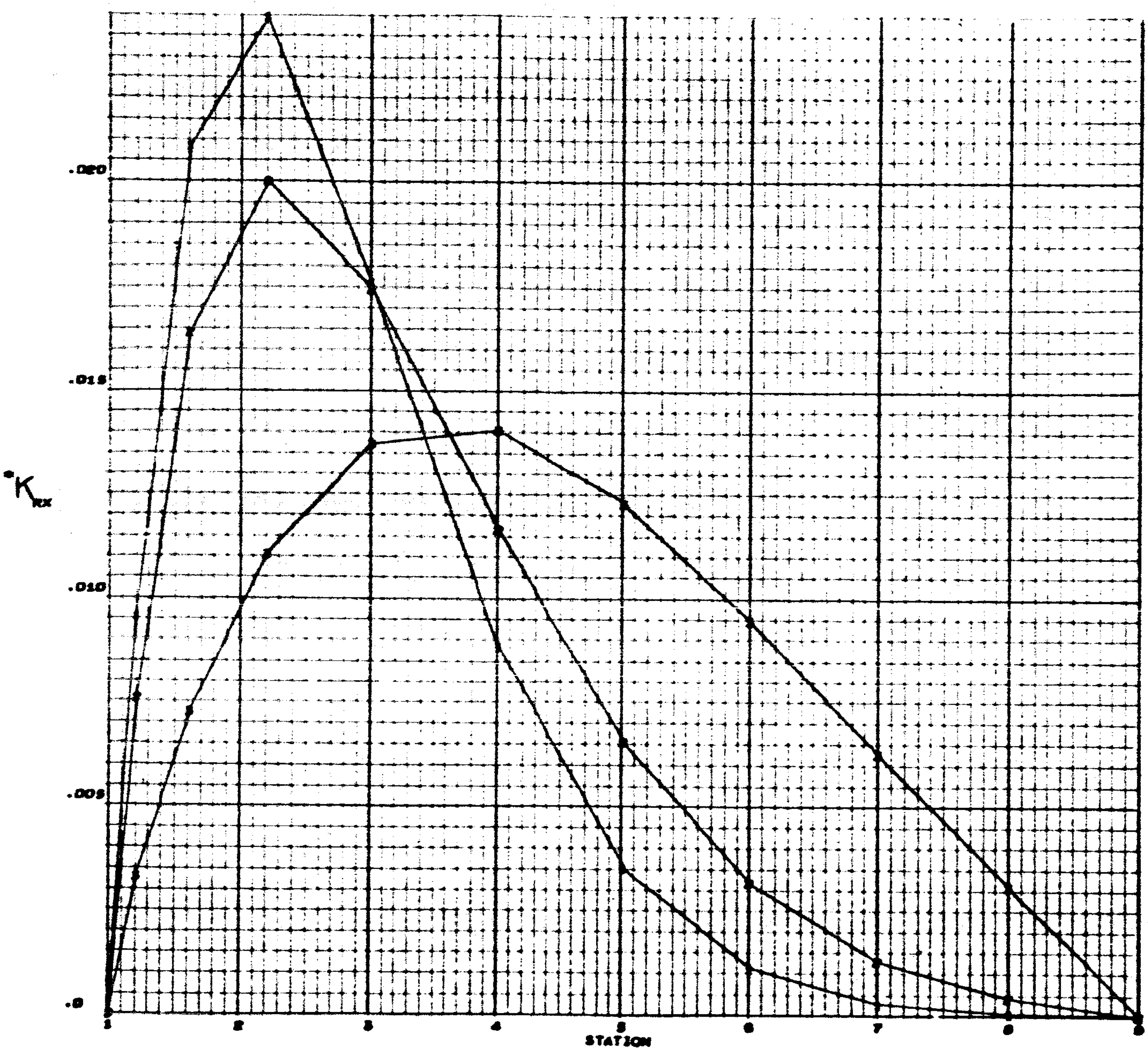
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

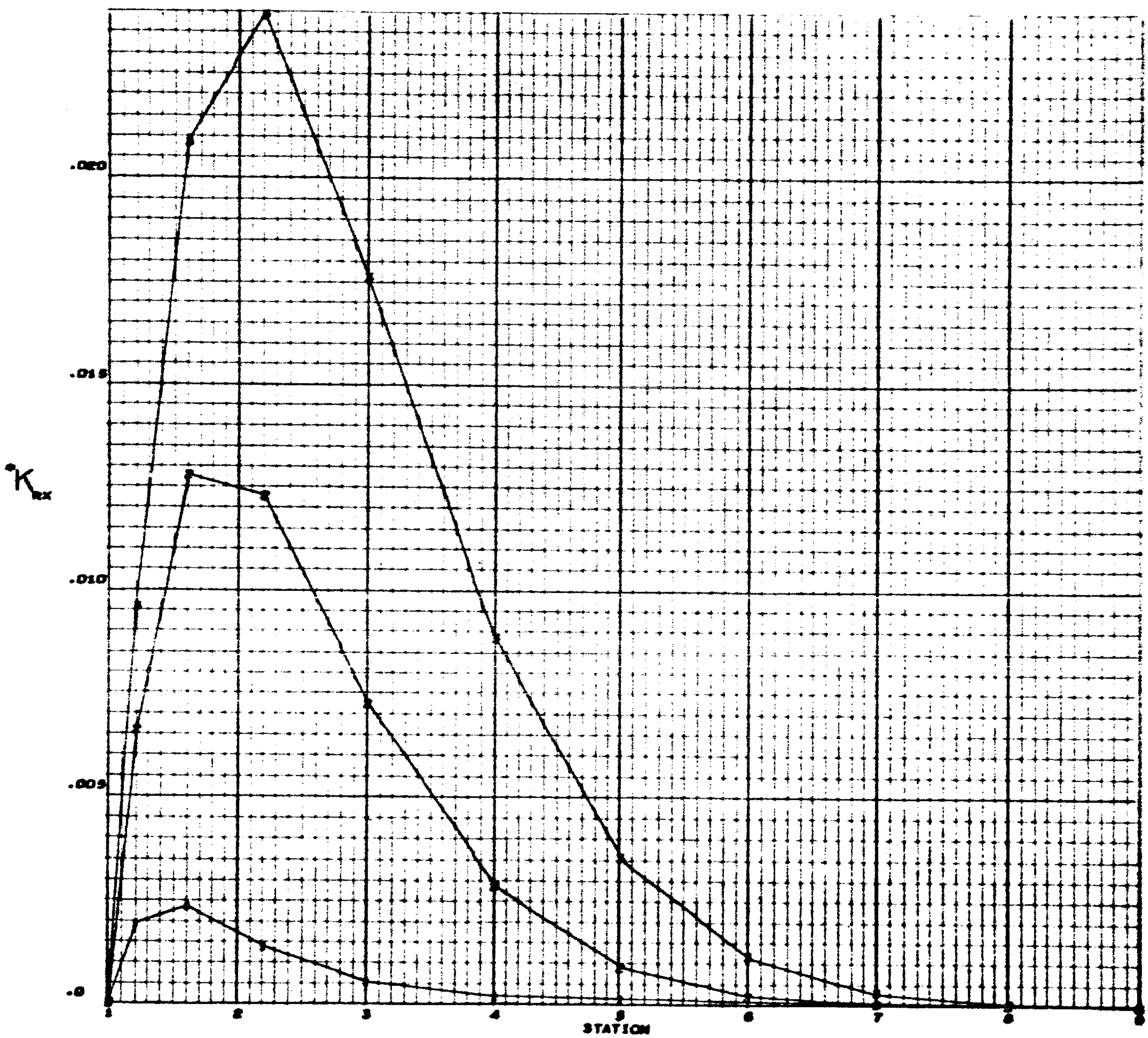
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

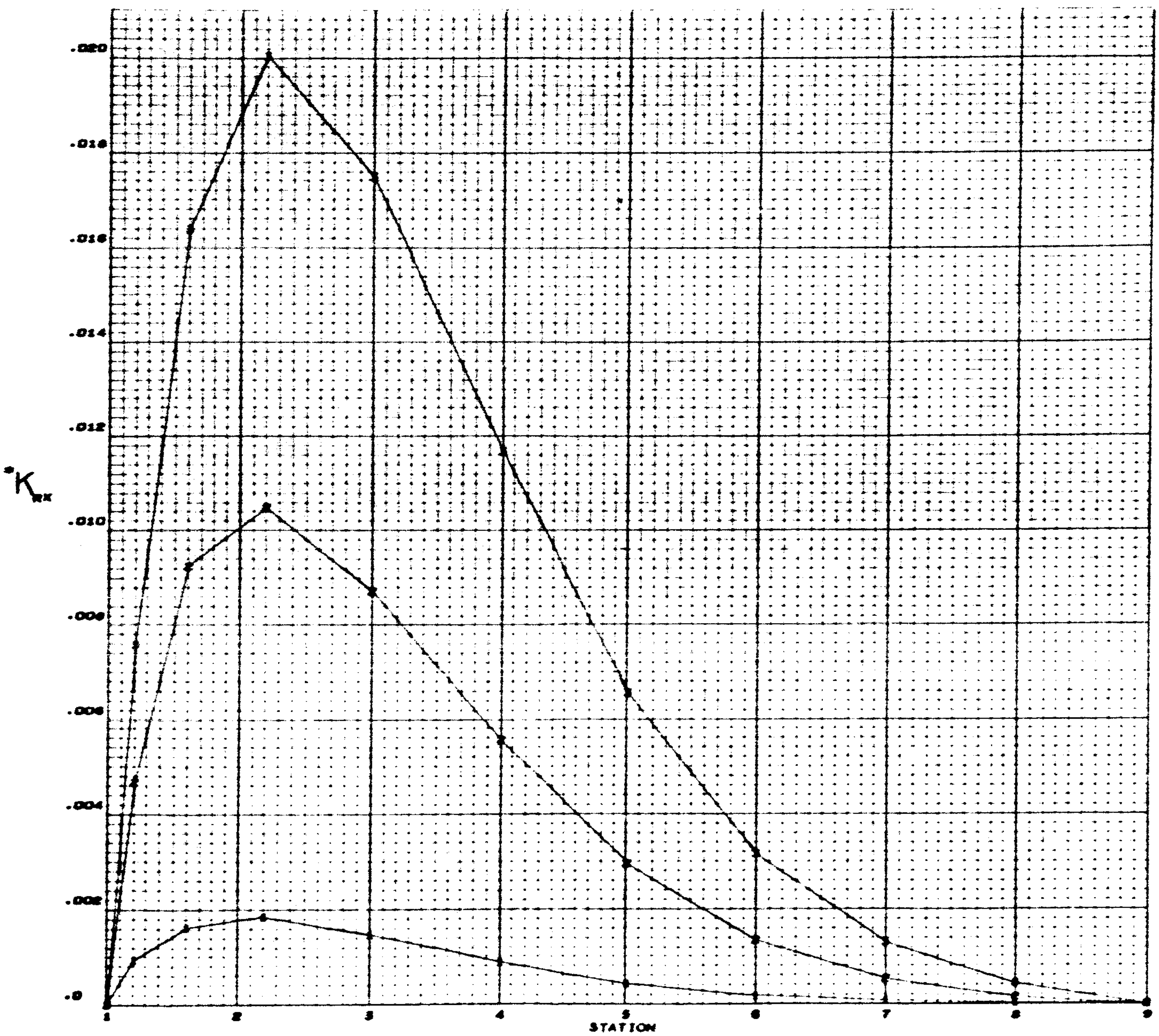
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.09

*NOTE - ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE

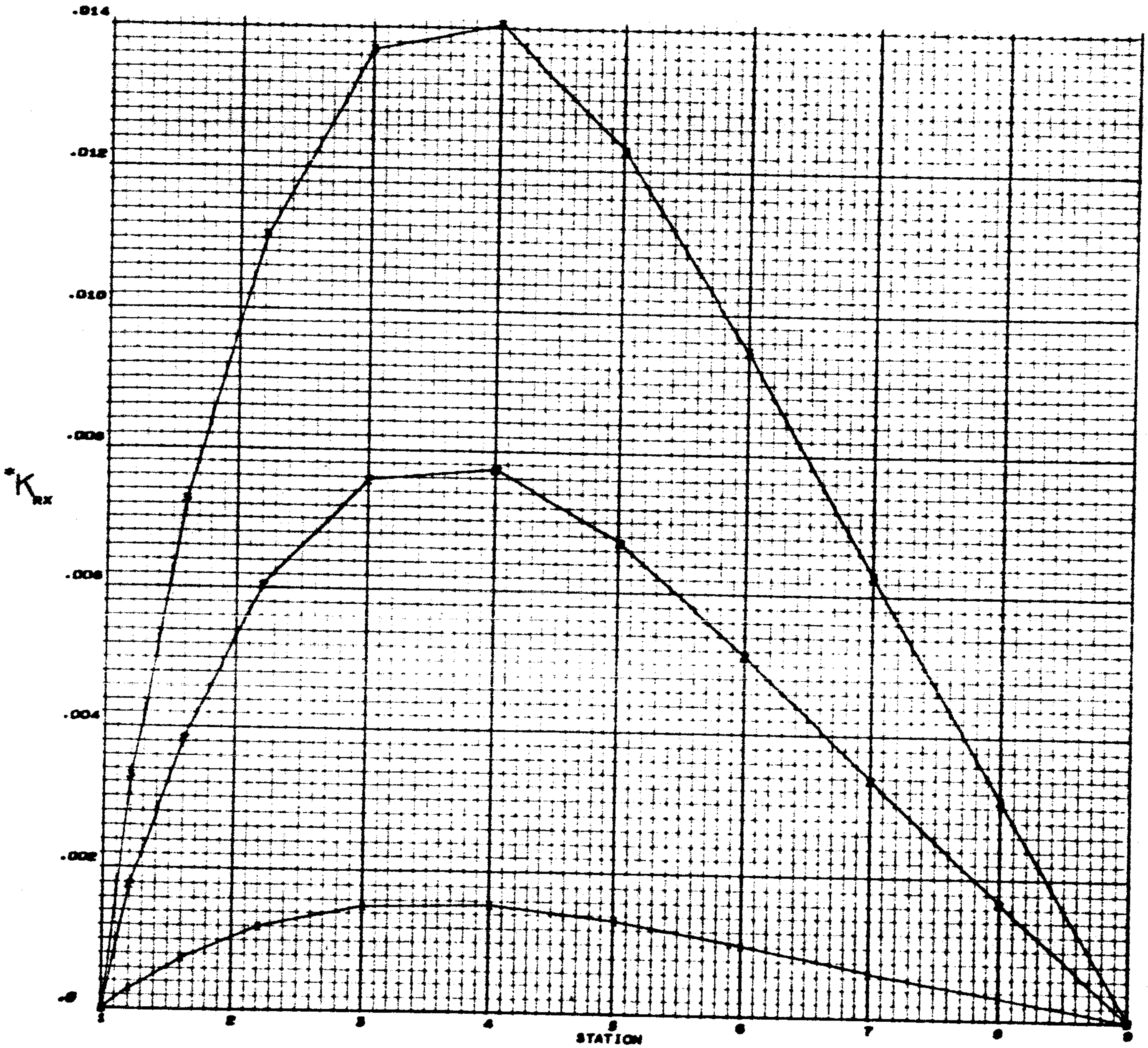


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

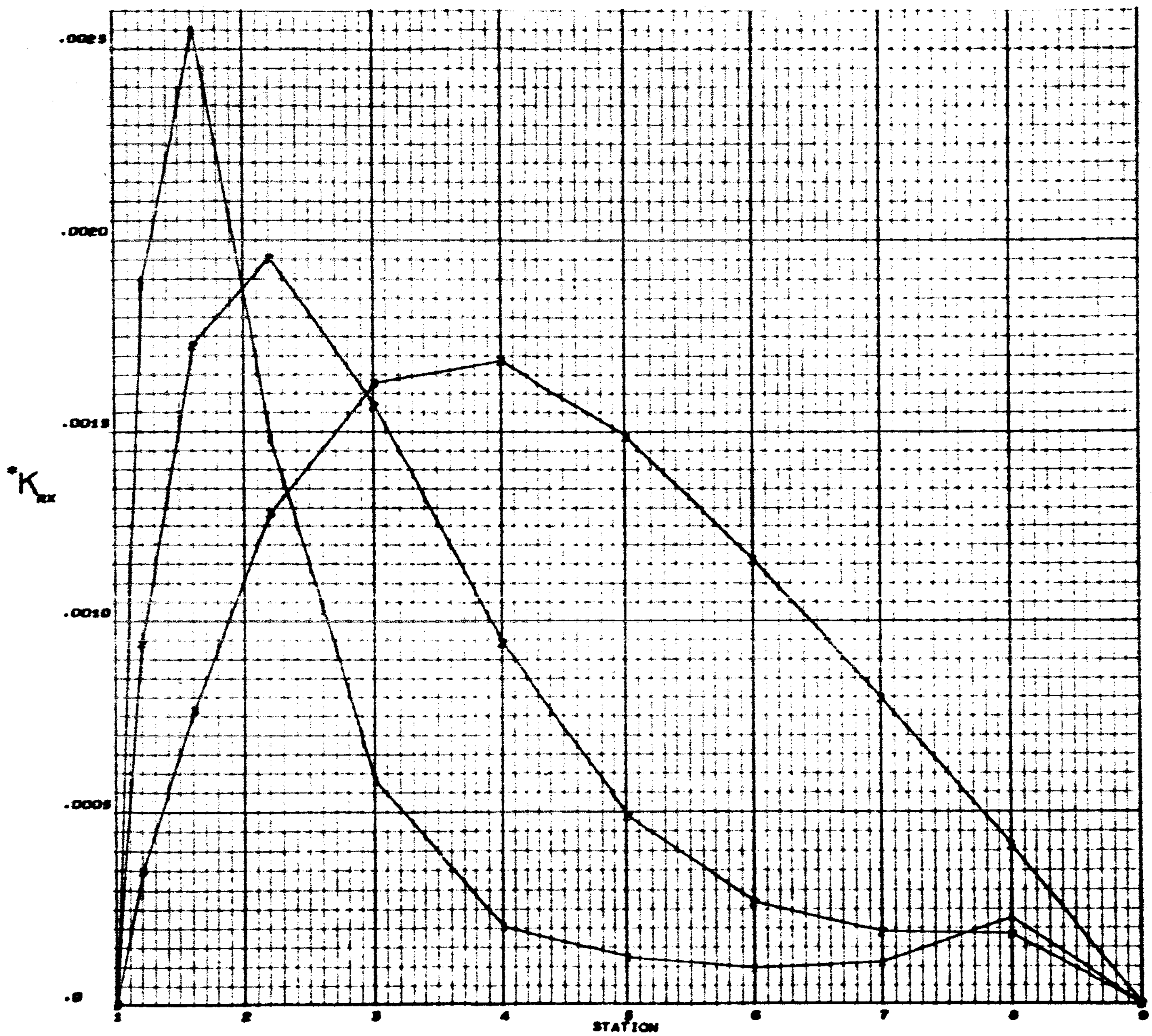
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.01, GJ/EI VARIABLE



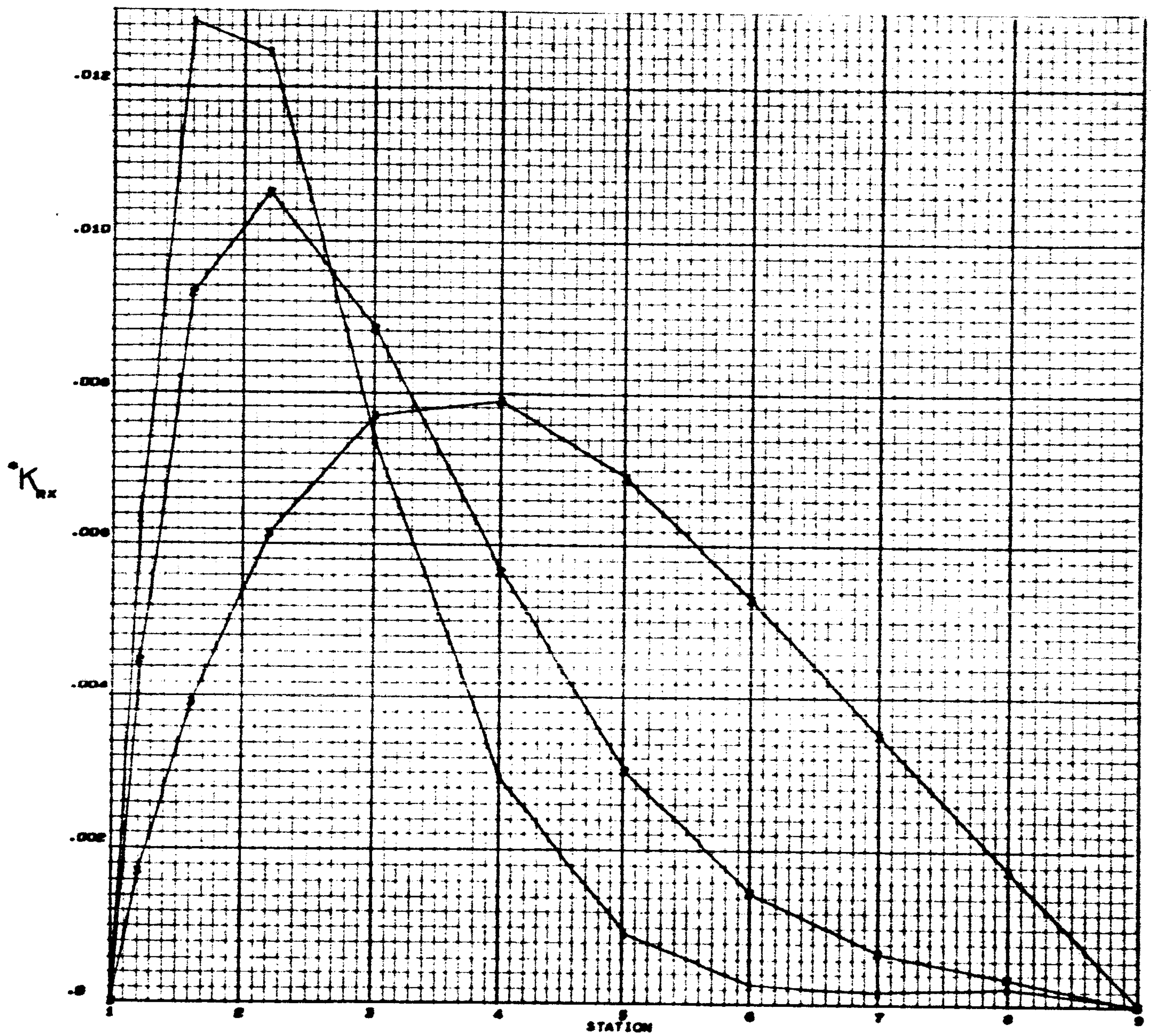
CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER

R_X, ROTATION ABOUT THE X AXIS

C/R = 0.05, GJ/EI VARIABLE



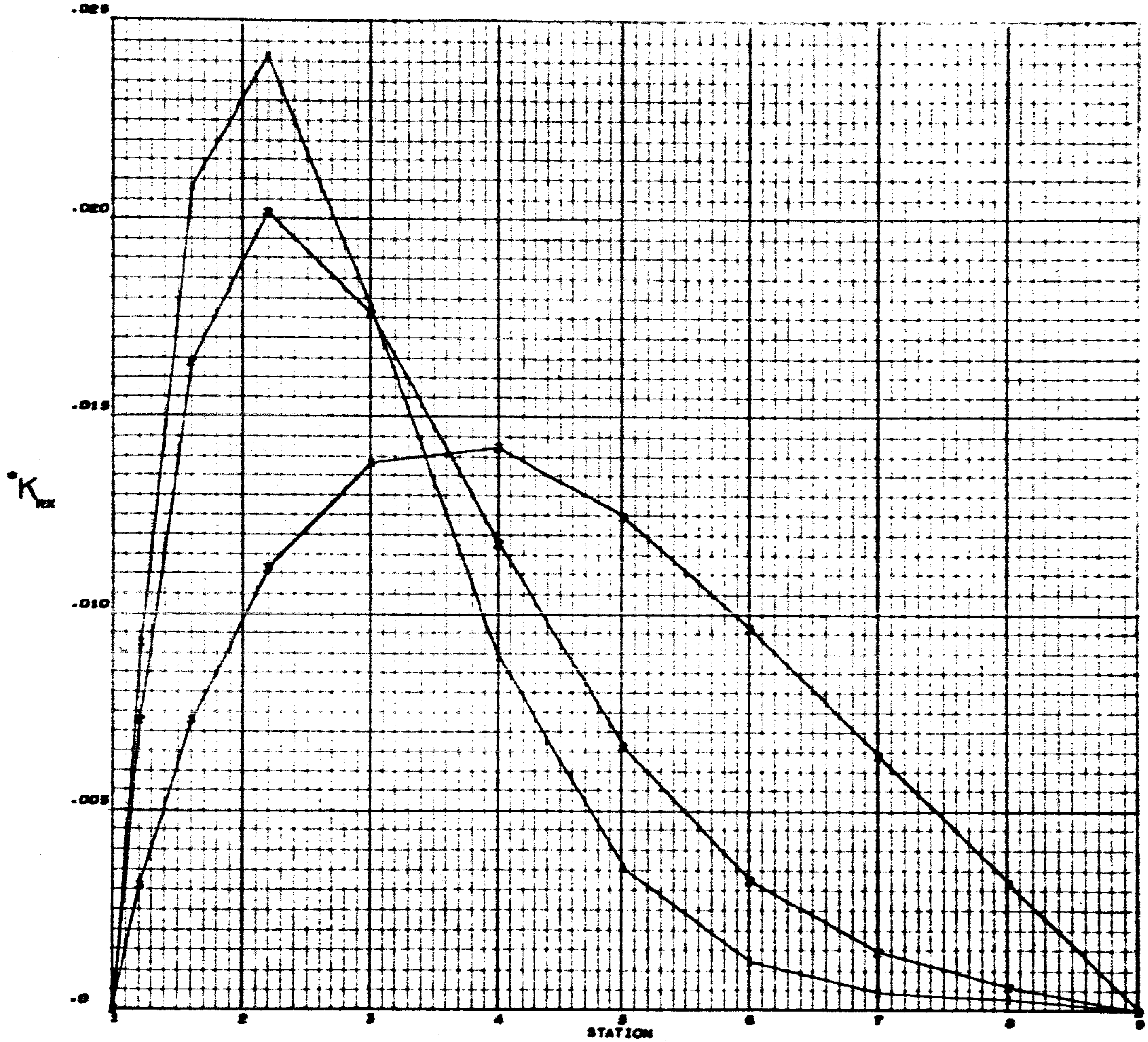
CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER

R_X, ROTATION ABOUT THE X AXIS

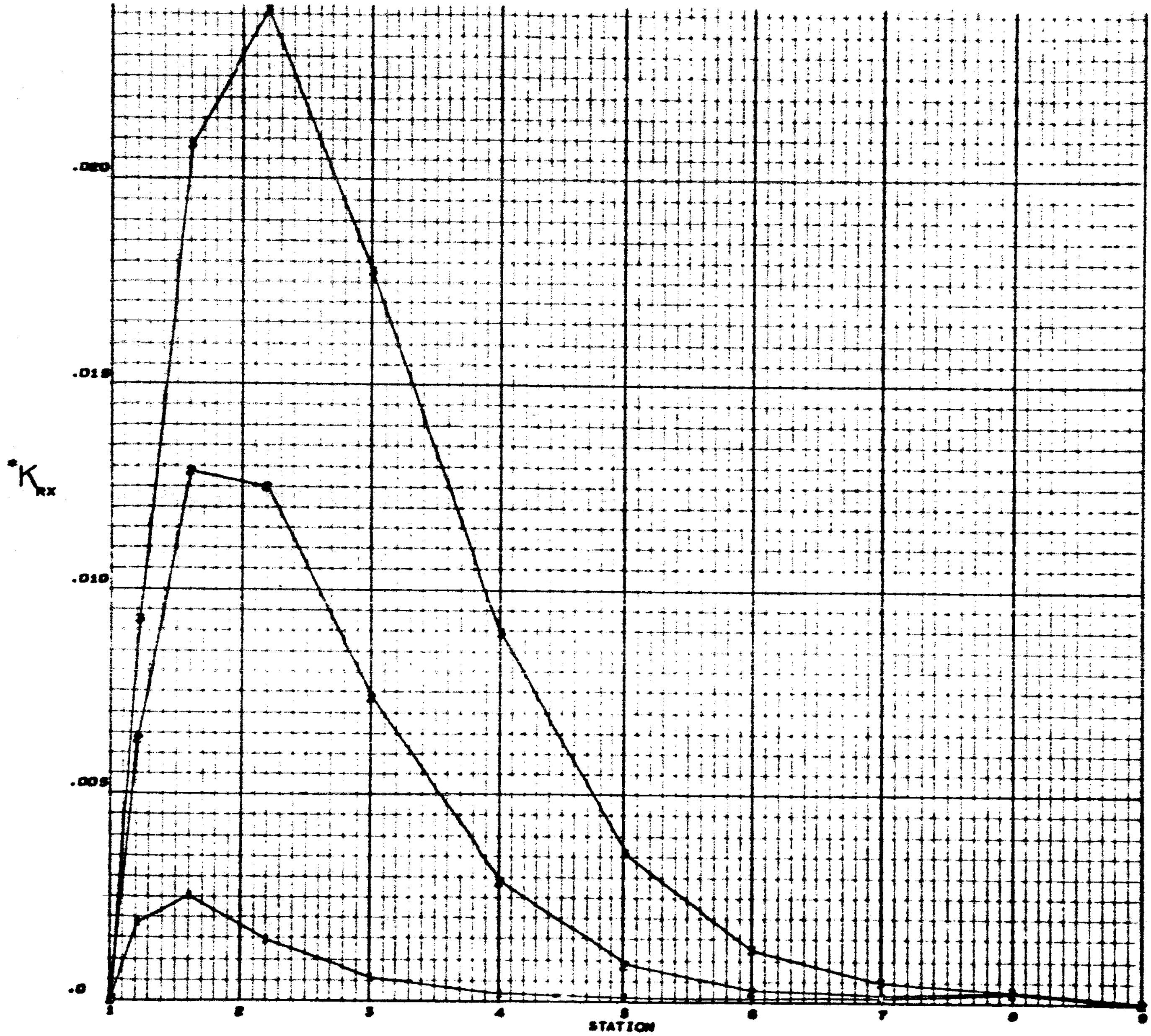
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

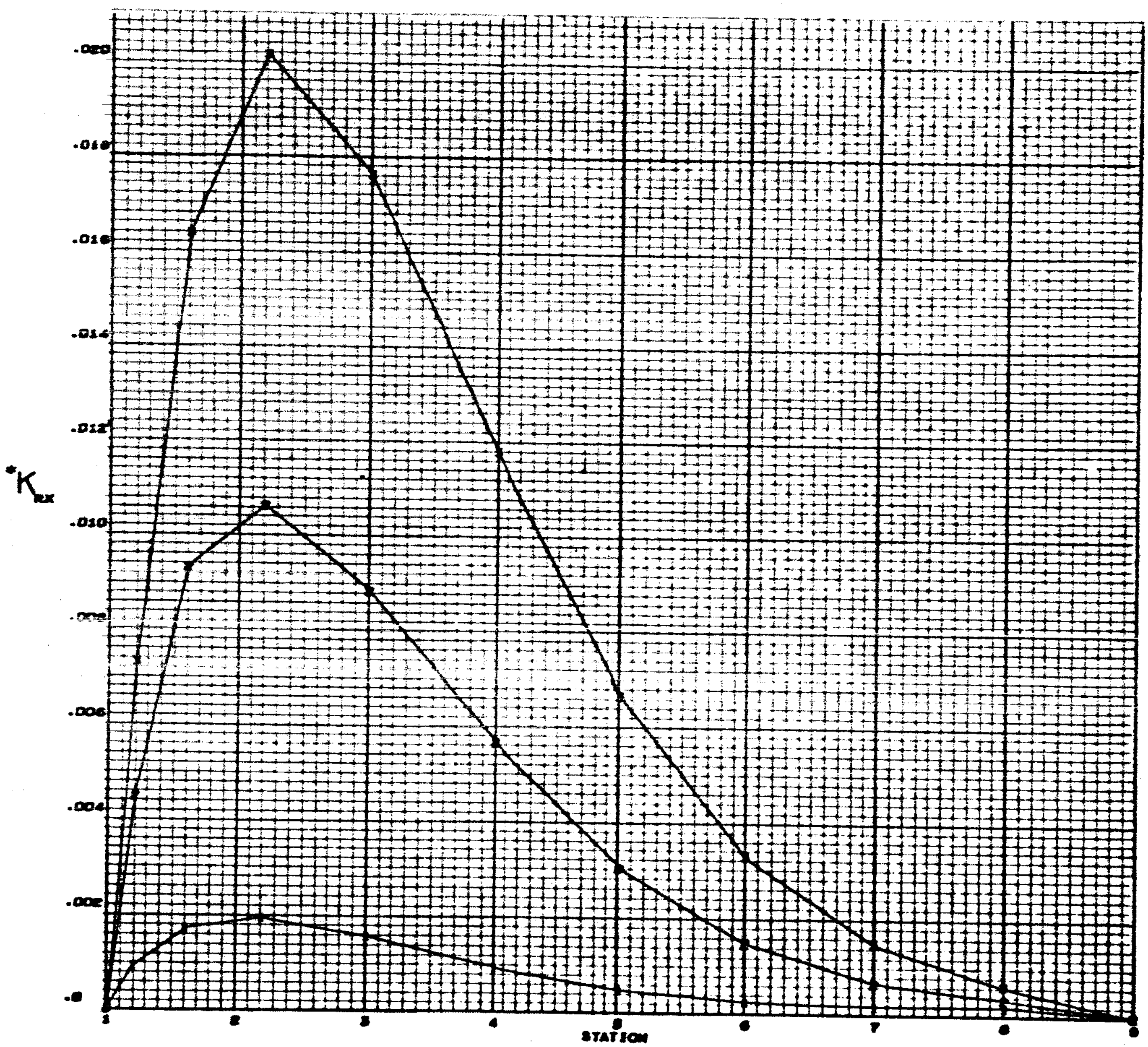
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.02
3	0.05

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

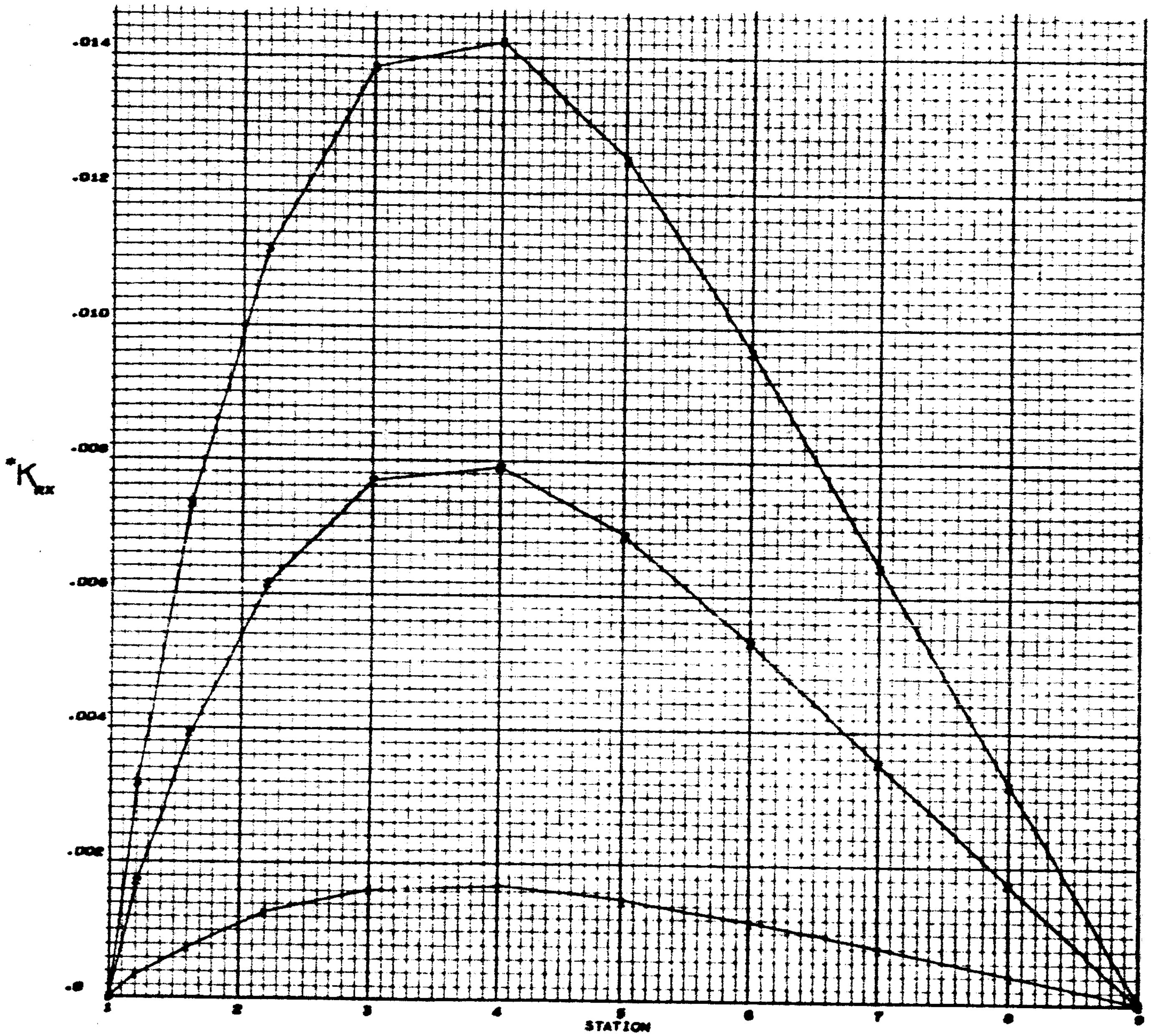
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

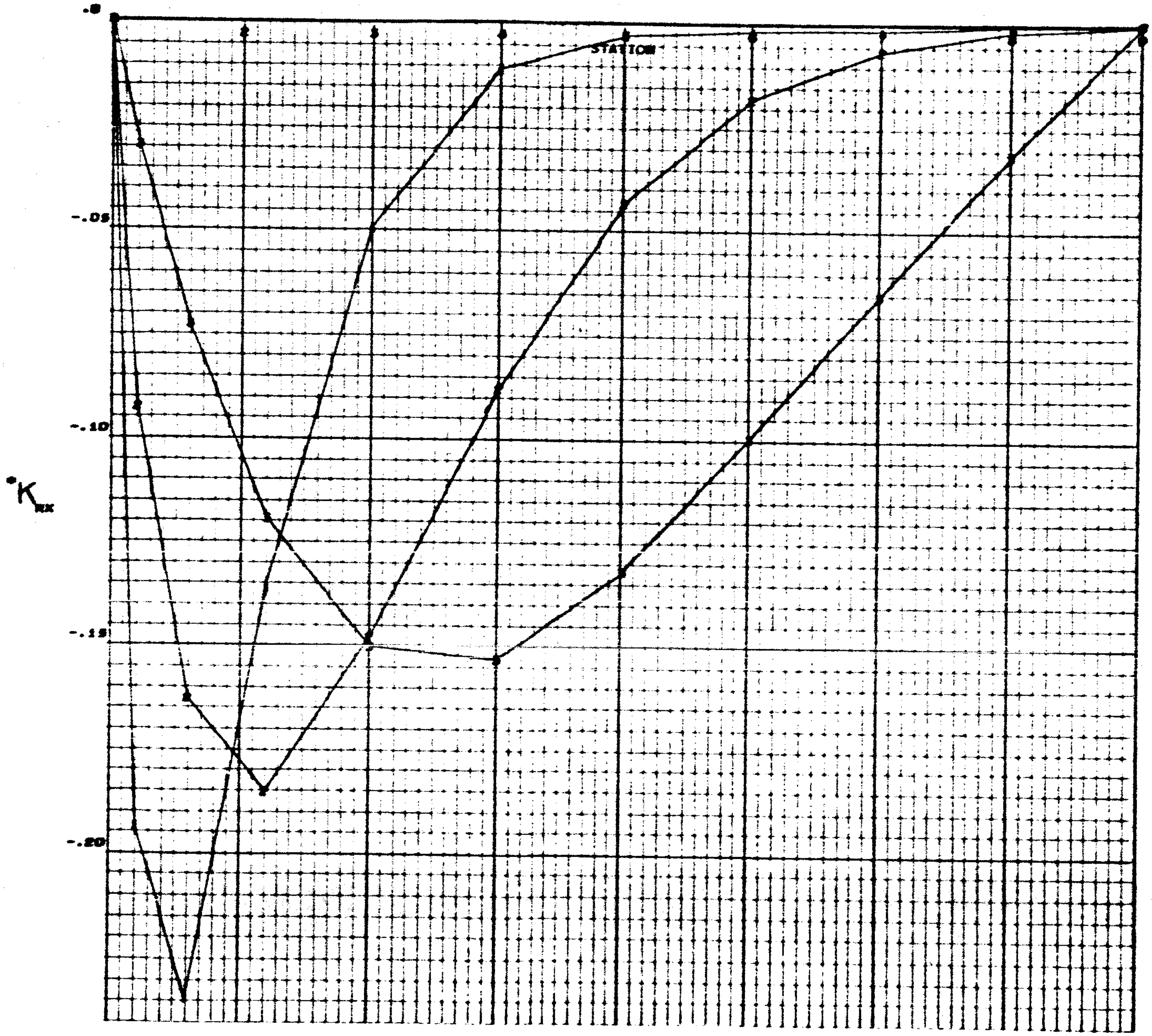
UNIT FORCE DISTRIBUTED OVER ELEMENT I ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

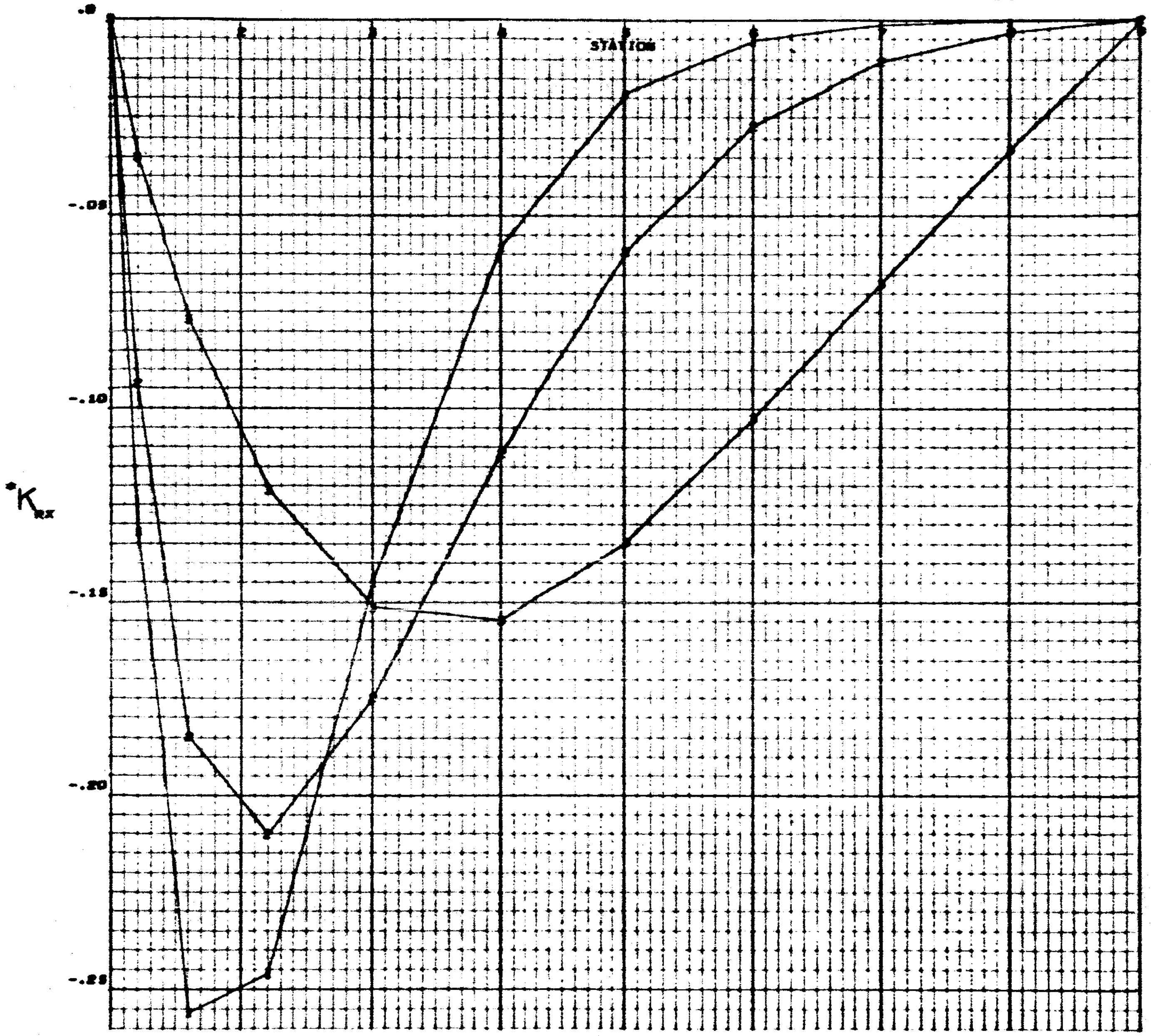
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

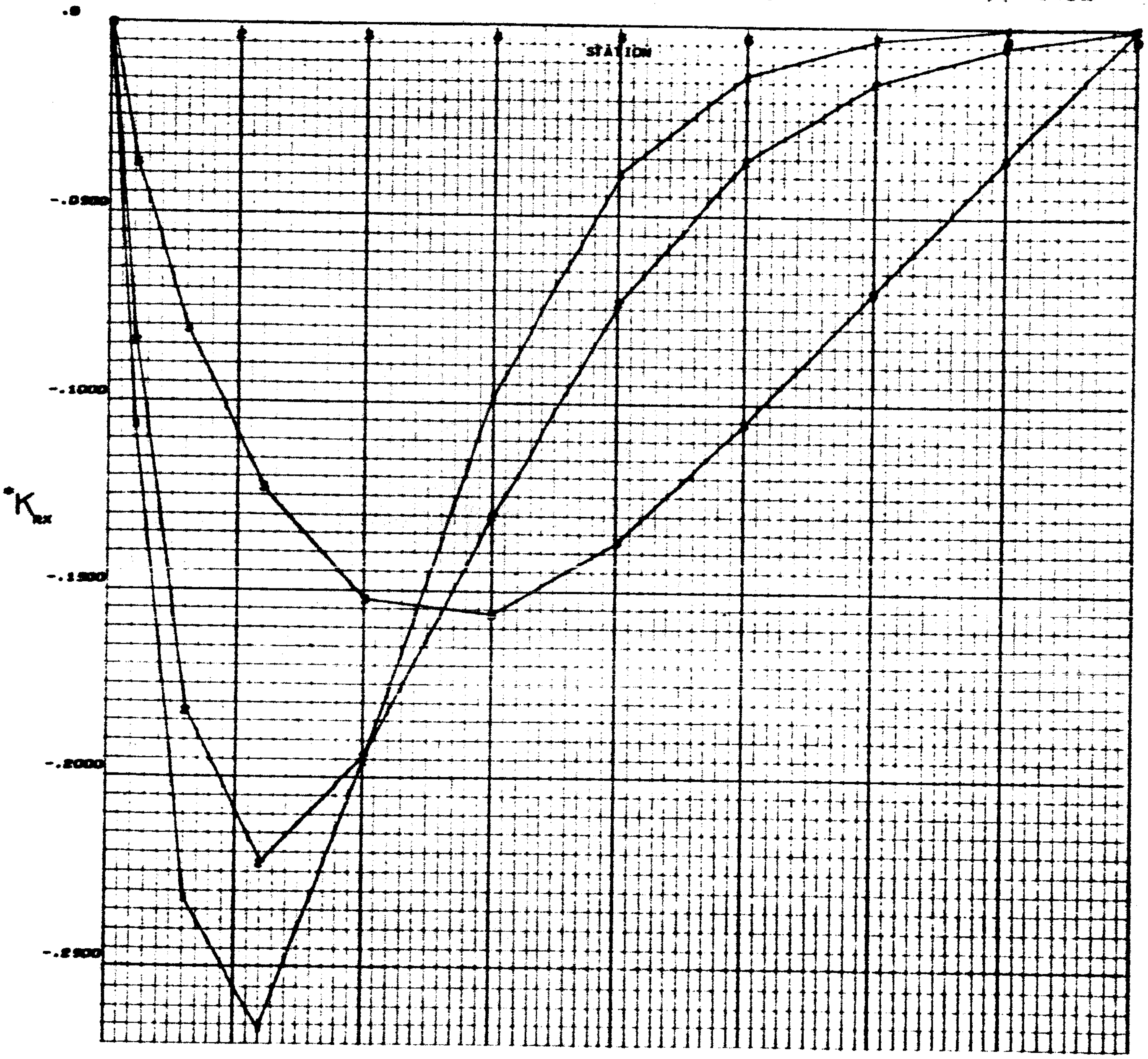
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

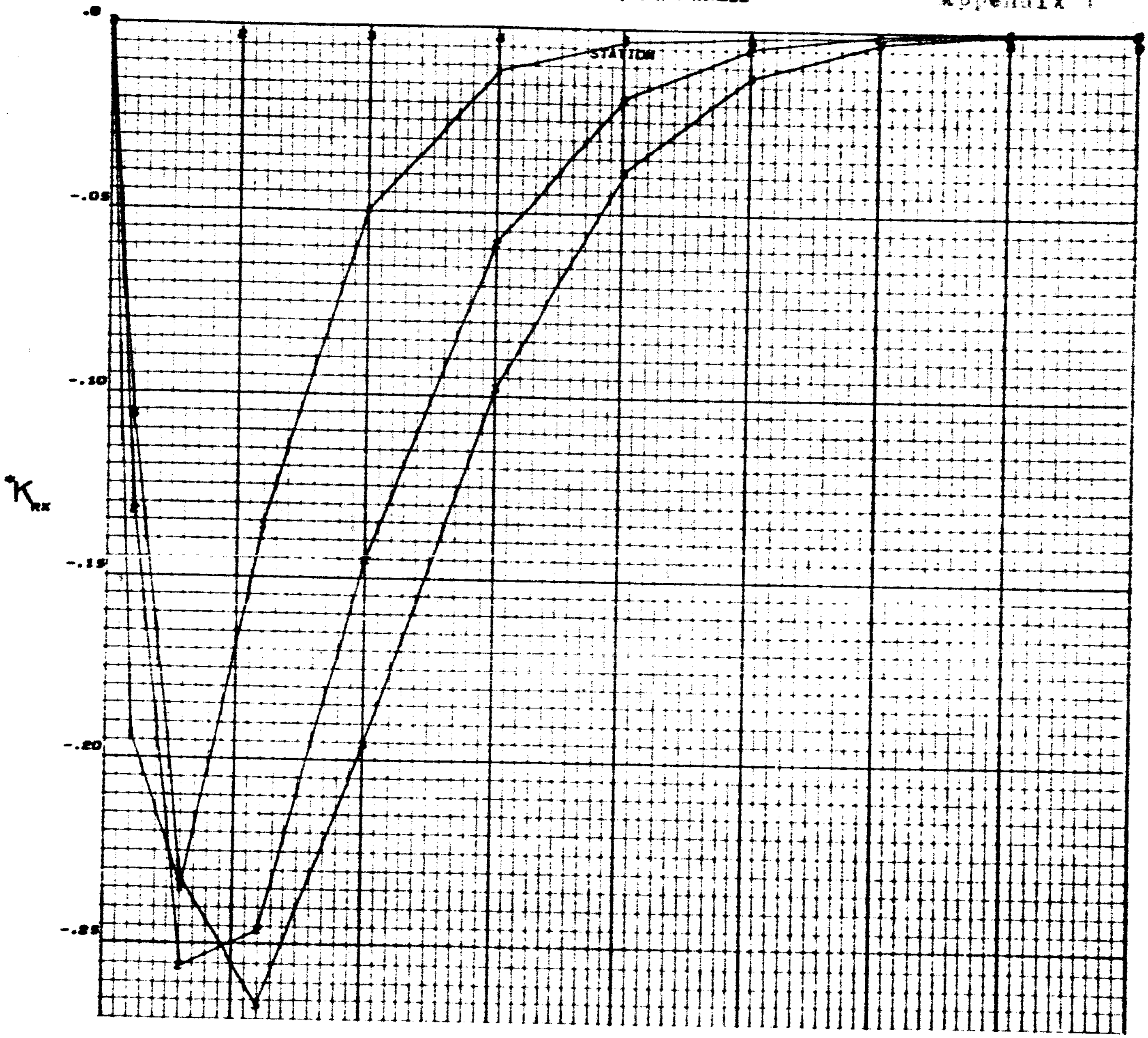
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}$(R /EI)

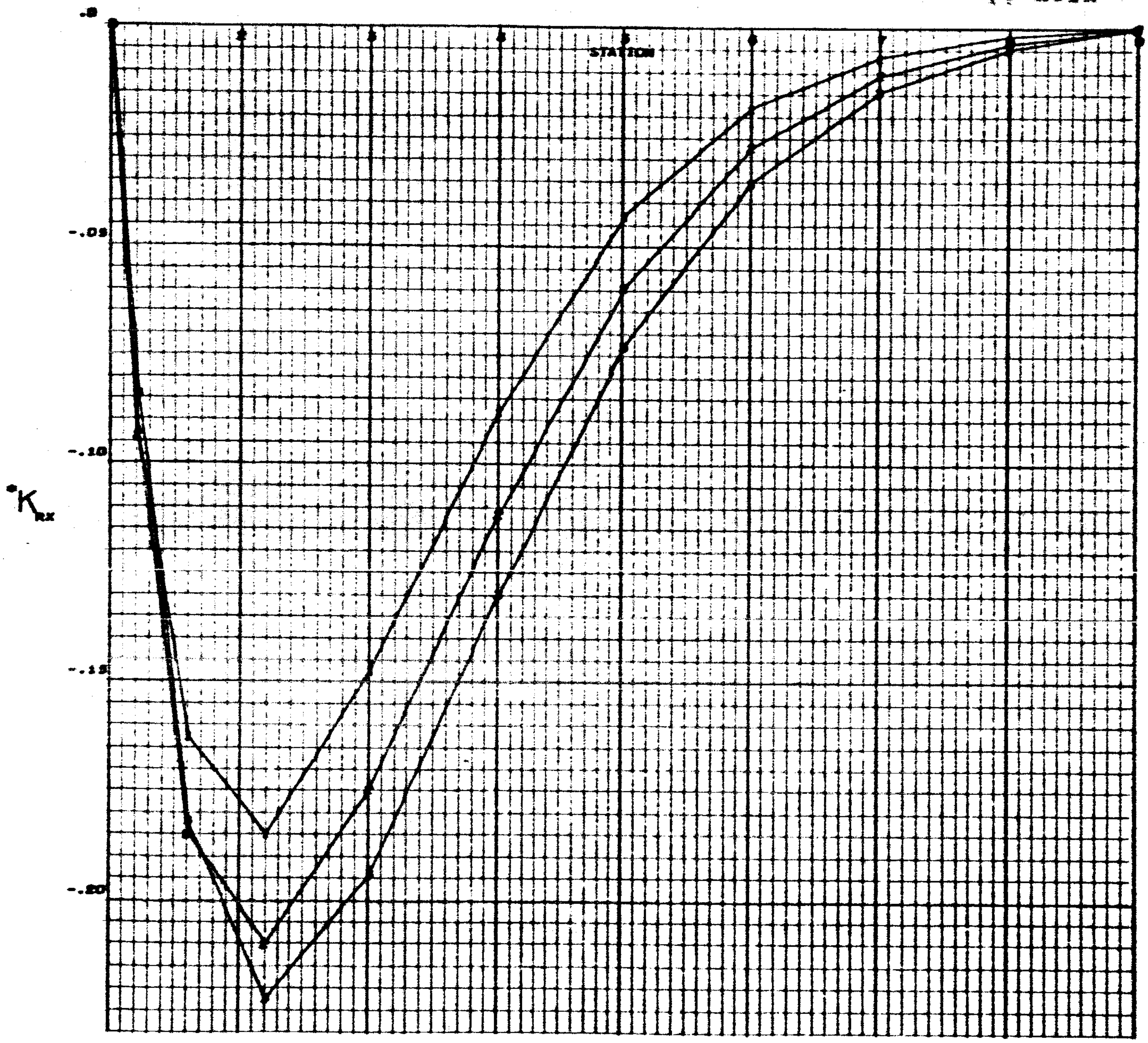
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

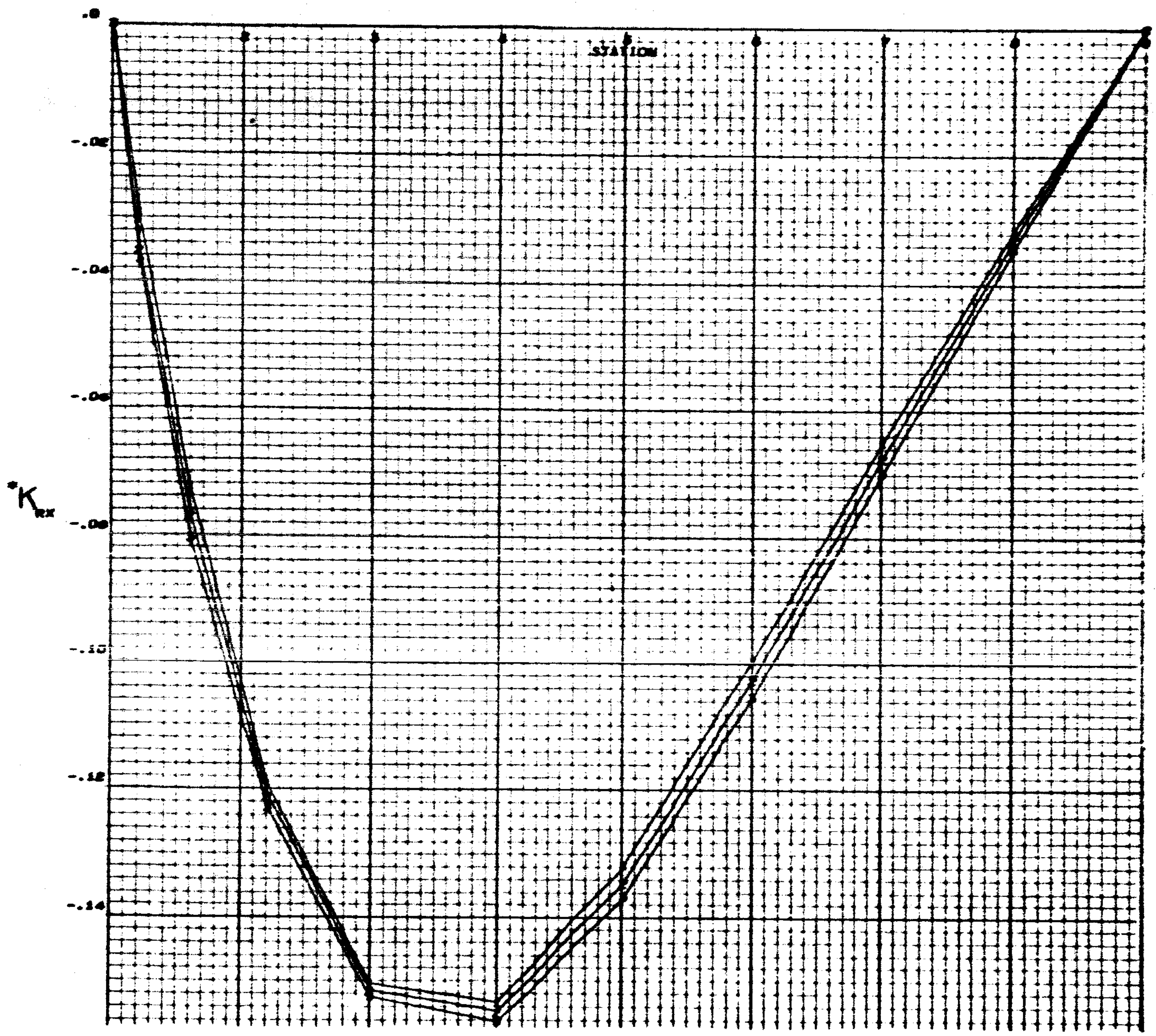
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
2	[illegible]
3	[illegible]

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}$(R /EI)

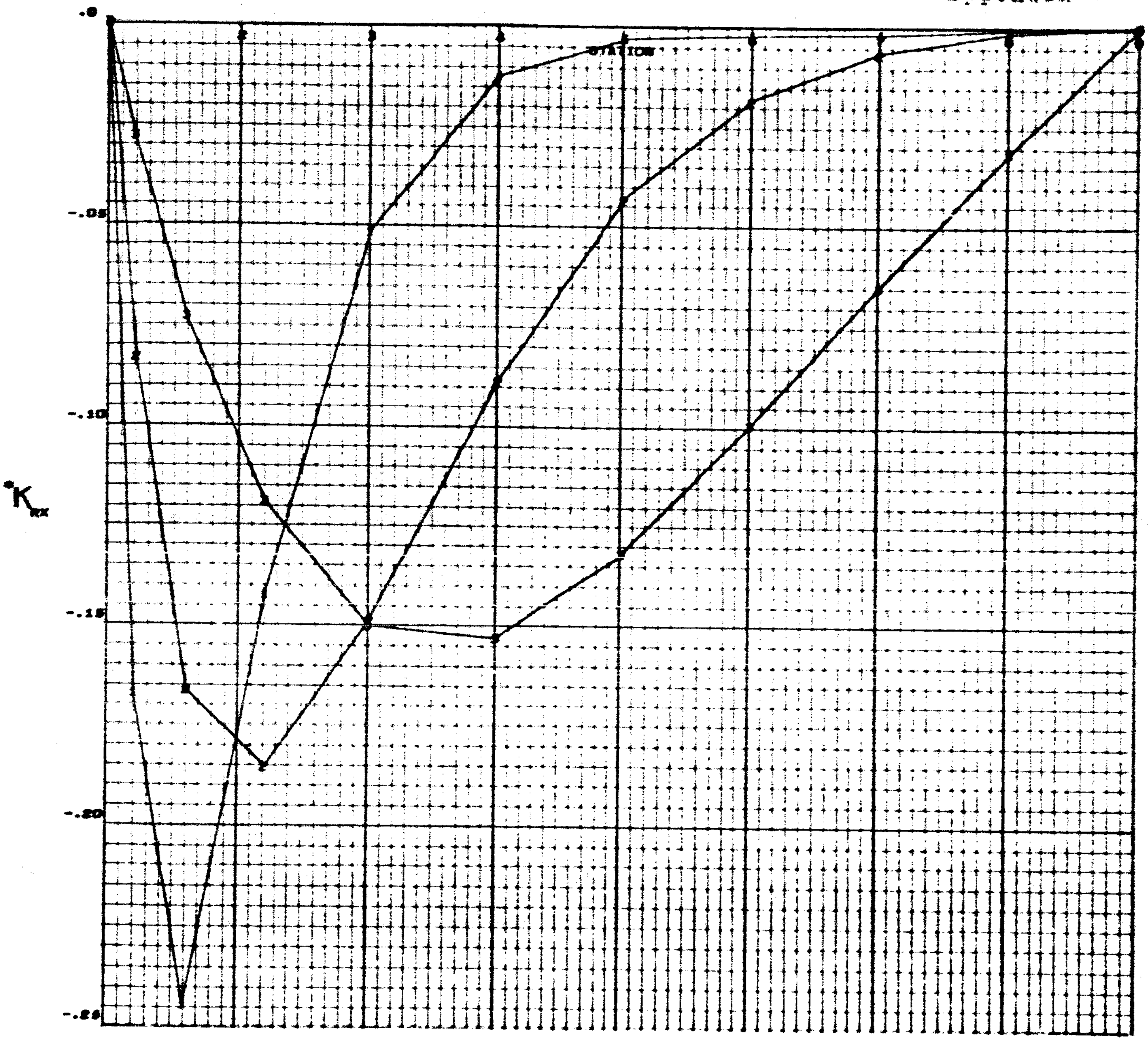
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

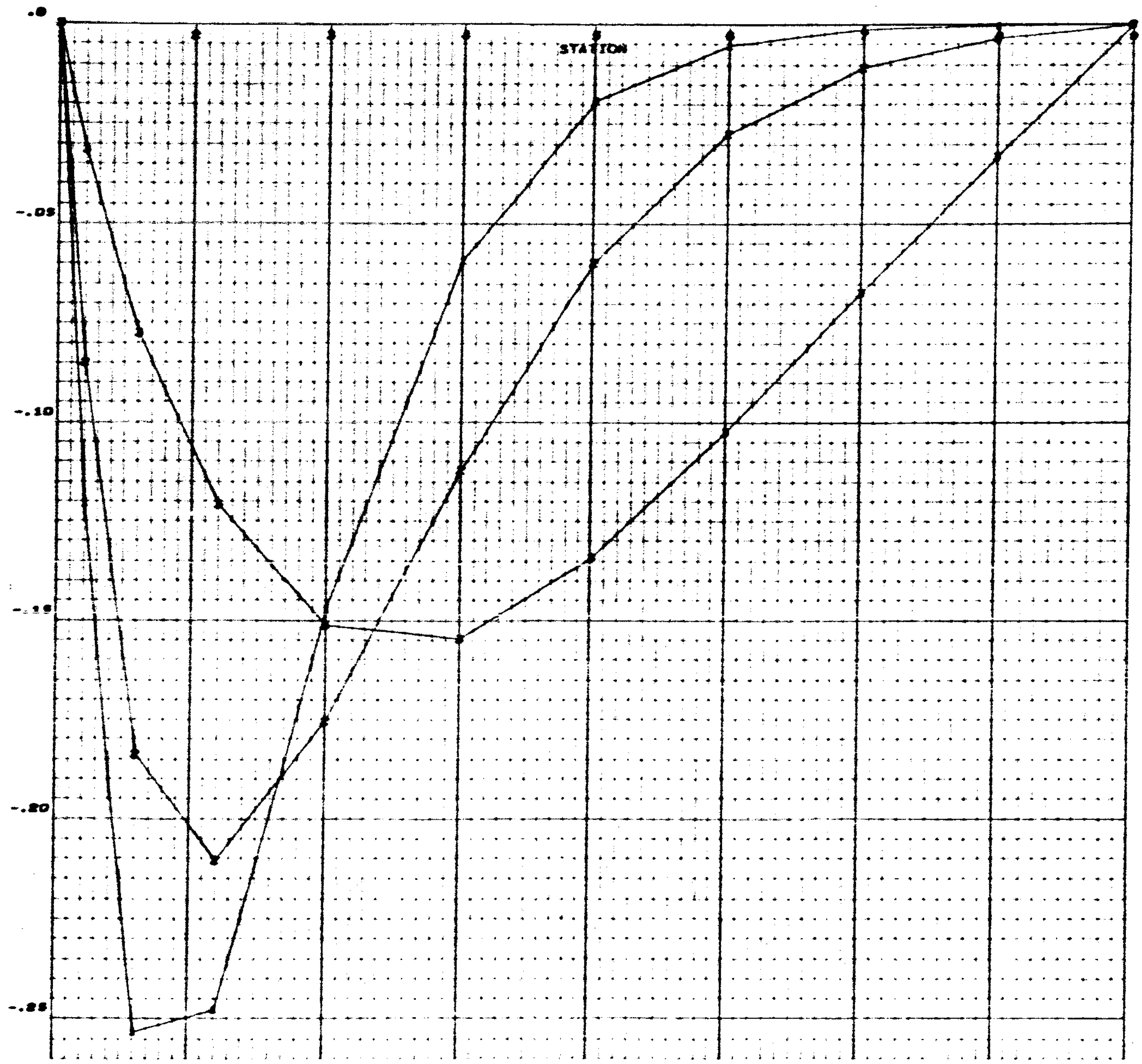
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ /EI)$

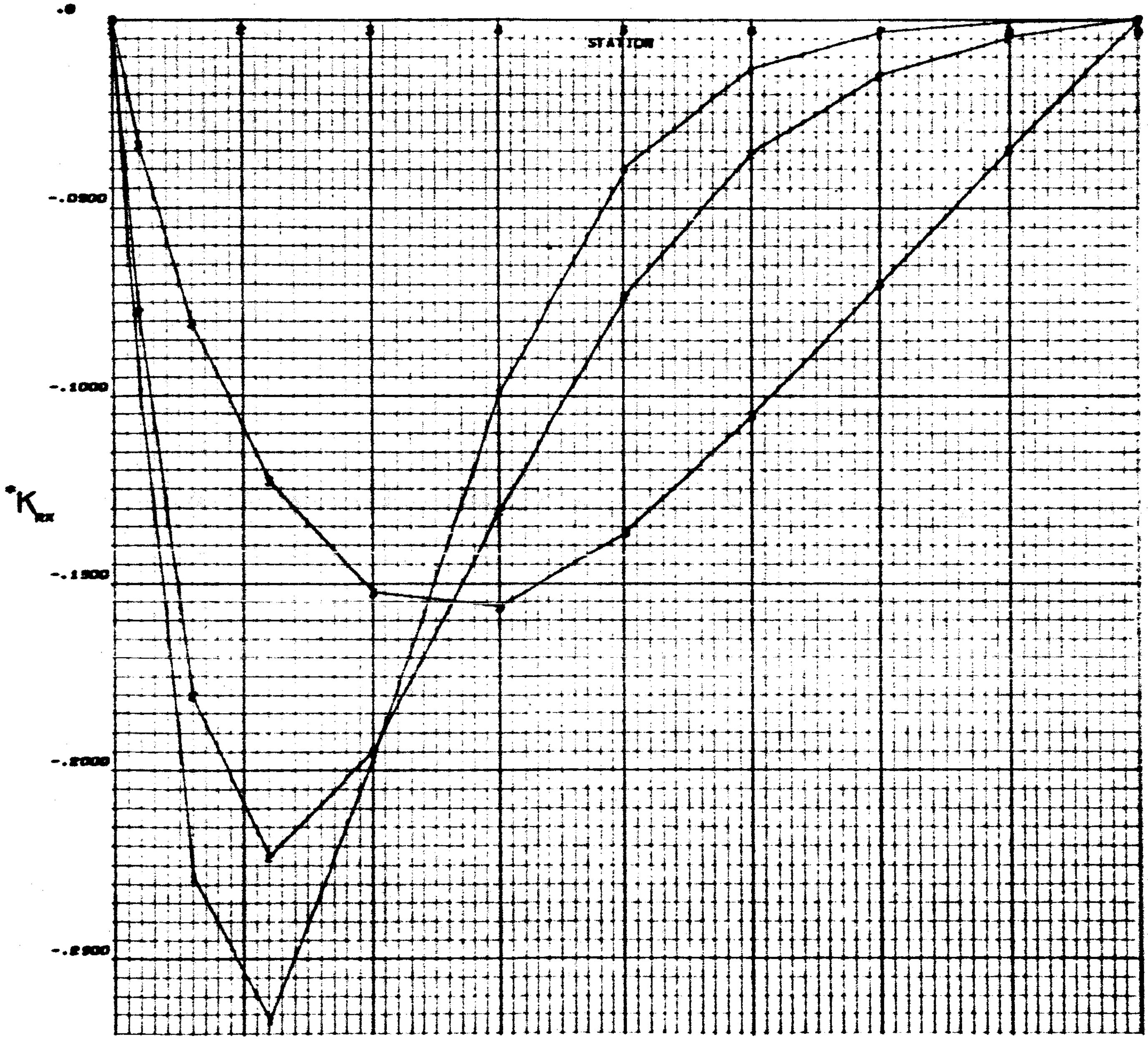
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
C/R = 0.09, GJ/EI VARIABLE

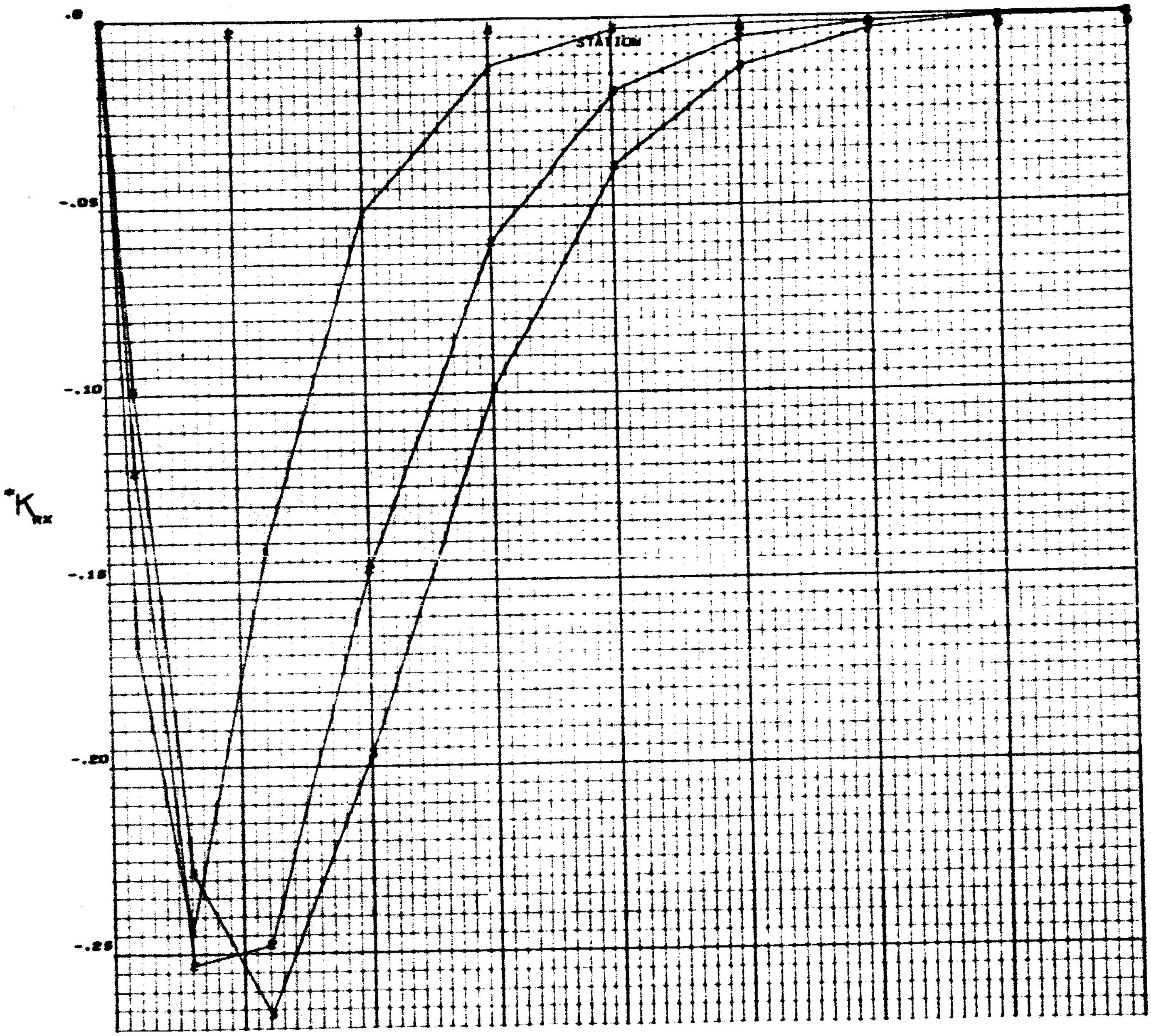


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

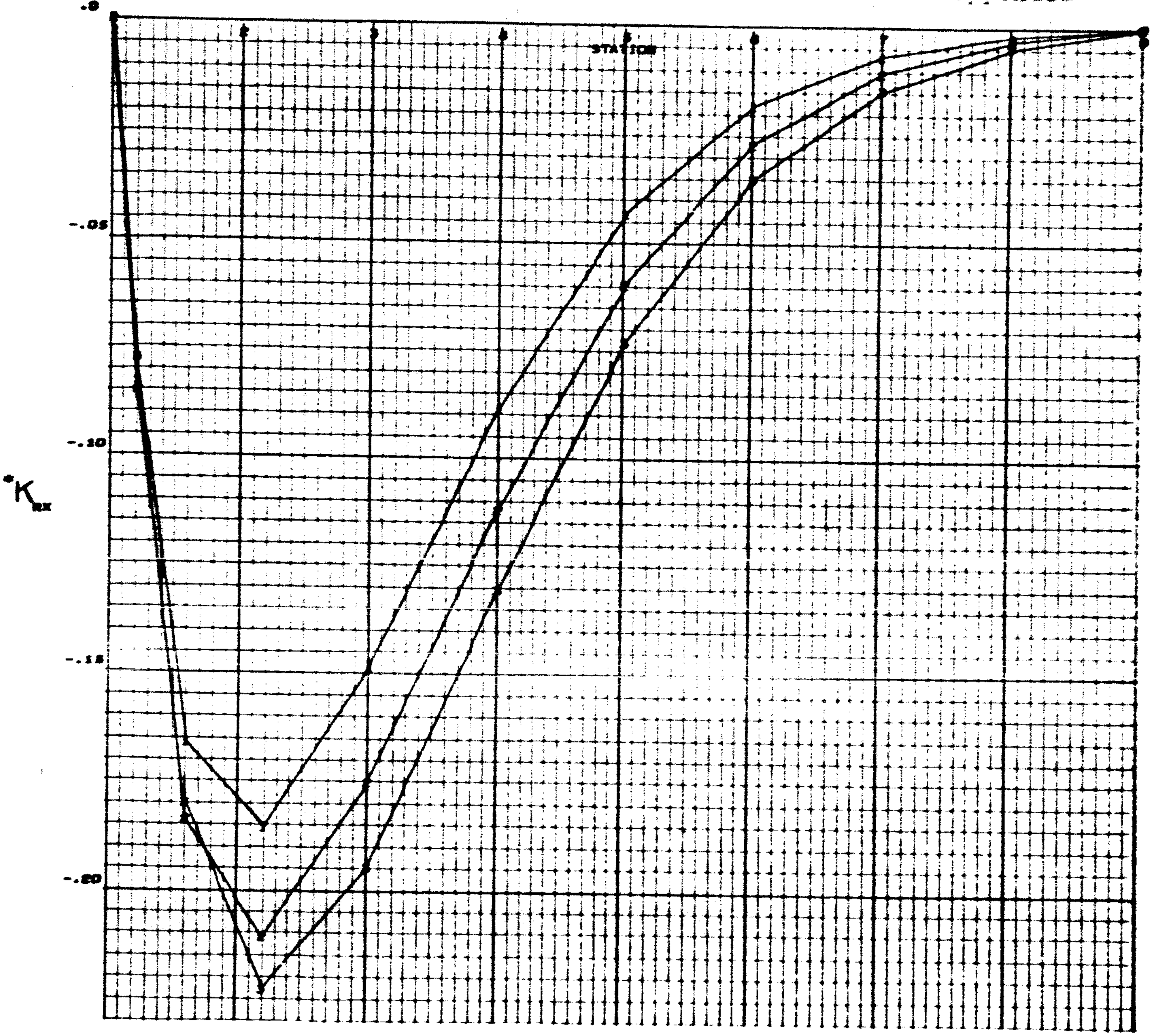
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	[illegible]
3	[illegible]

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE



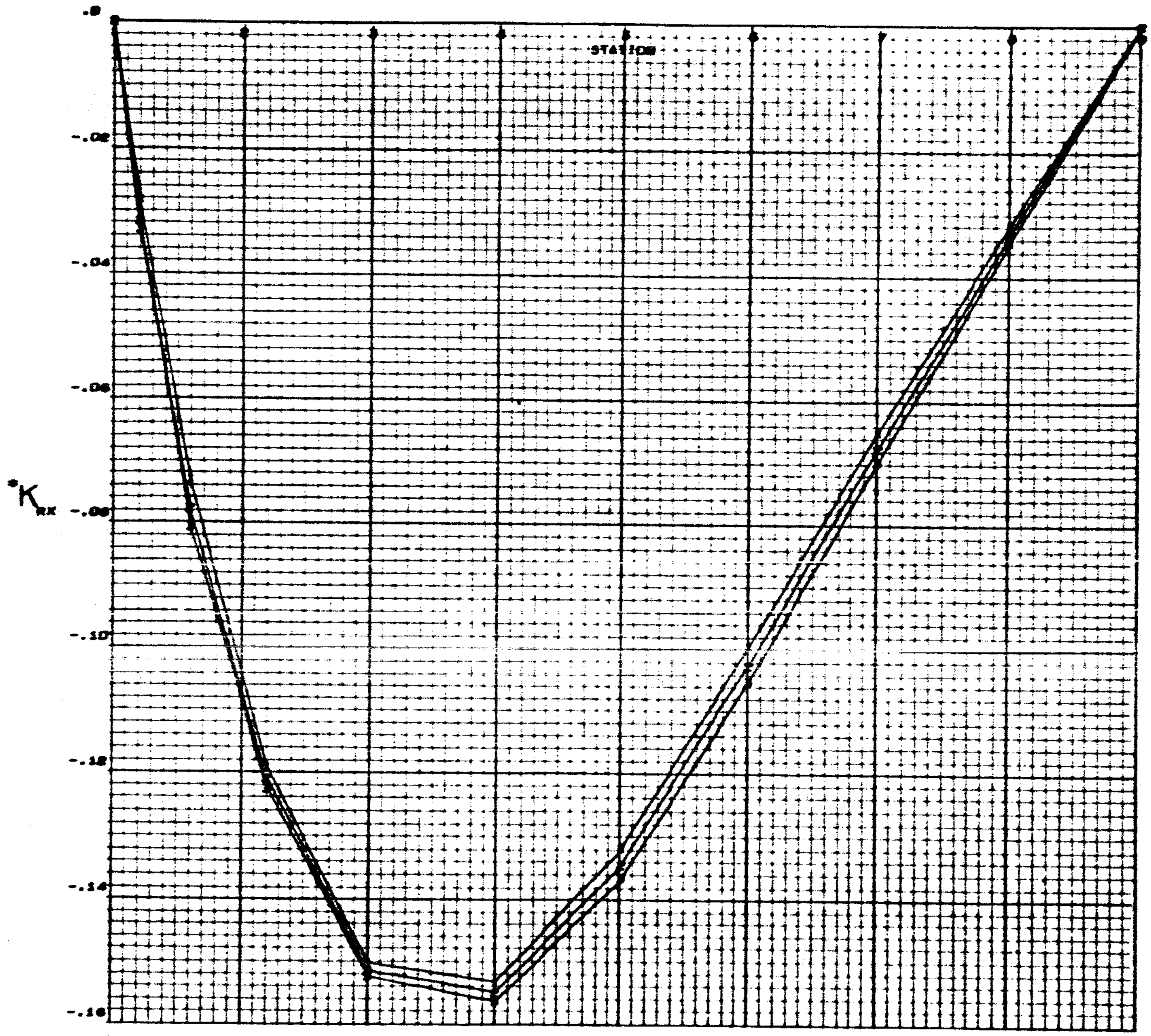
CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1

R_X, ROTATION ABOUT THE X AXIS

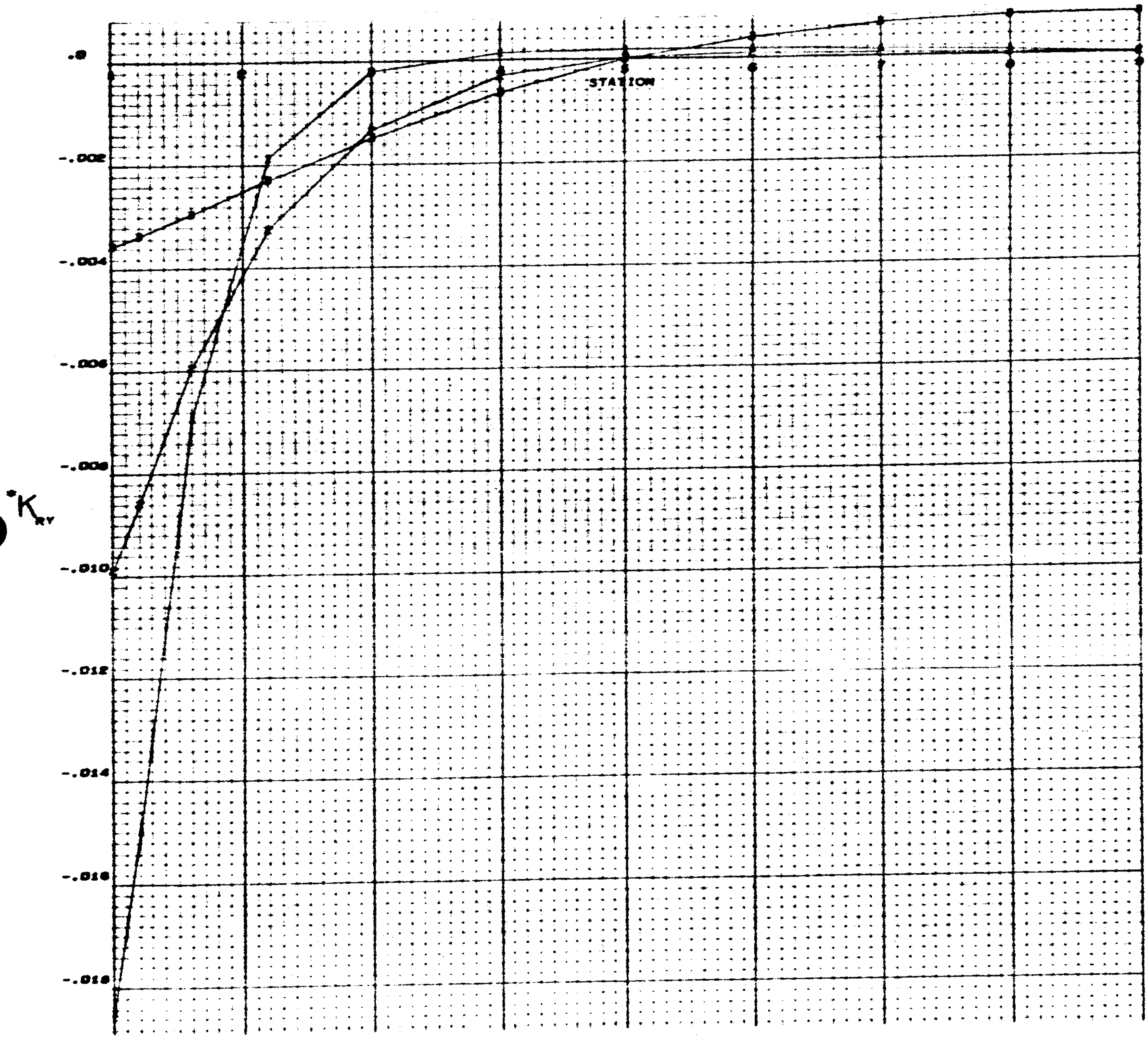
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.01, GJ/EI VARIABLE

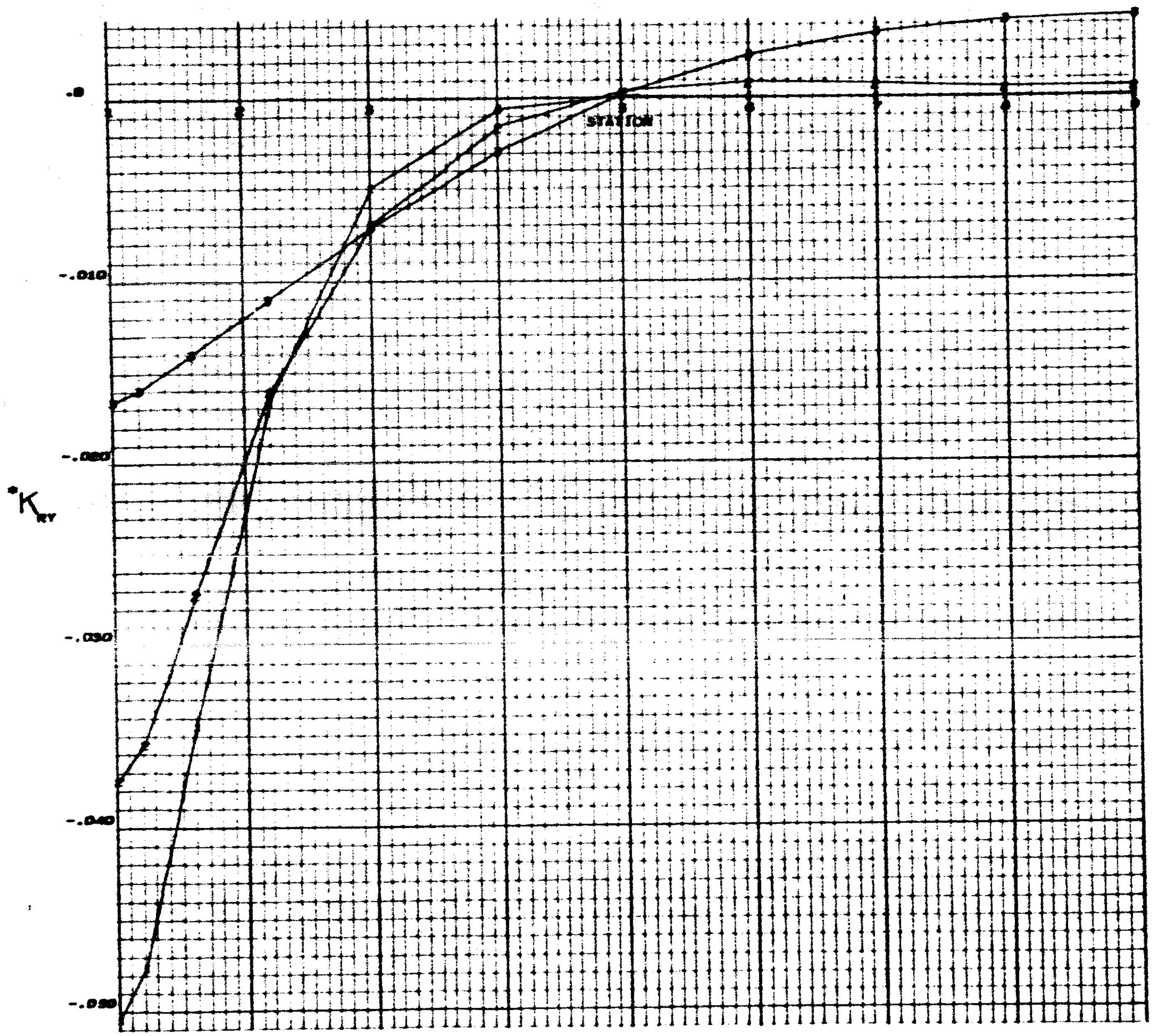


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

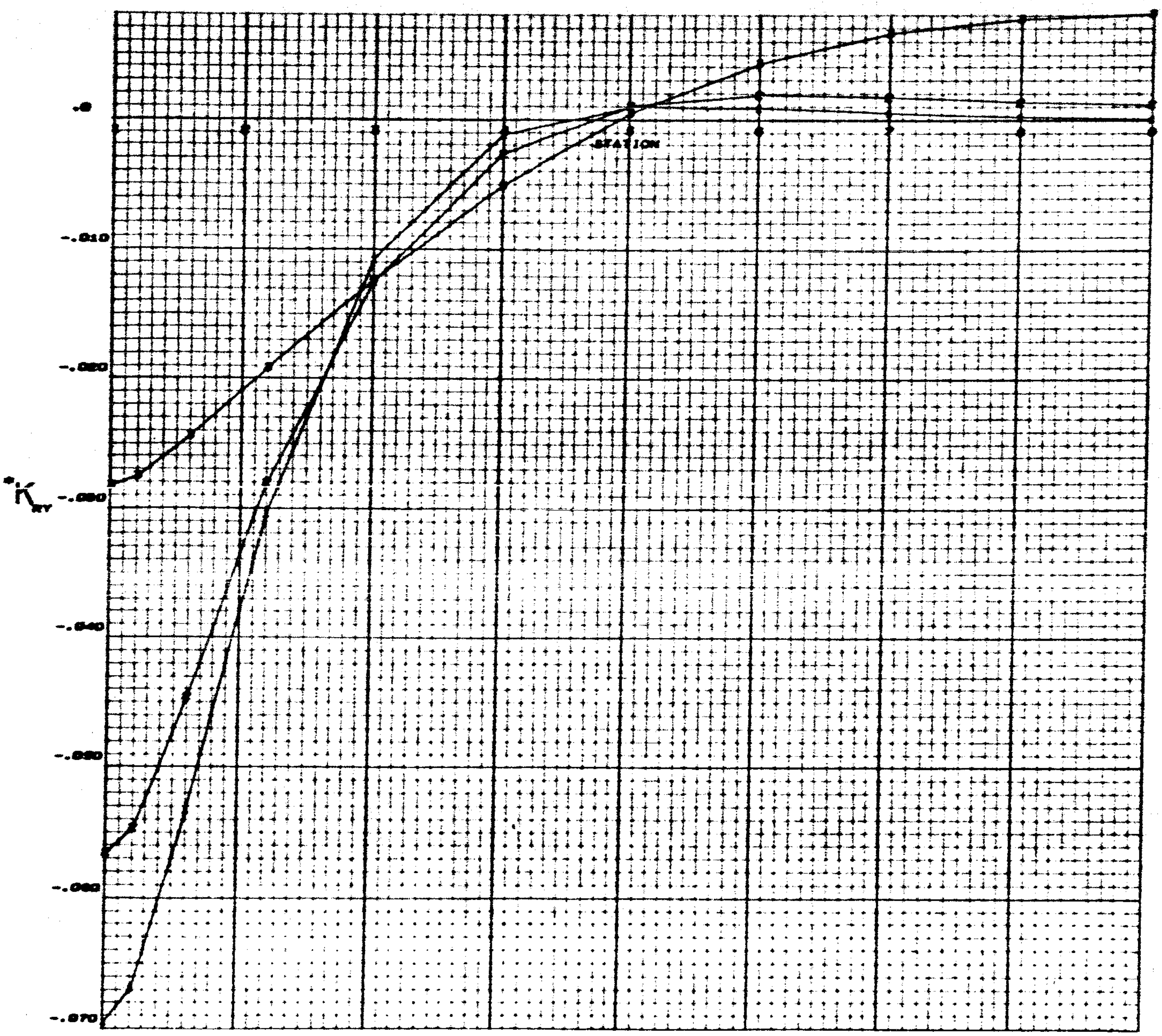
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2 / EI)$

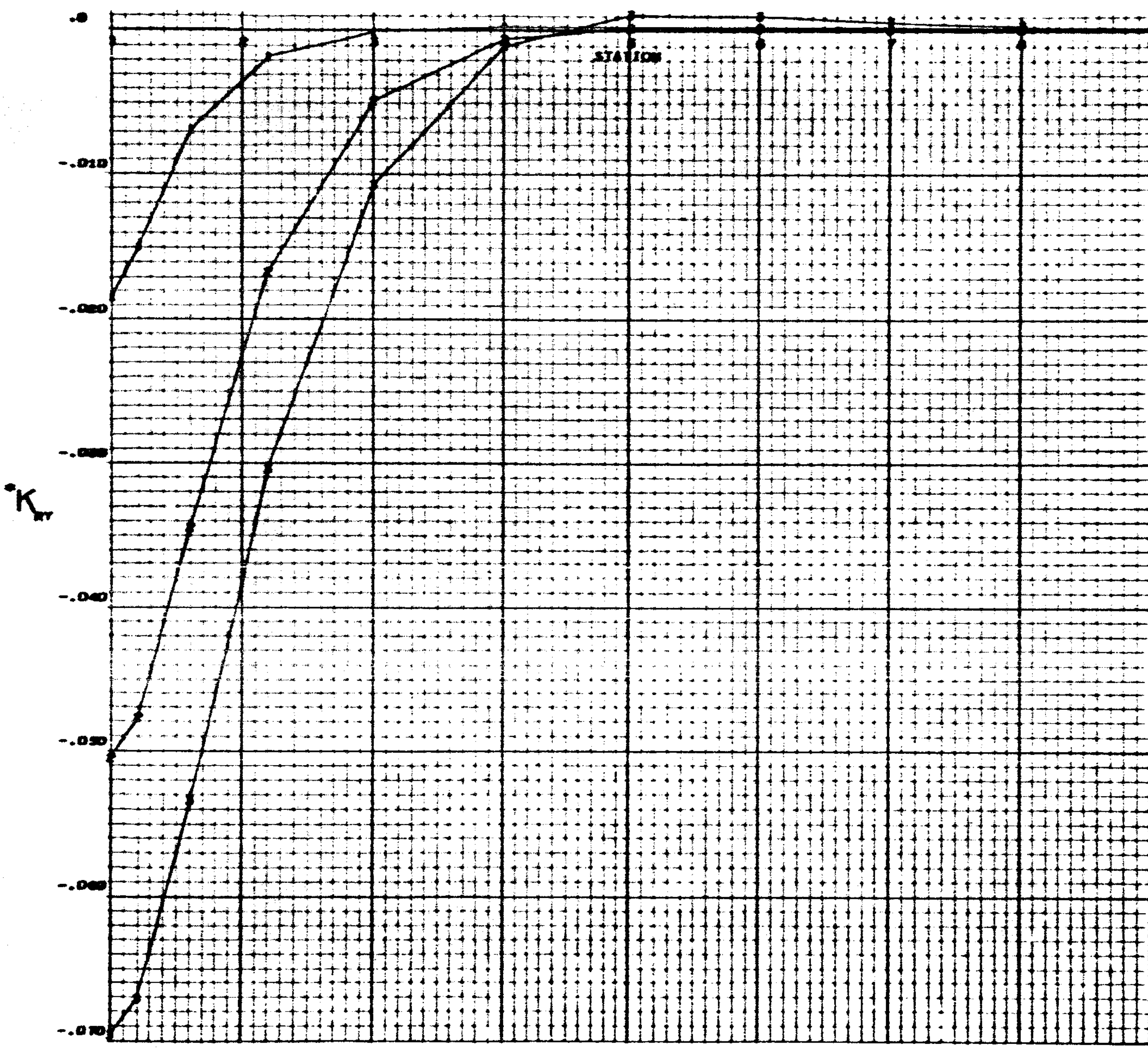
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.00, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

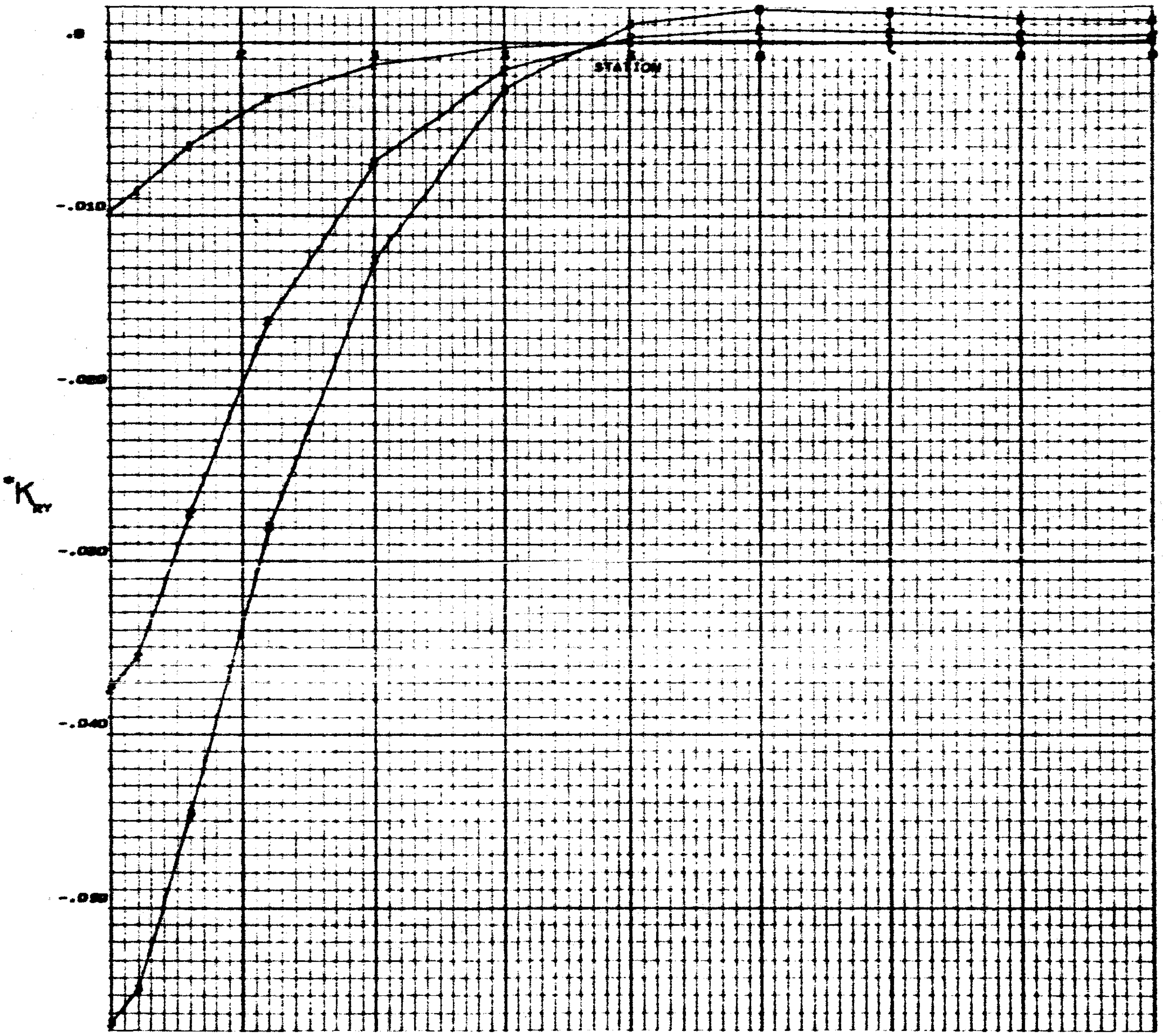
*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2 / EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

R_Y, ROTATION ABOUT THE Y AXIS

GJ/EI = 0.20, C/R VARIABLE

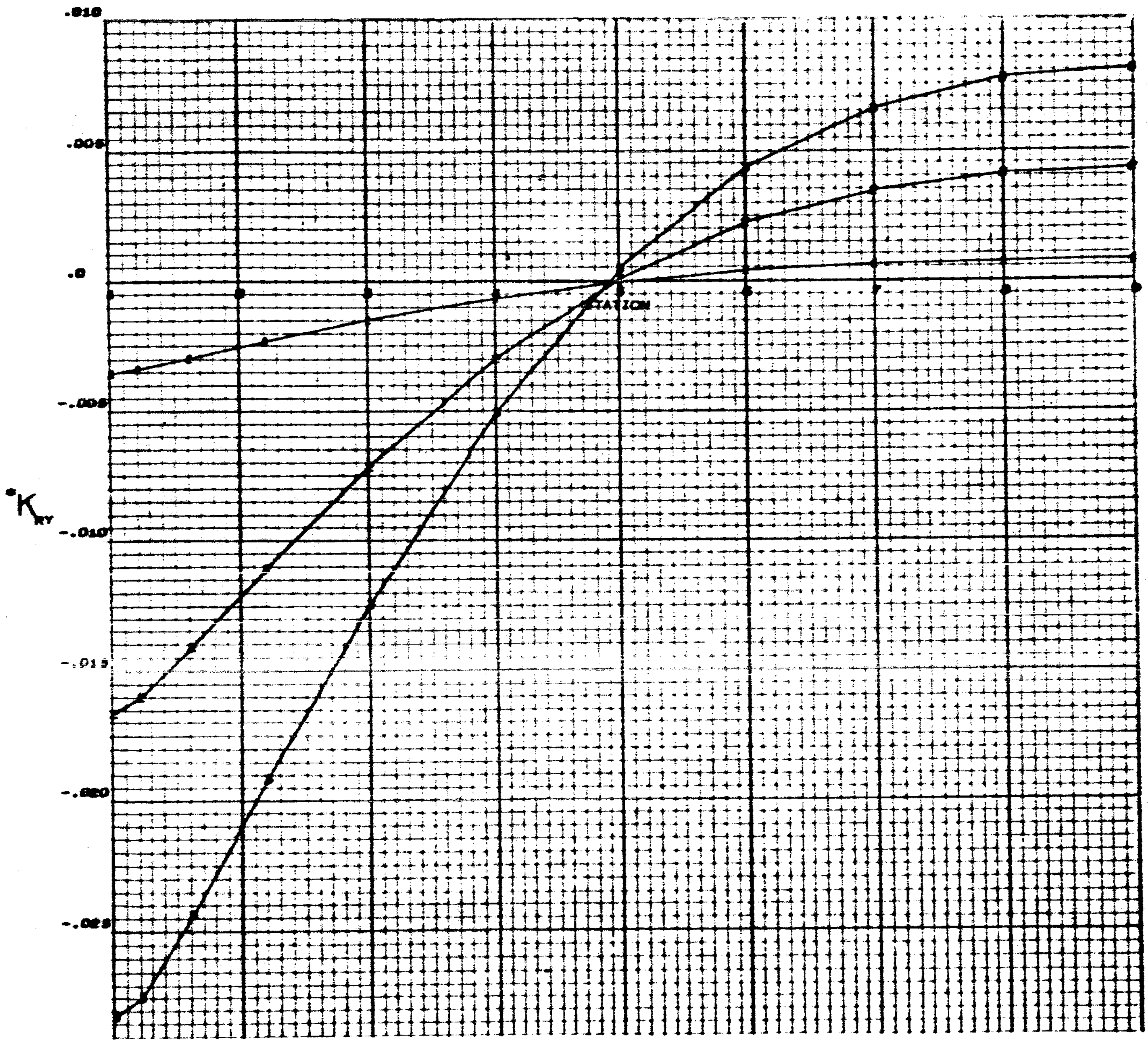


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE - ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2 / EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

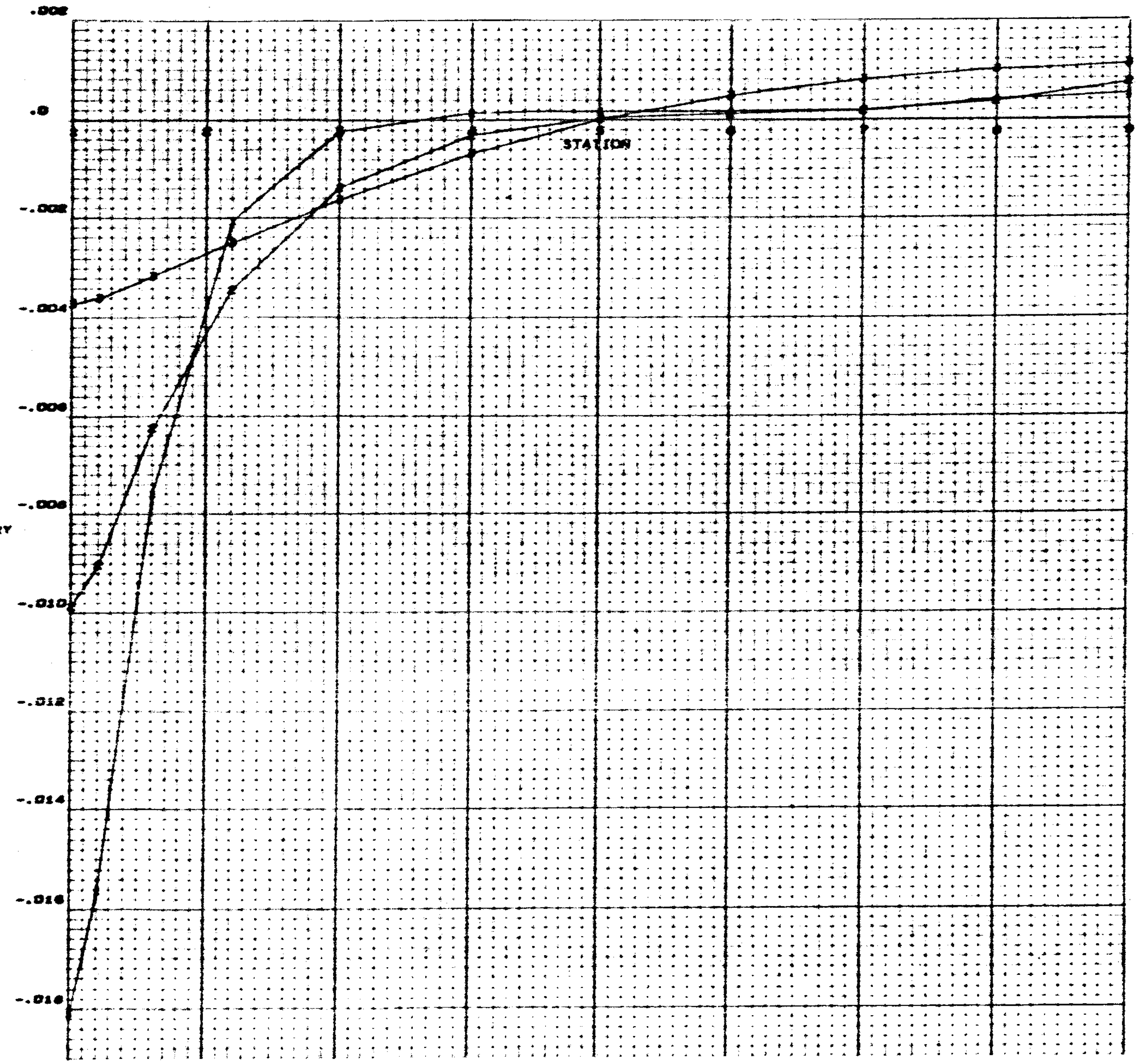
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.08

*NOTE . ROTATION ABOUT THE Y AXIS. $R_Y = K_{RY}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT I ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.01, GJ/EI VARIABLE

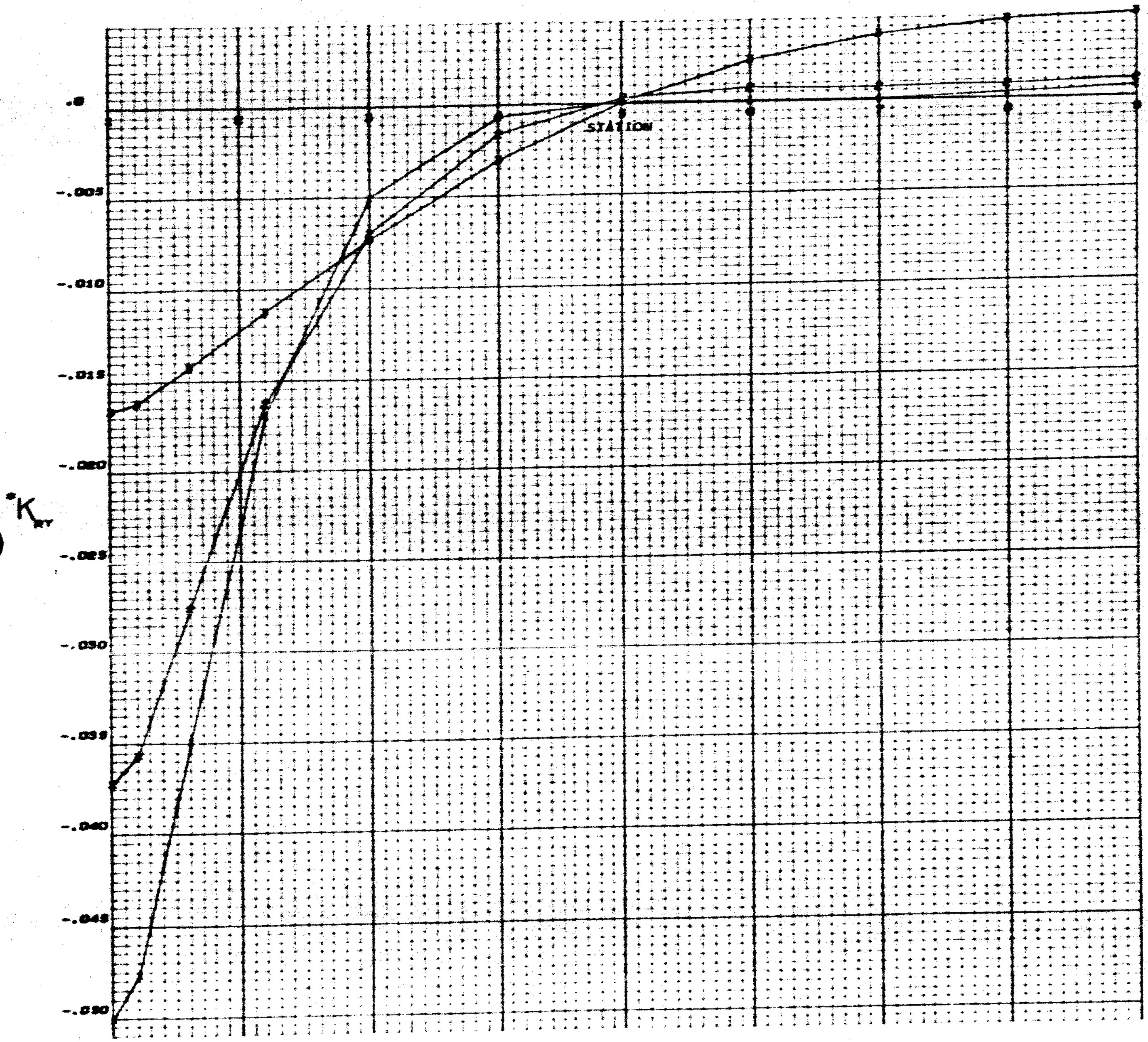


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

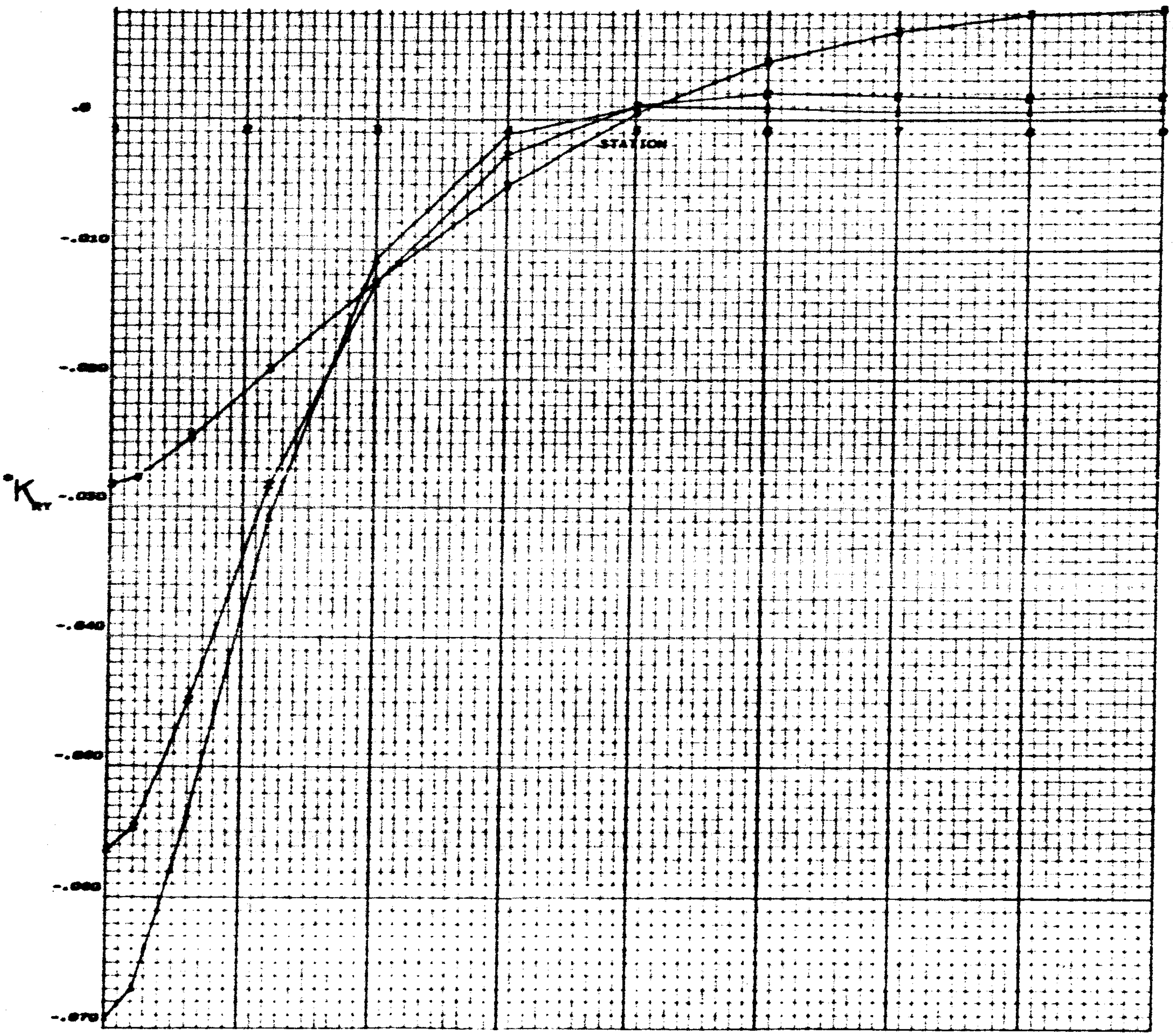
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.00, GJ/EI VARIABLE

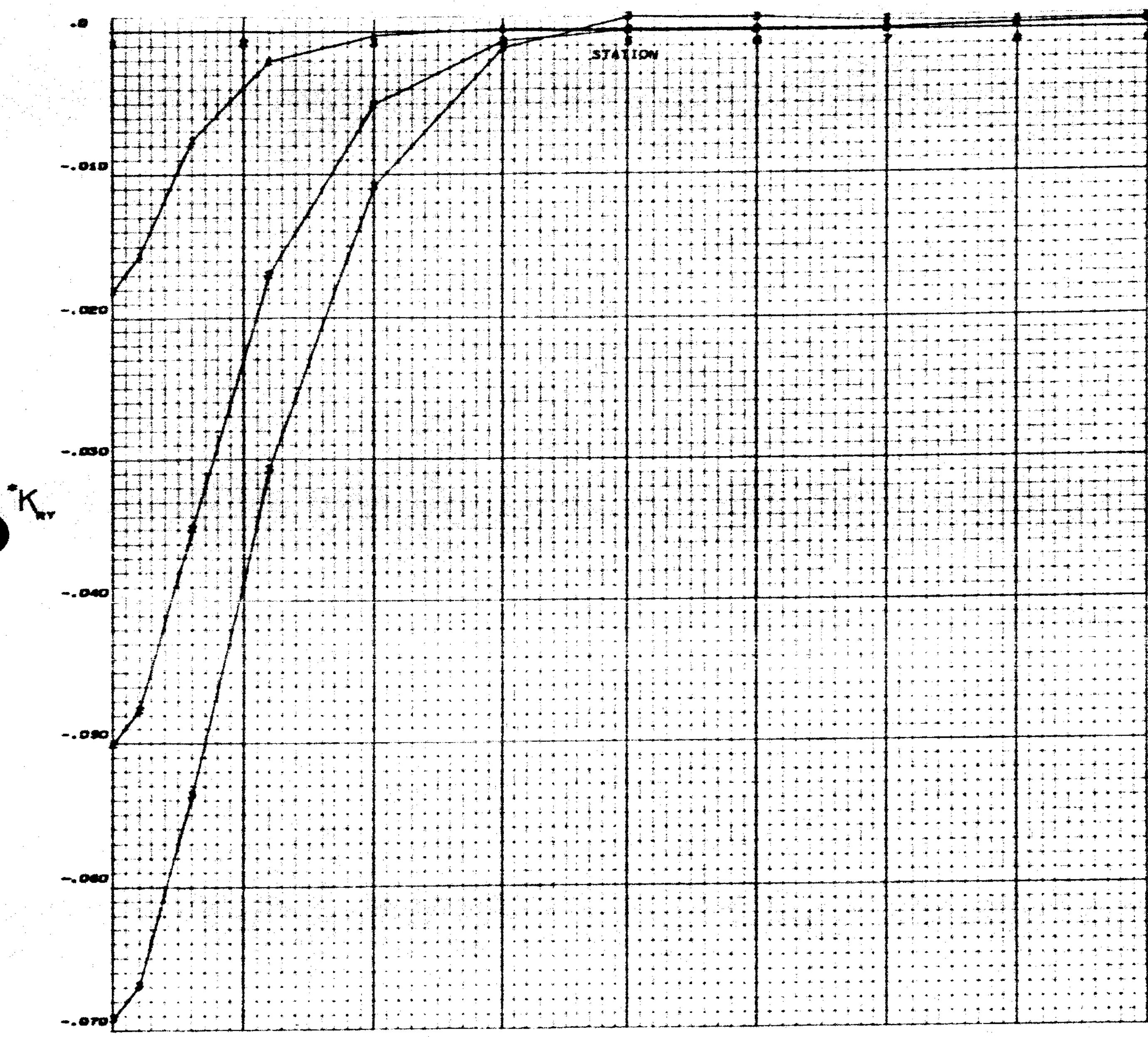


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

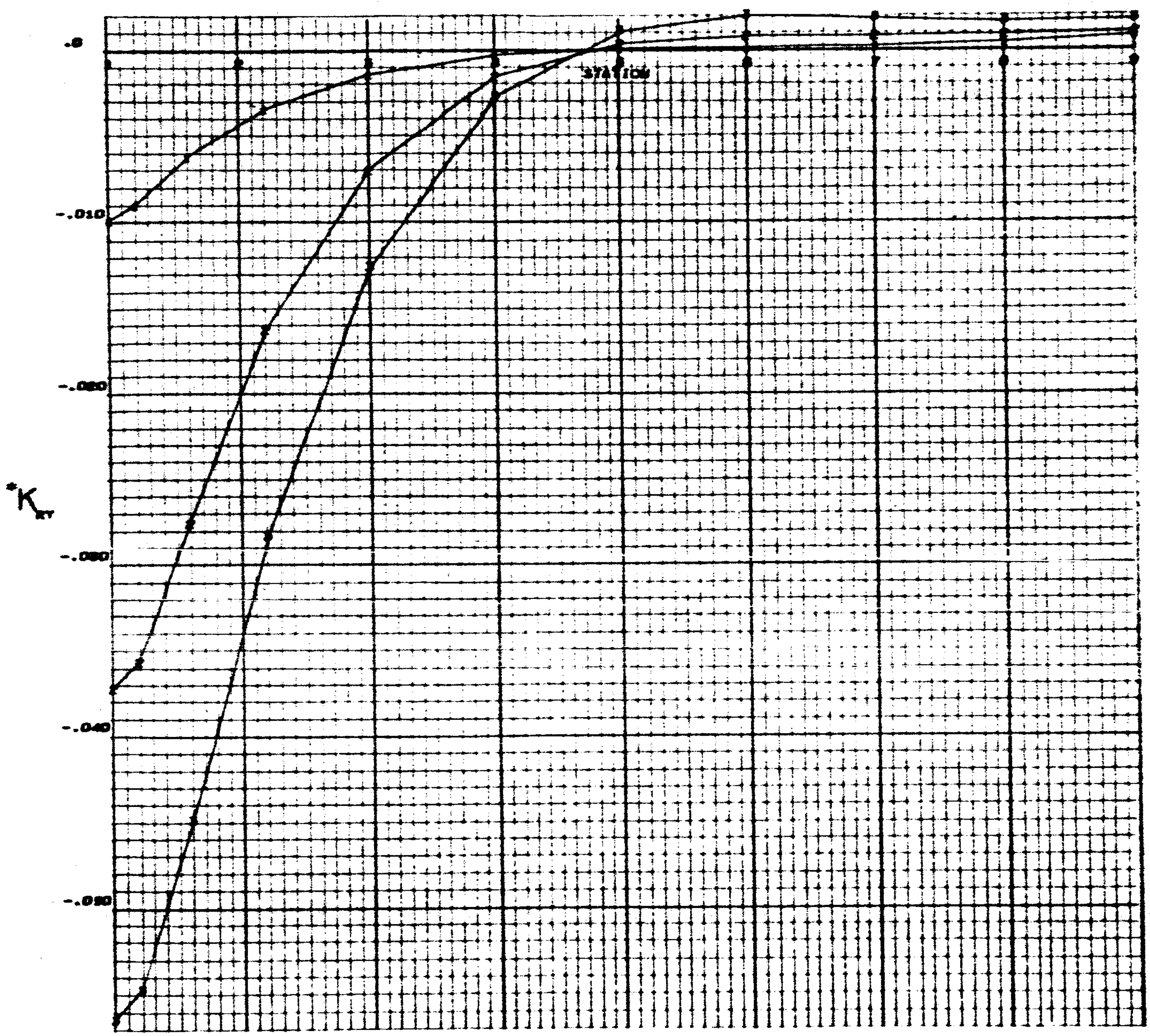
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
6J/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

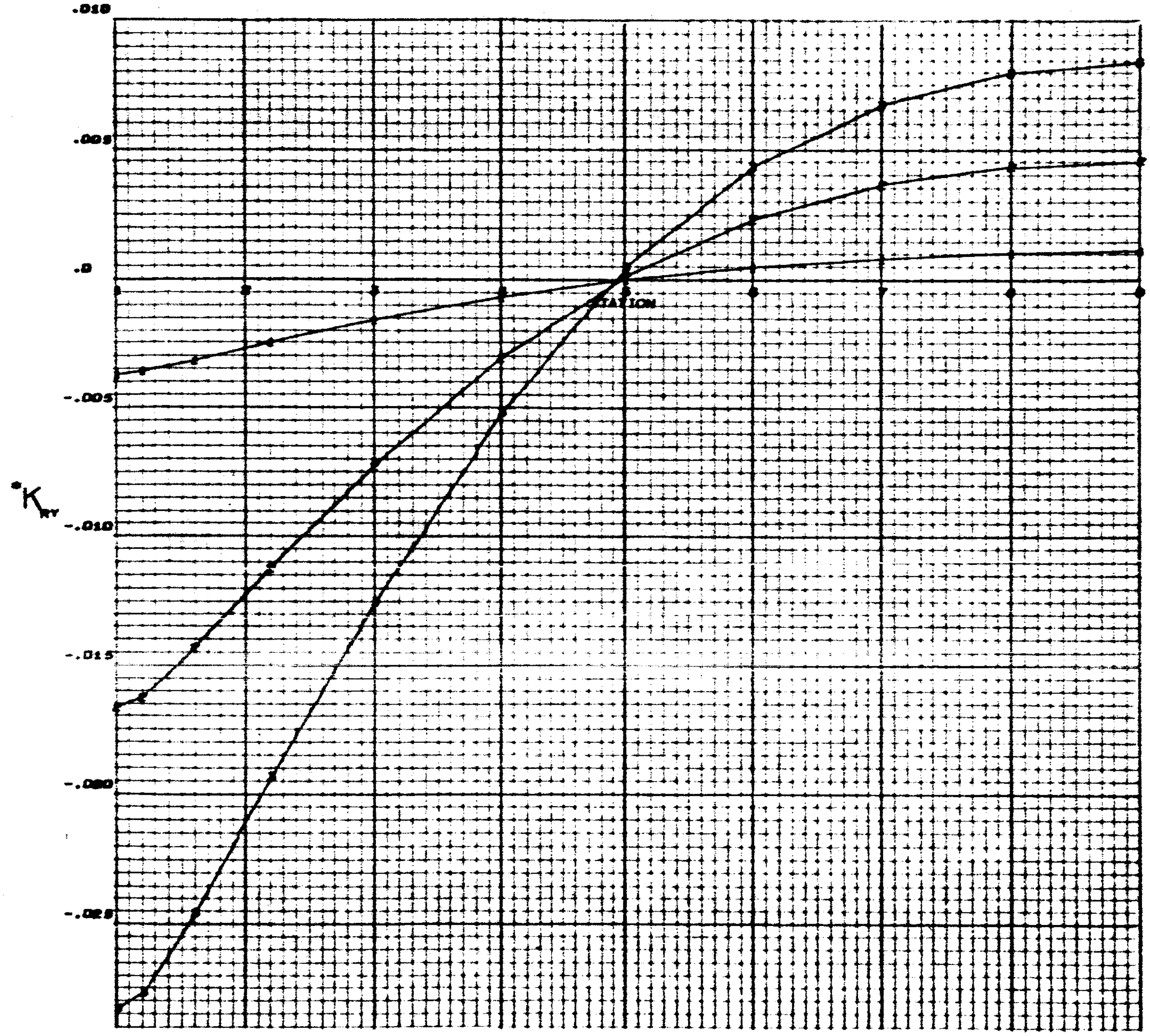
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.80, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

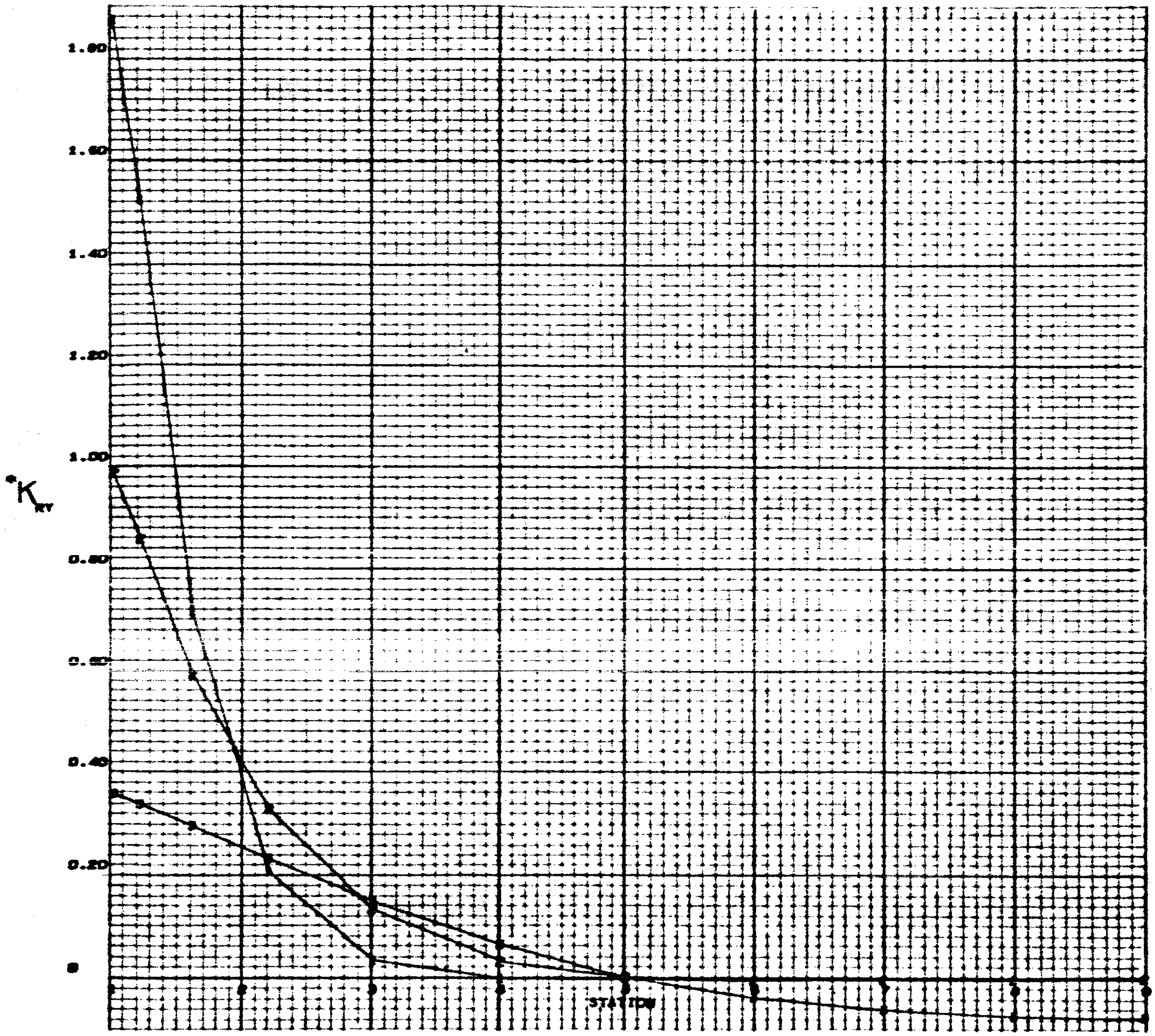
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	0.01
2	[illegible]
3	[illegible]

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2/EI)$

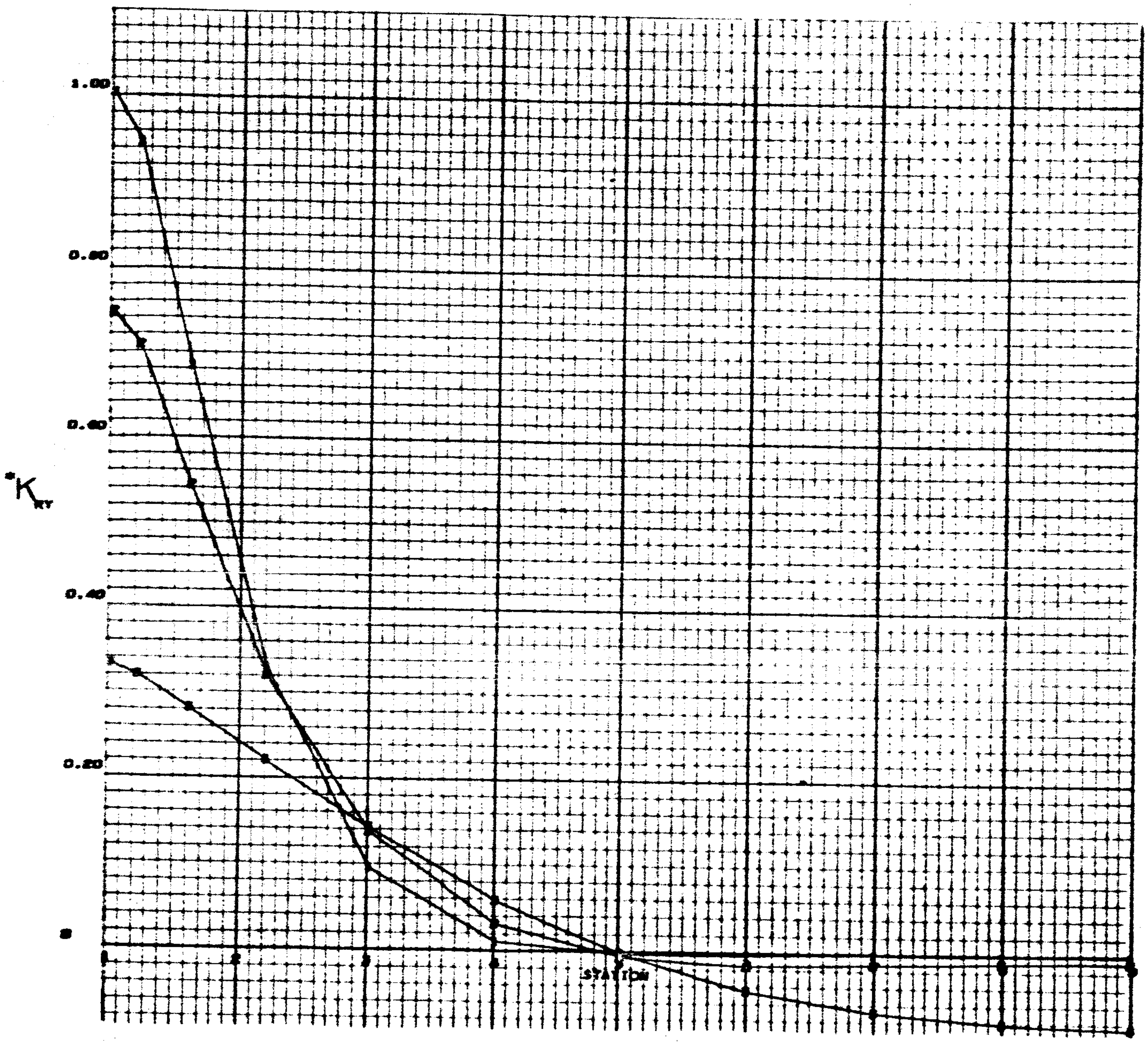
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.01, 6J/EI VARIABLE



CURVE	6J/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

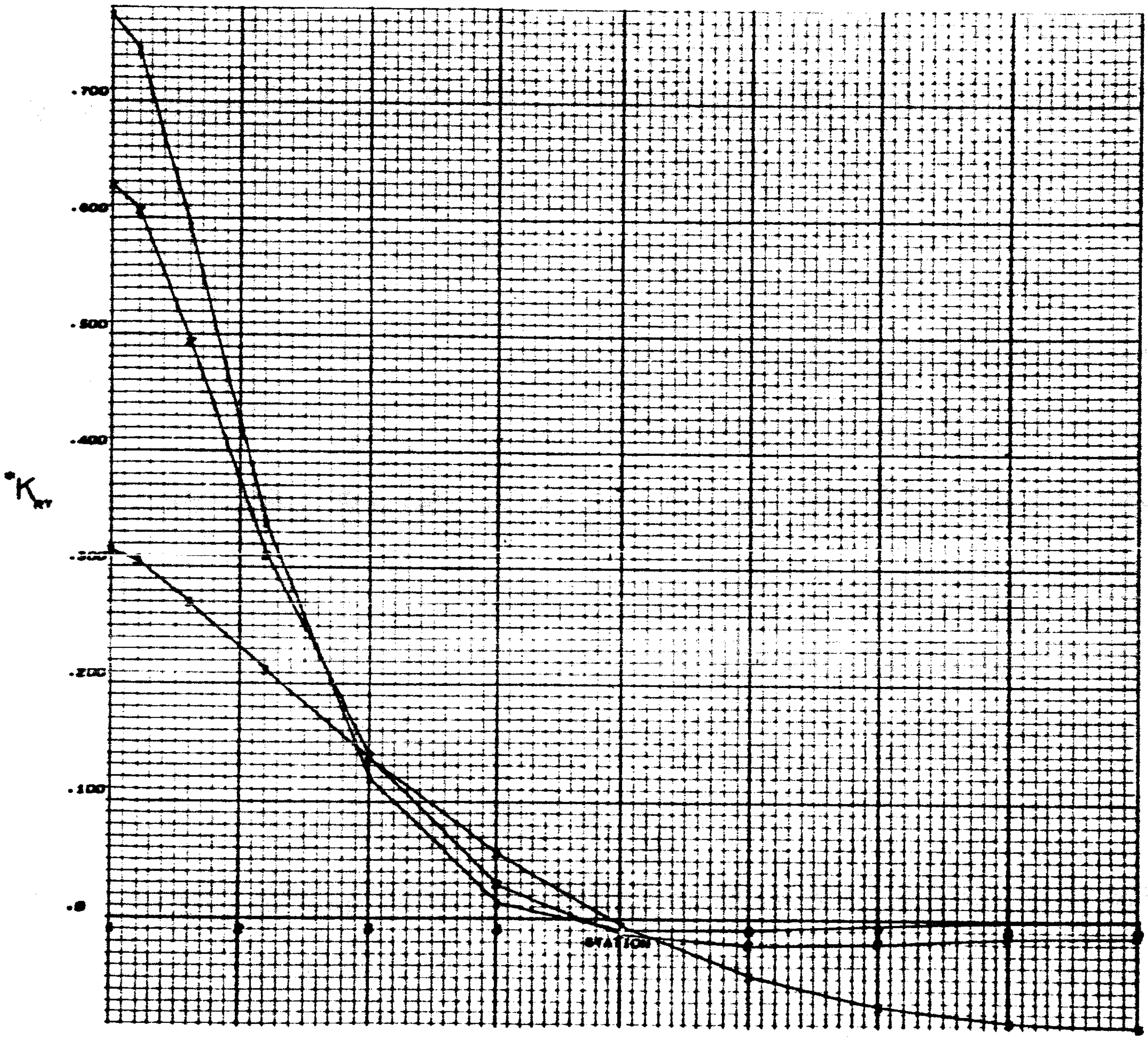
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R\ \ /EI)$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.00, GJ/EI VARIABLE

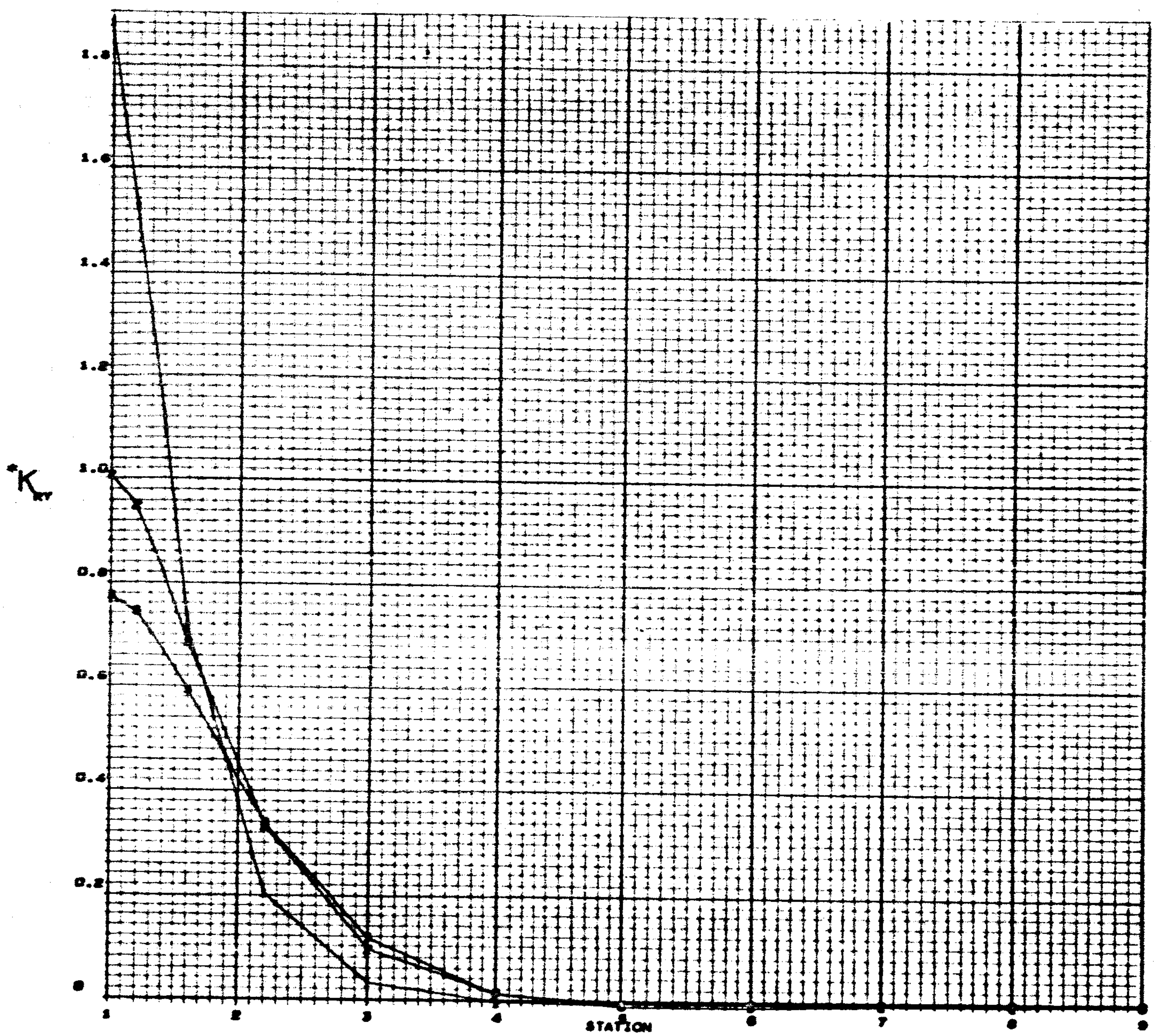


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

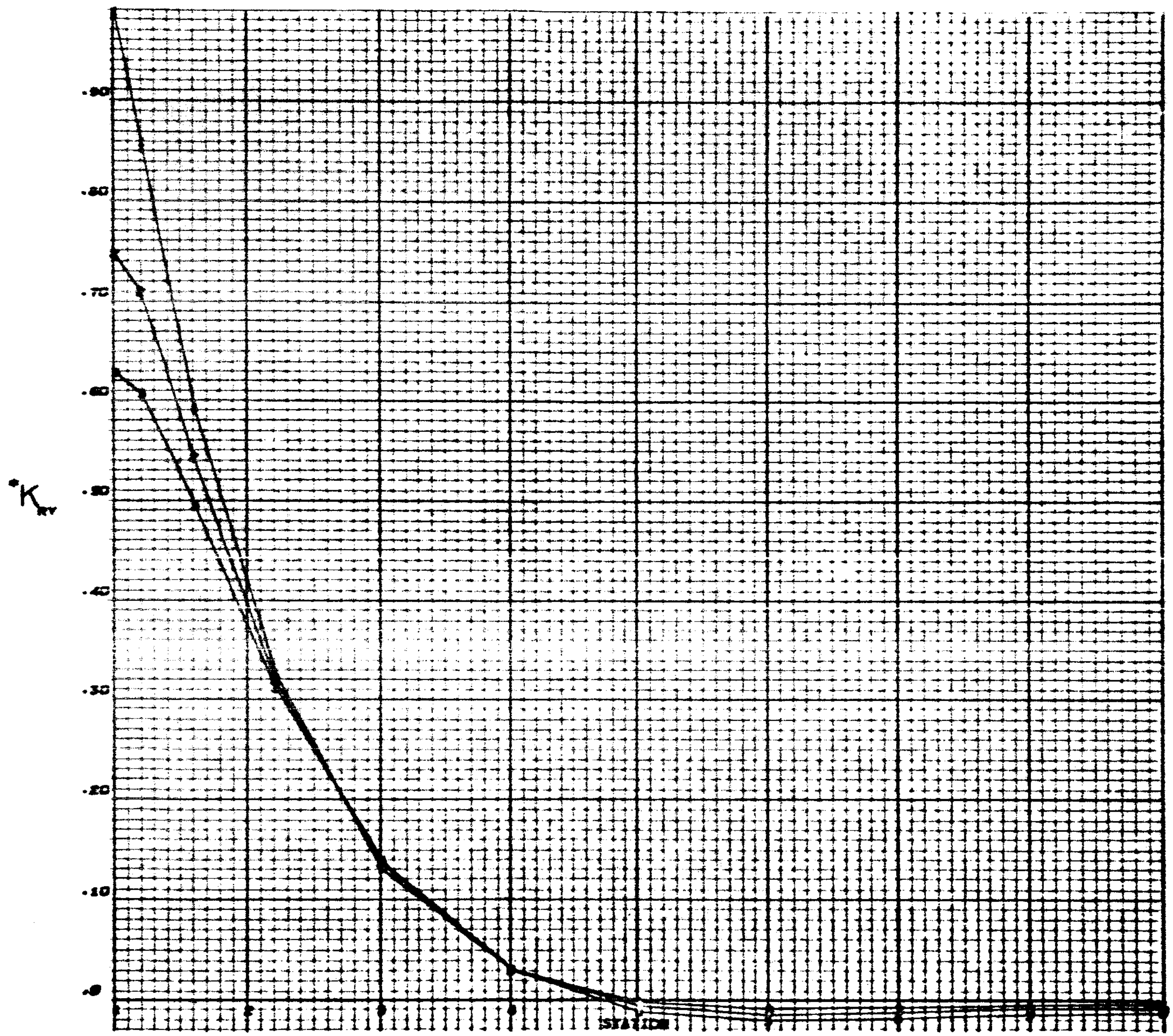
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	0.01
2	0.03
3	0.08

*NOTE - ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

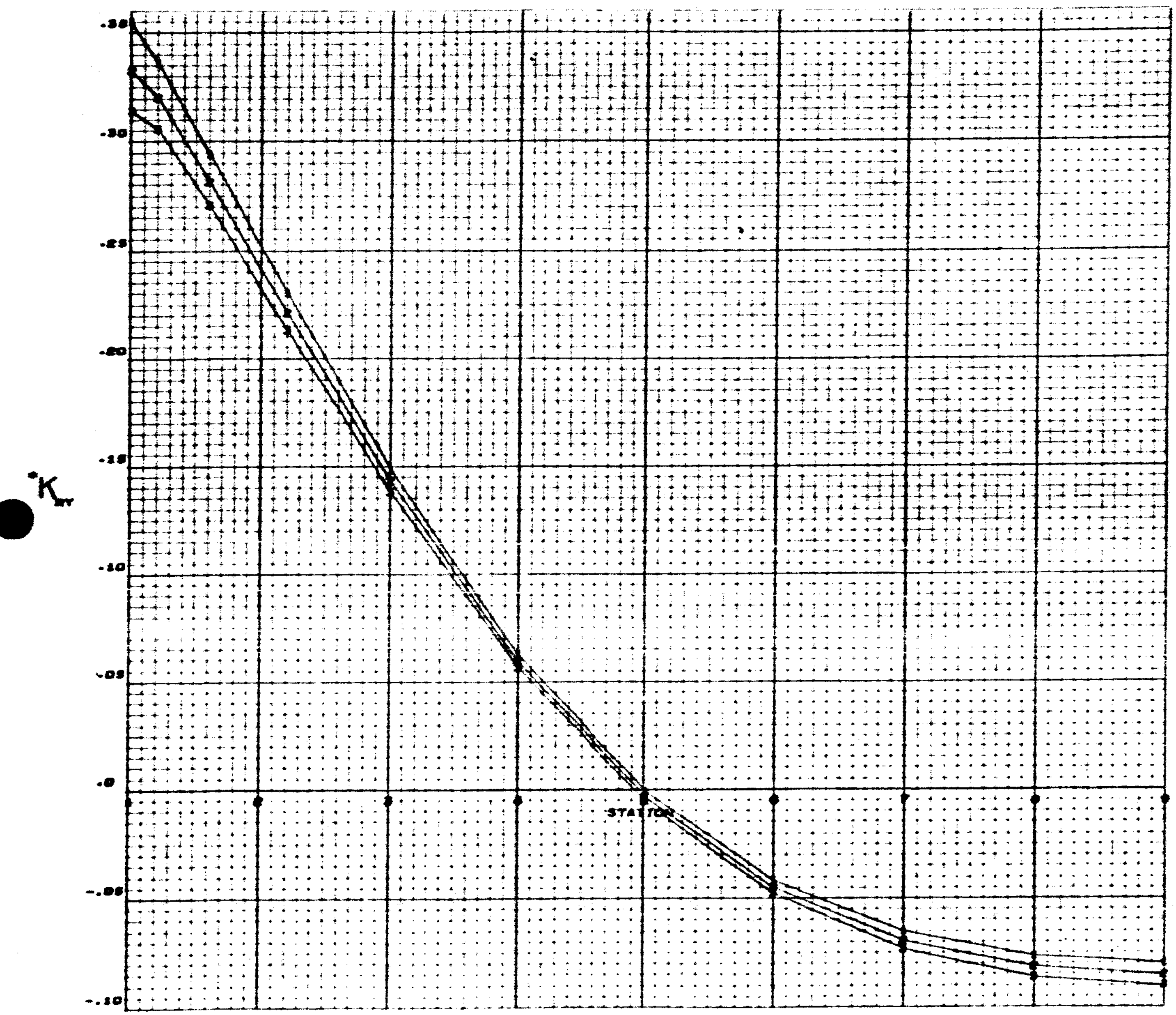
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	0.01
[illegible]	[illegible]
[illegible]	[illegible]

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R \quad /EI)$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE

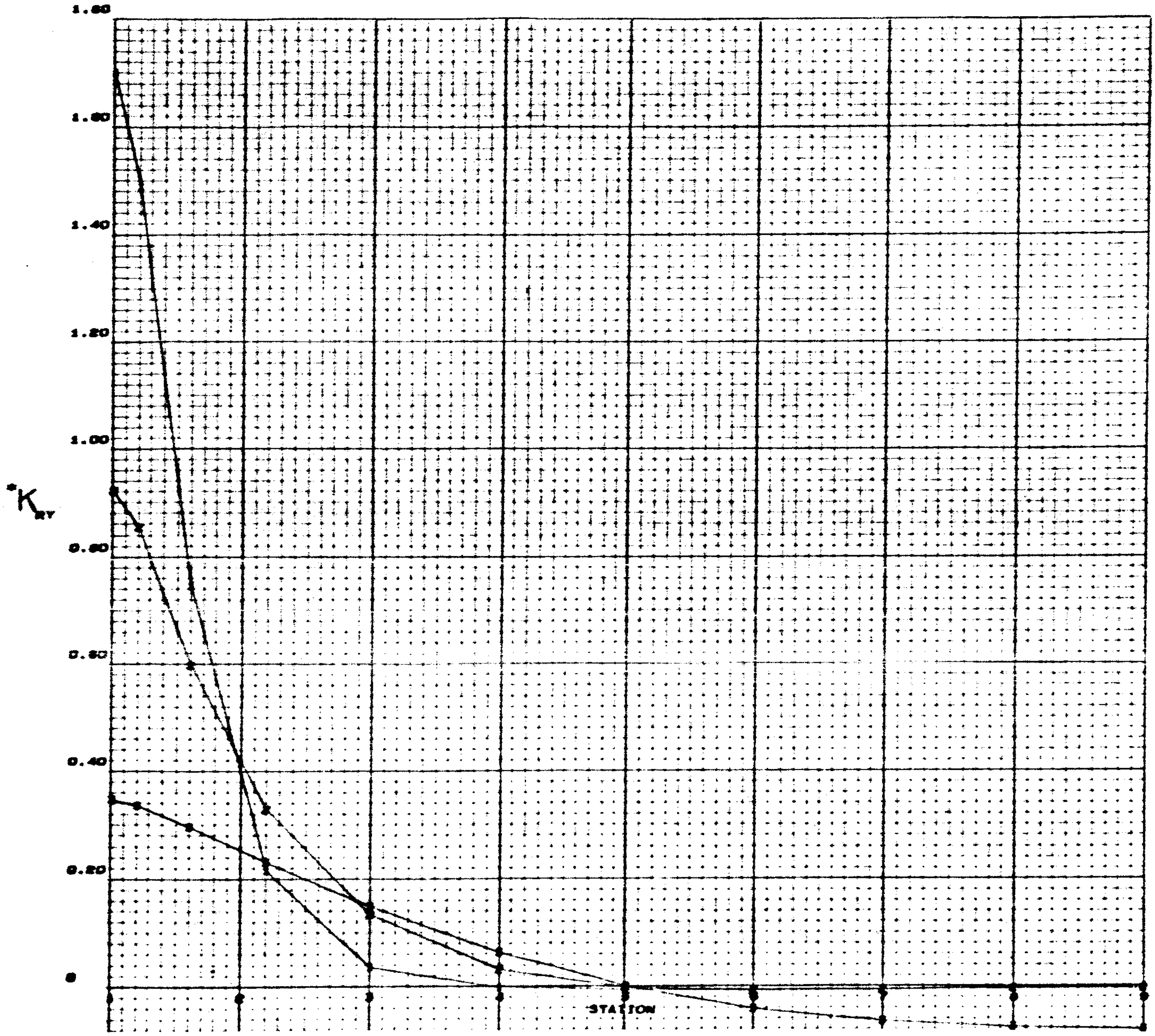


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

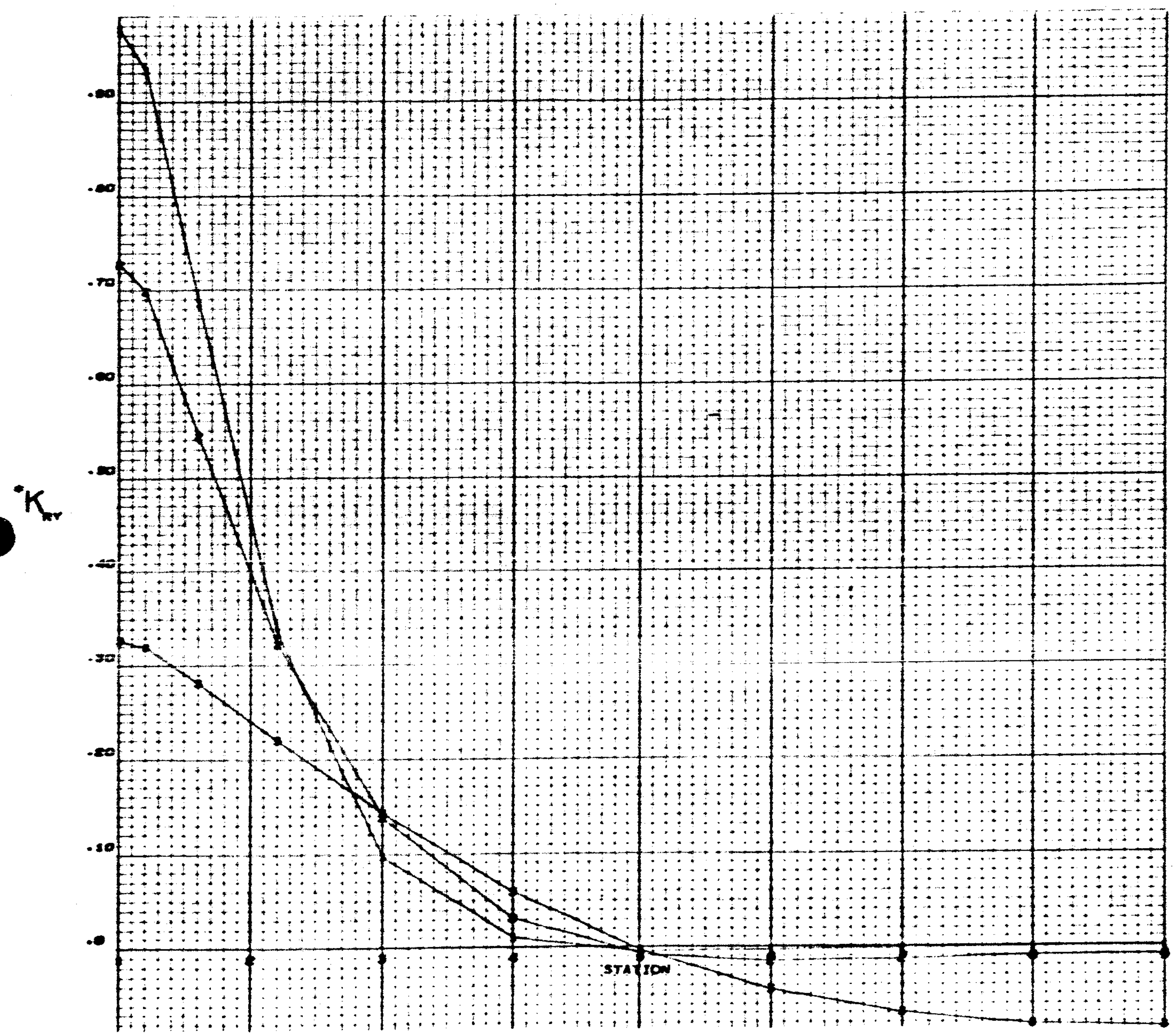
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.05, GJ/EI VARIABLE

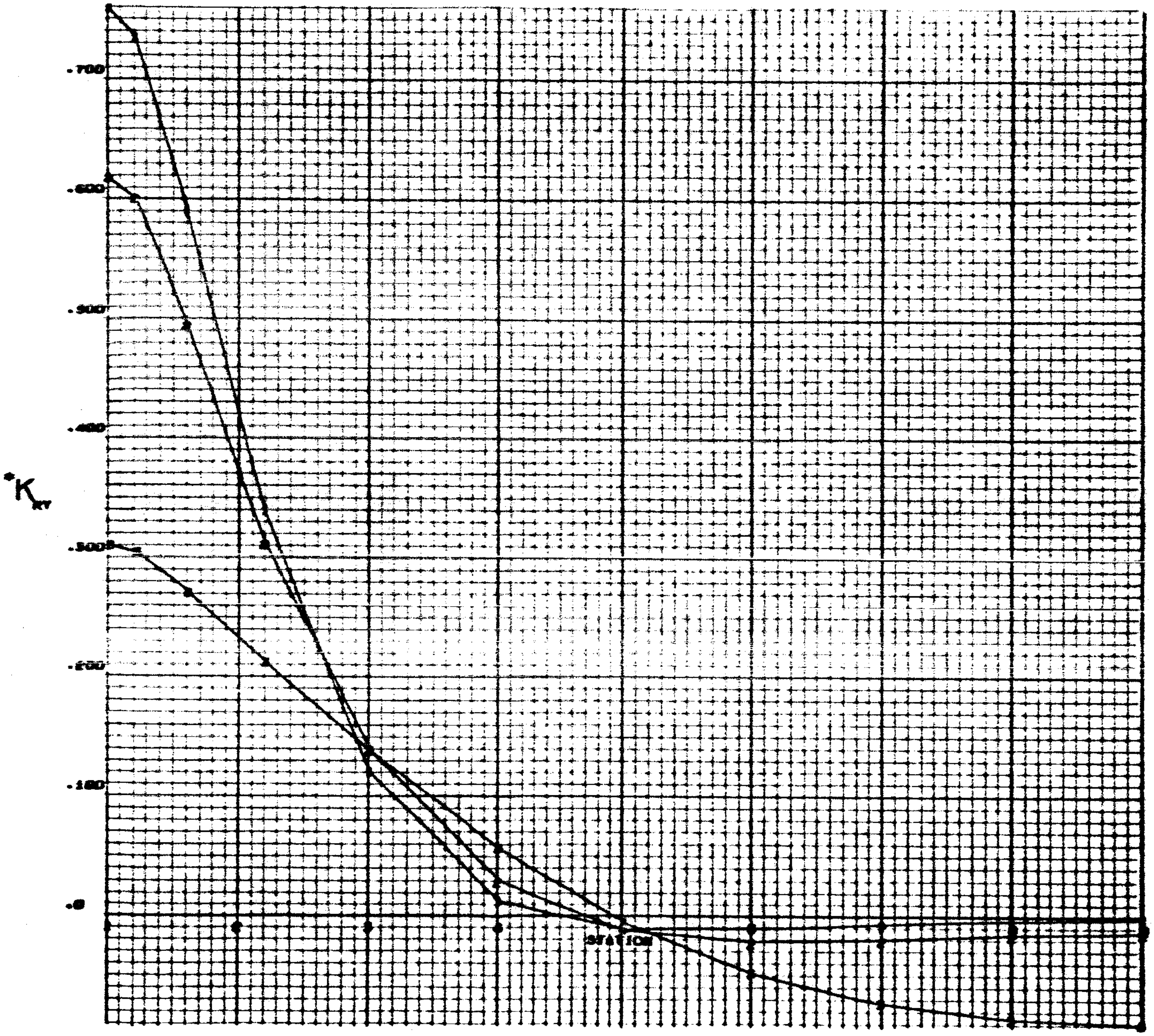


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R \quad /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT I
R_Y, ROTATION ABOUT THE Y AXIS
C/R = 0.08, GJ/EI VARIABLE

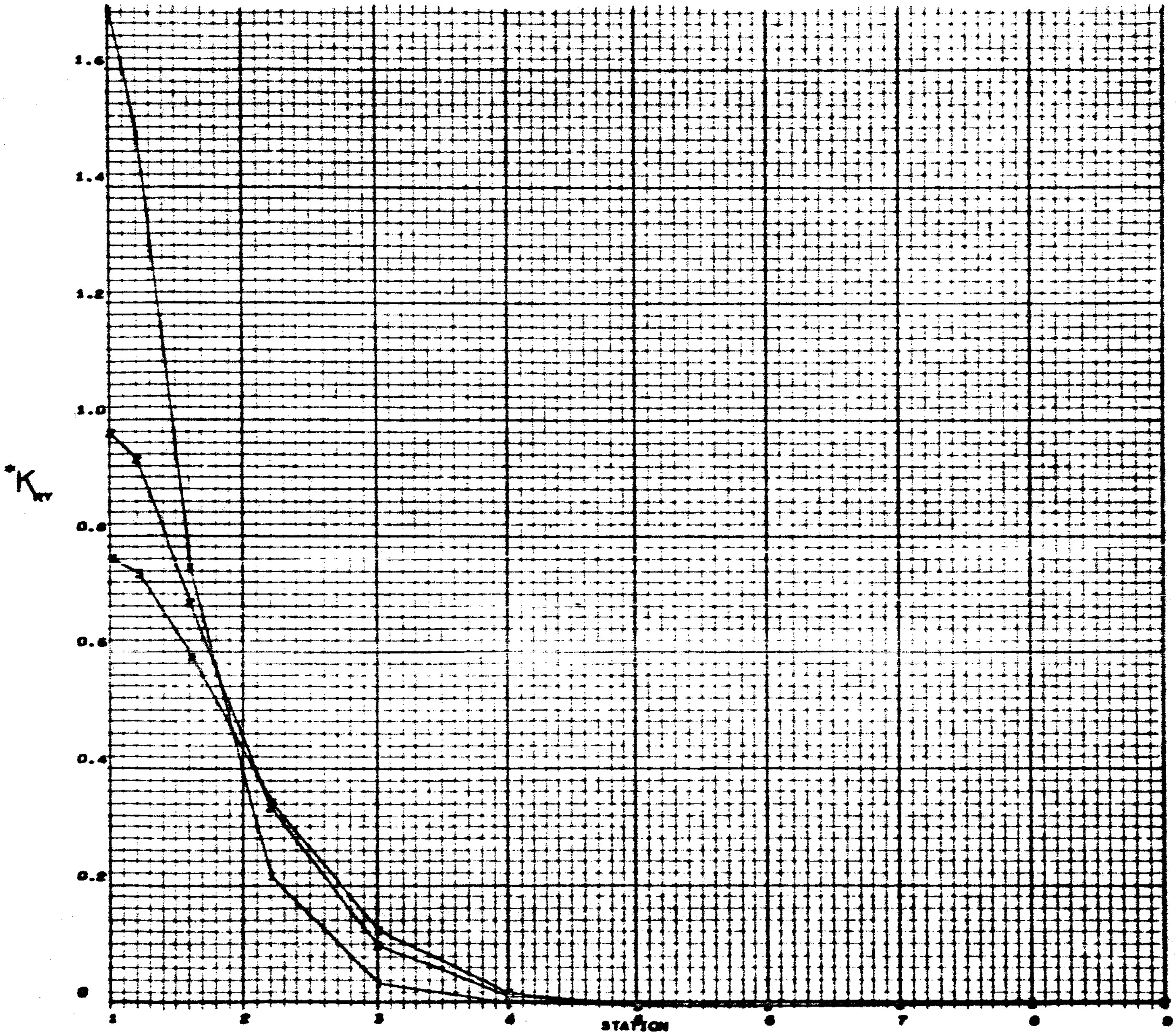


CURVE	GJ/EI
1	[illegible]
2	[illegible]
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE

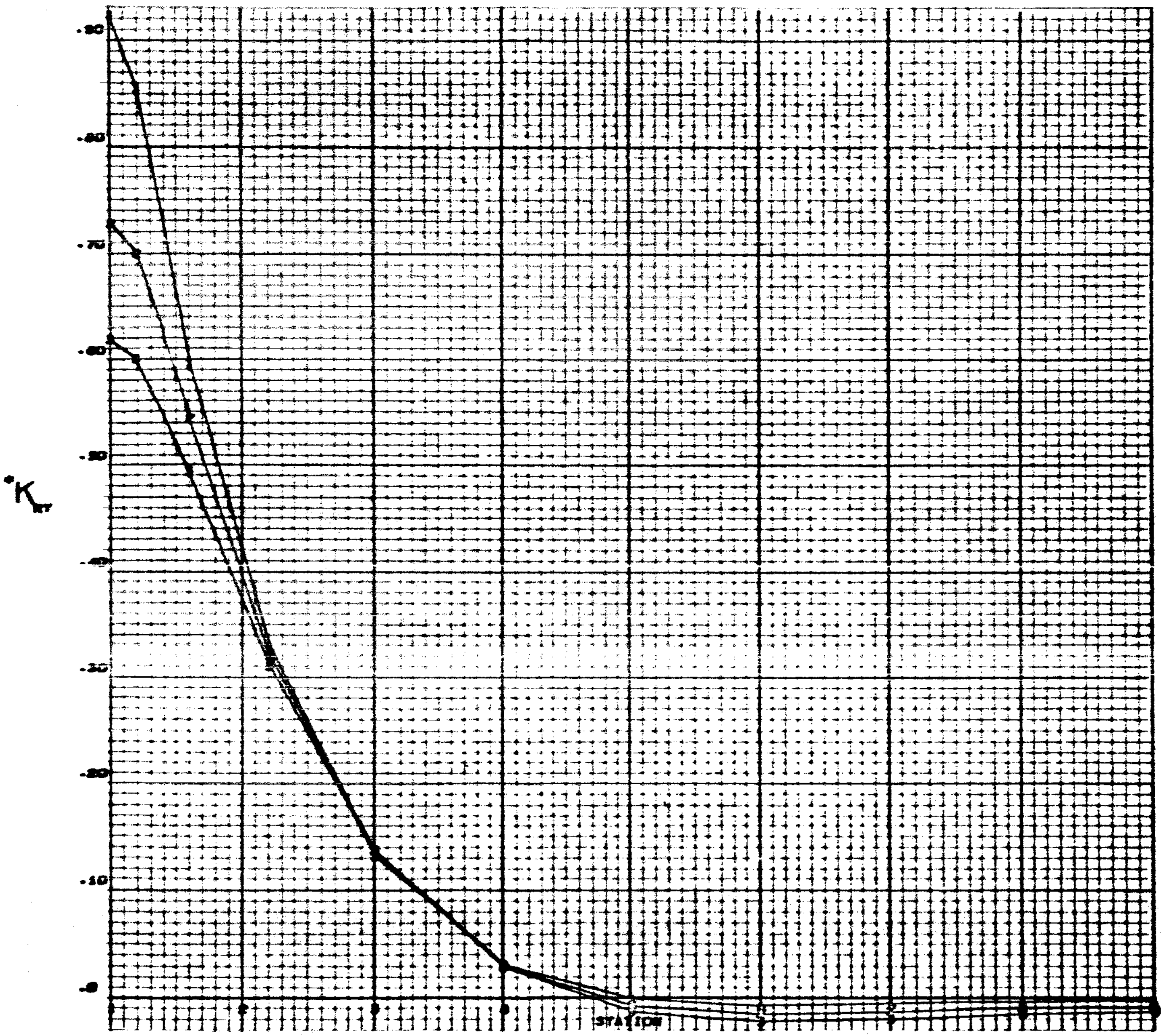


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.20, C/R VARIABLE

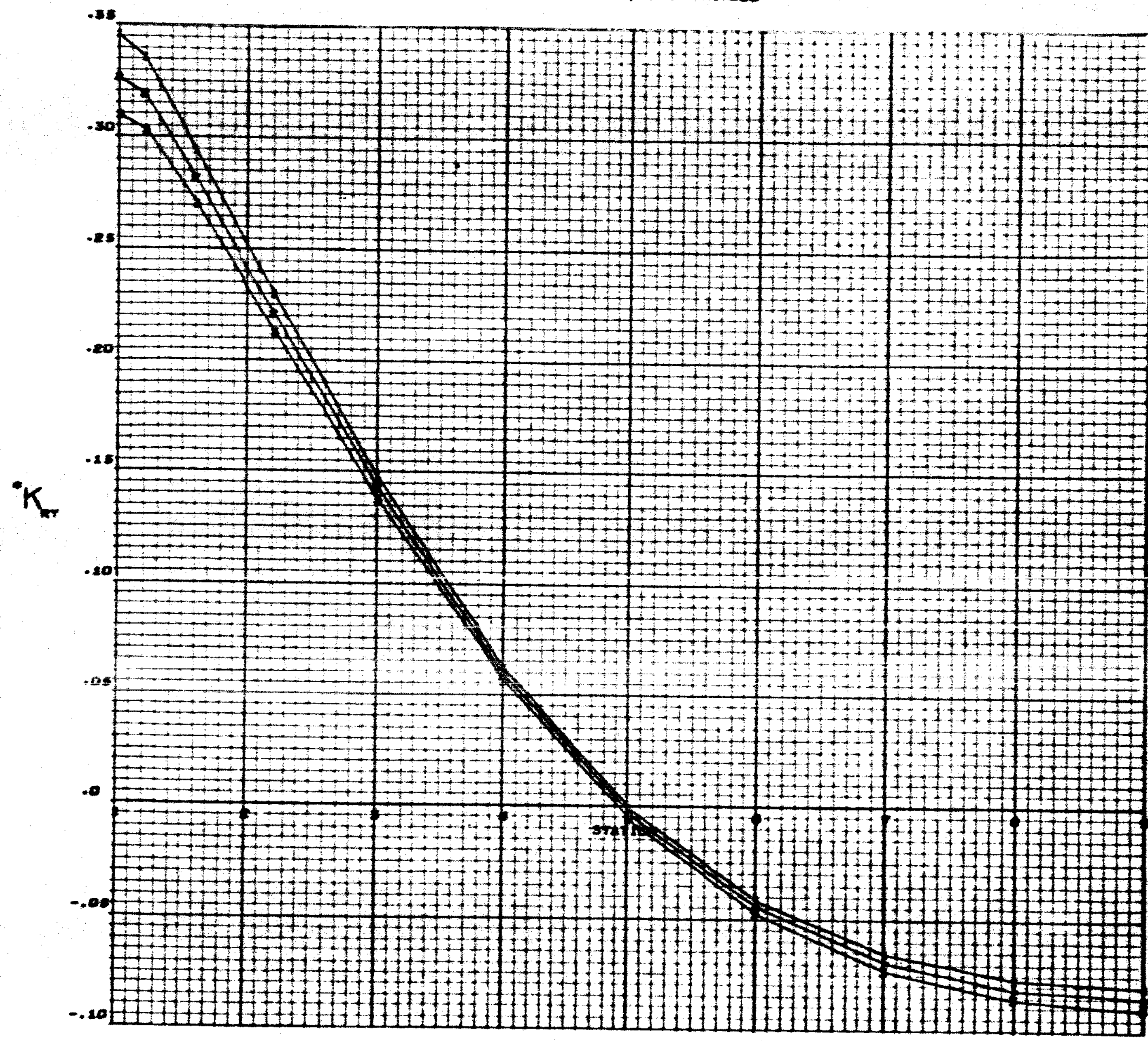


CURVE	C/R
1	0.01
2	0.05
3	0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

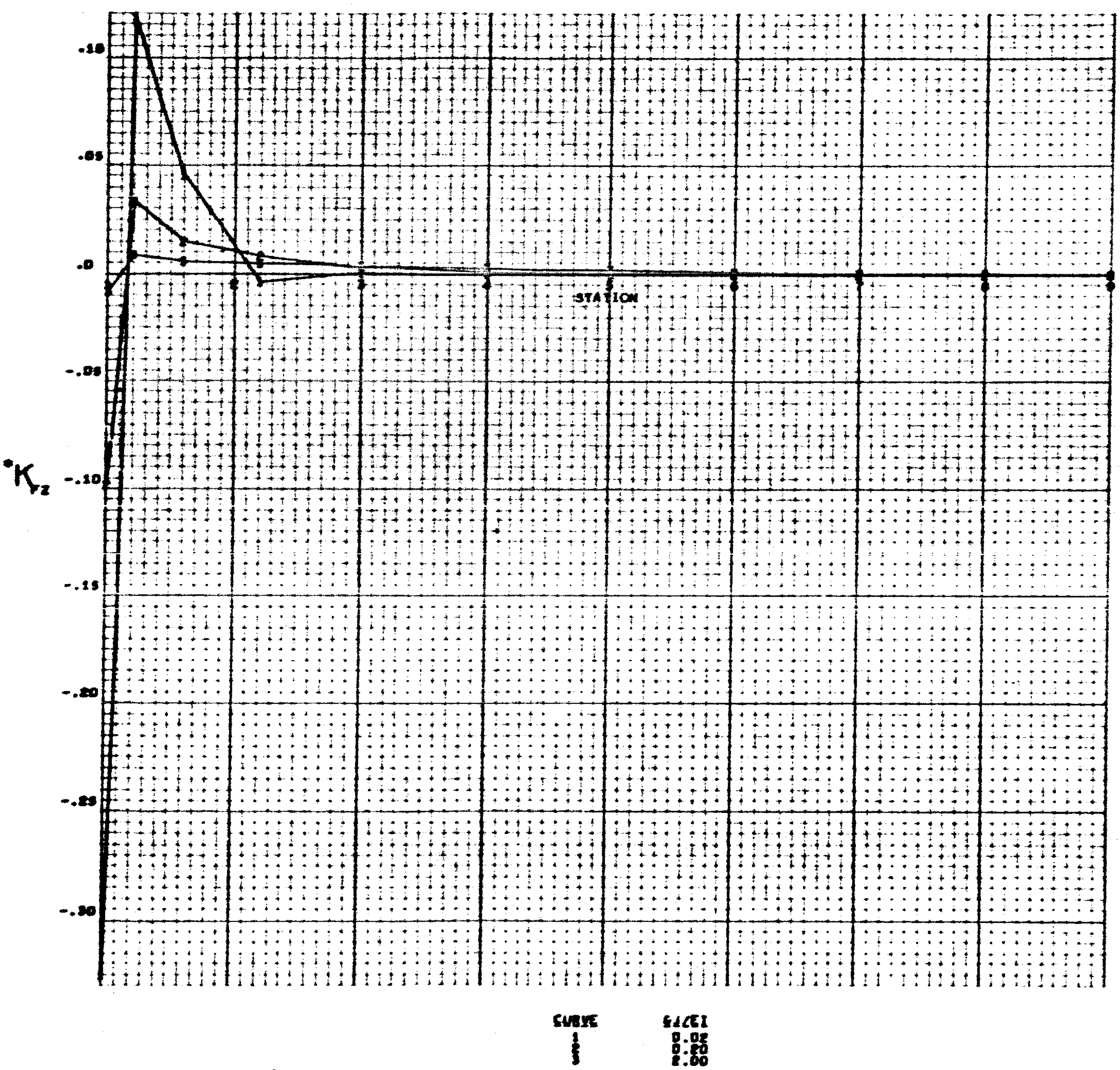
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	[illegible]
2	[illegible]
3	[illegible]

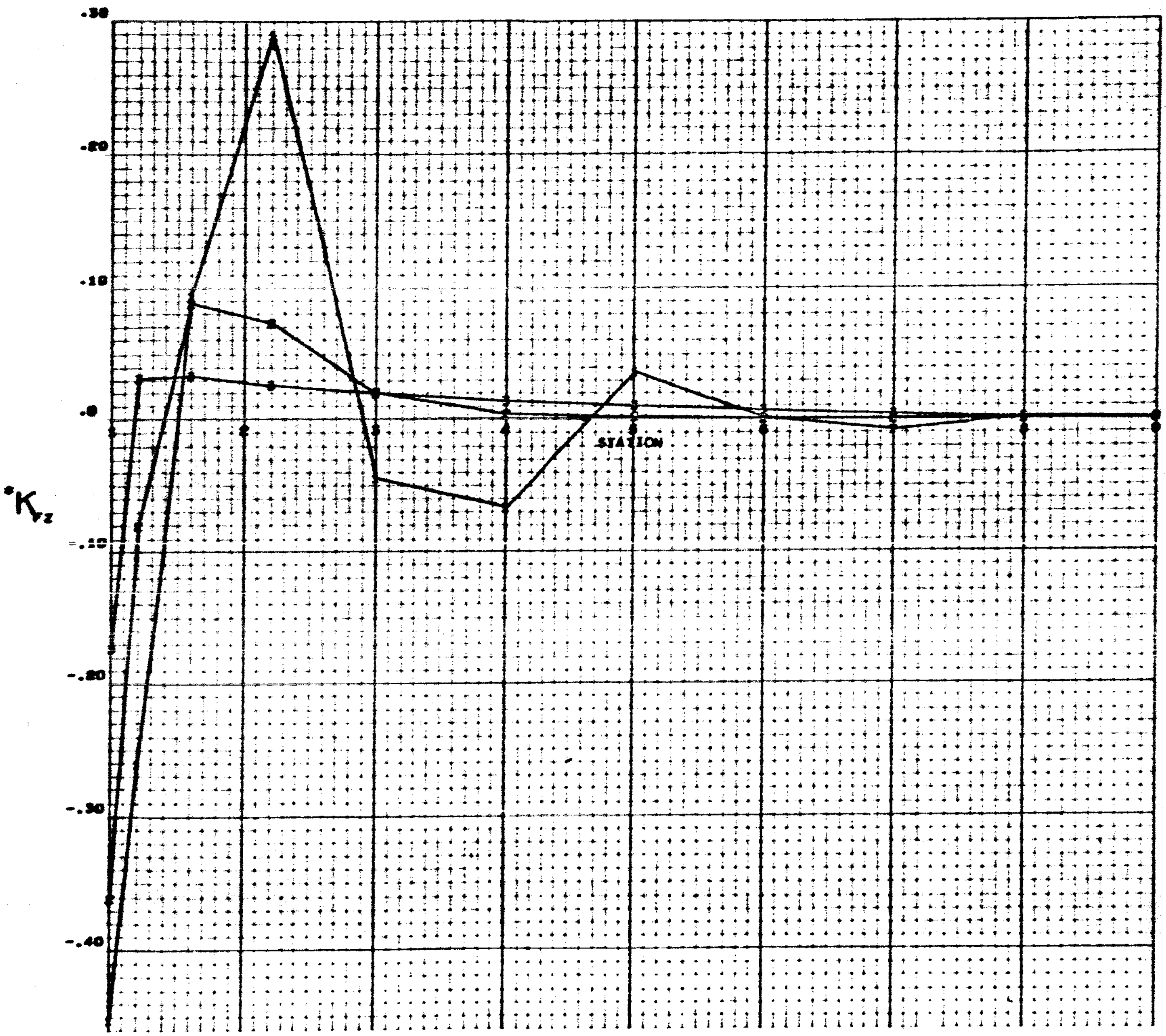
*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

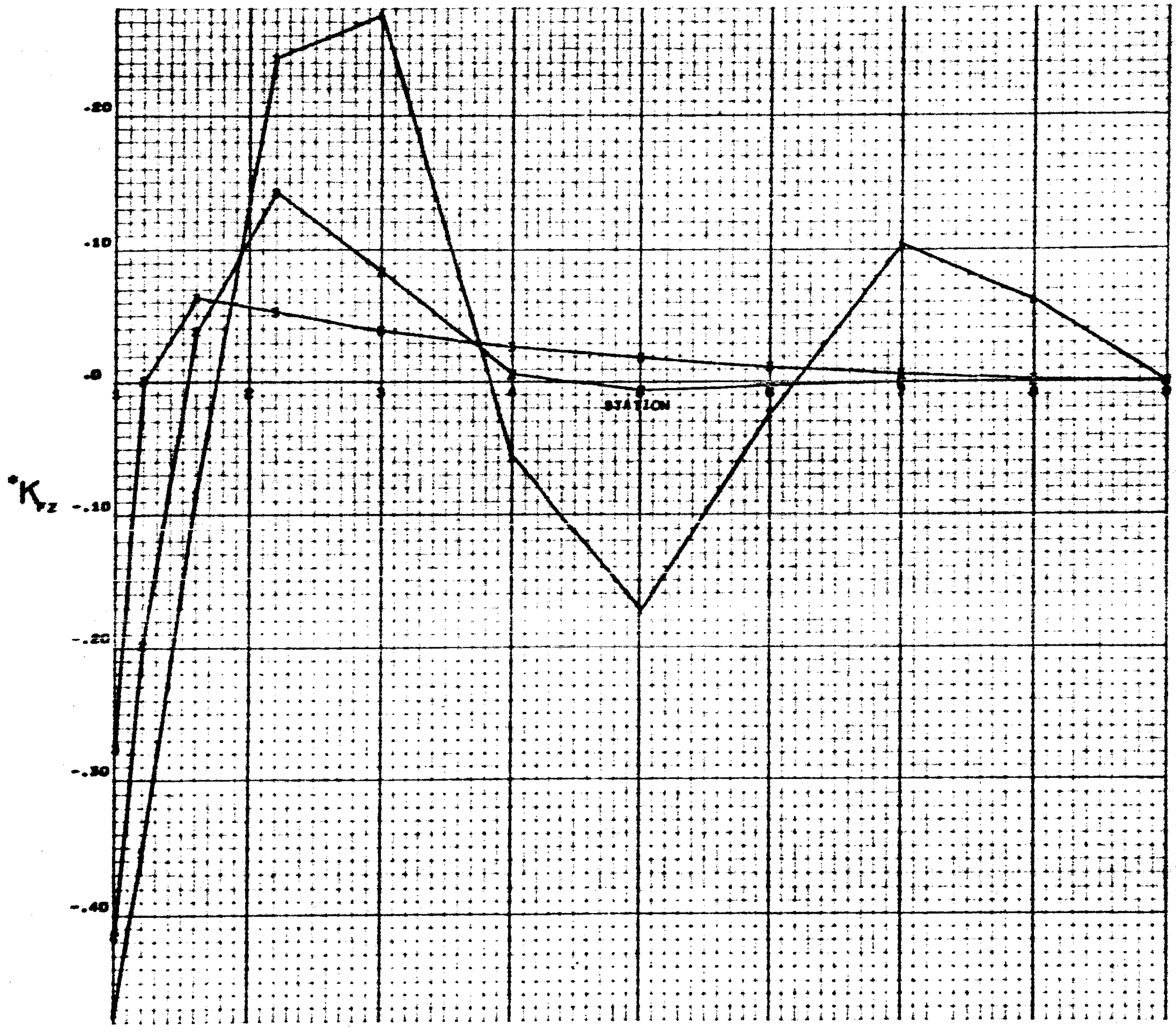
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE

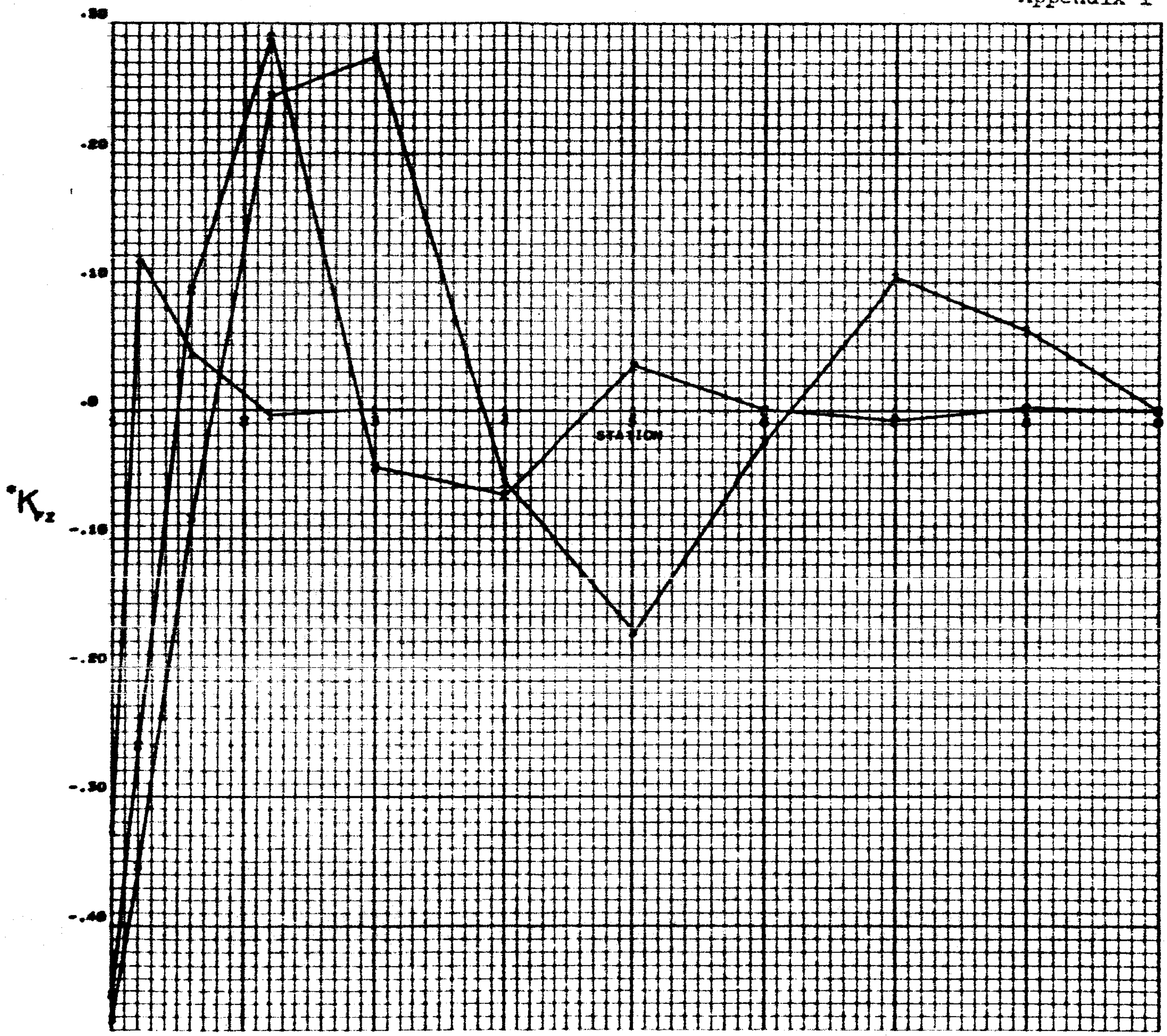


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

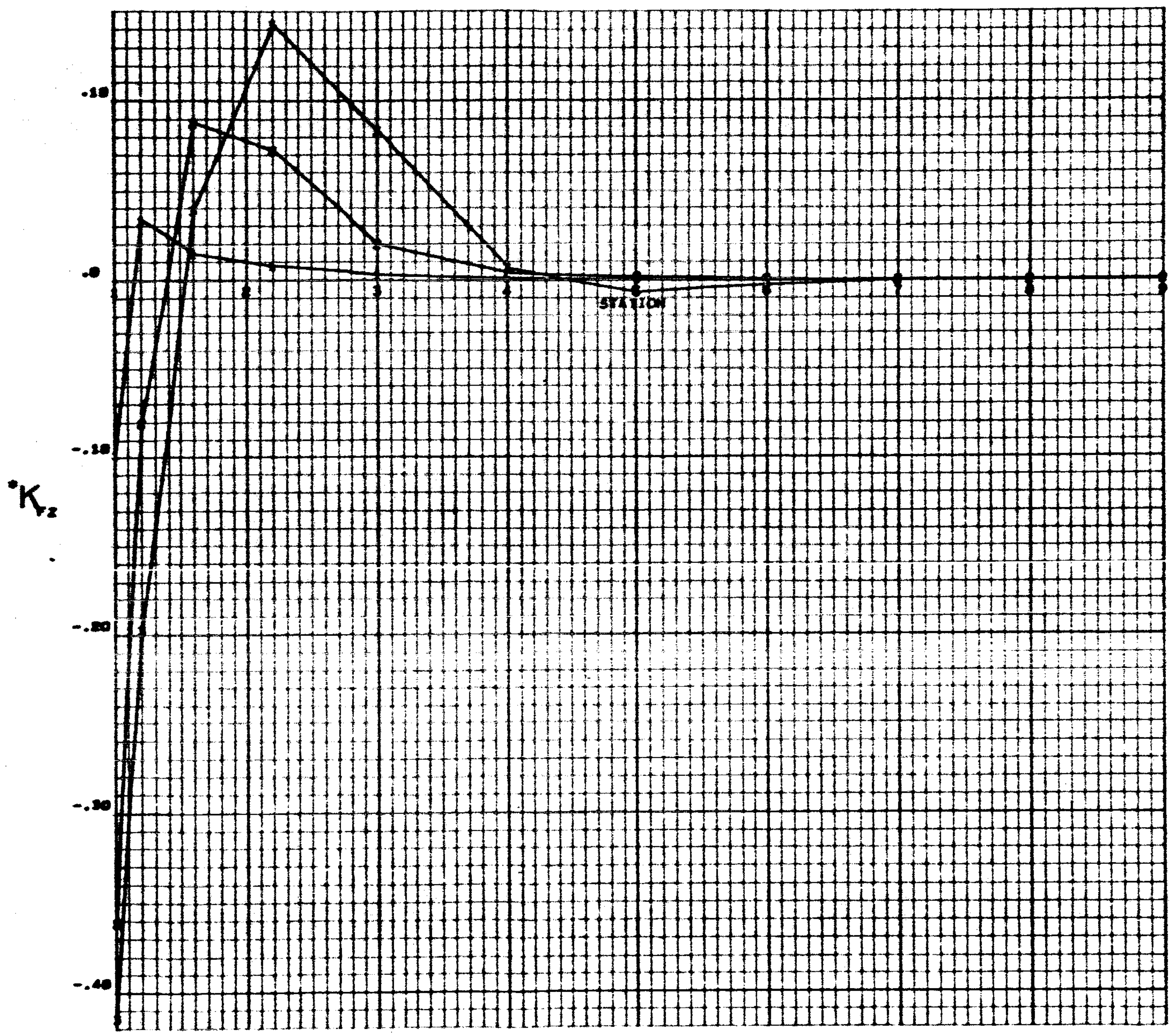
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

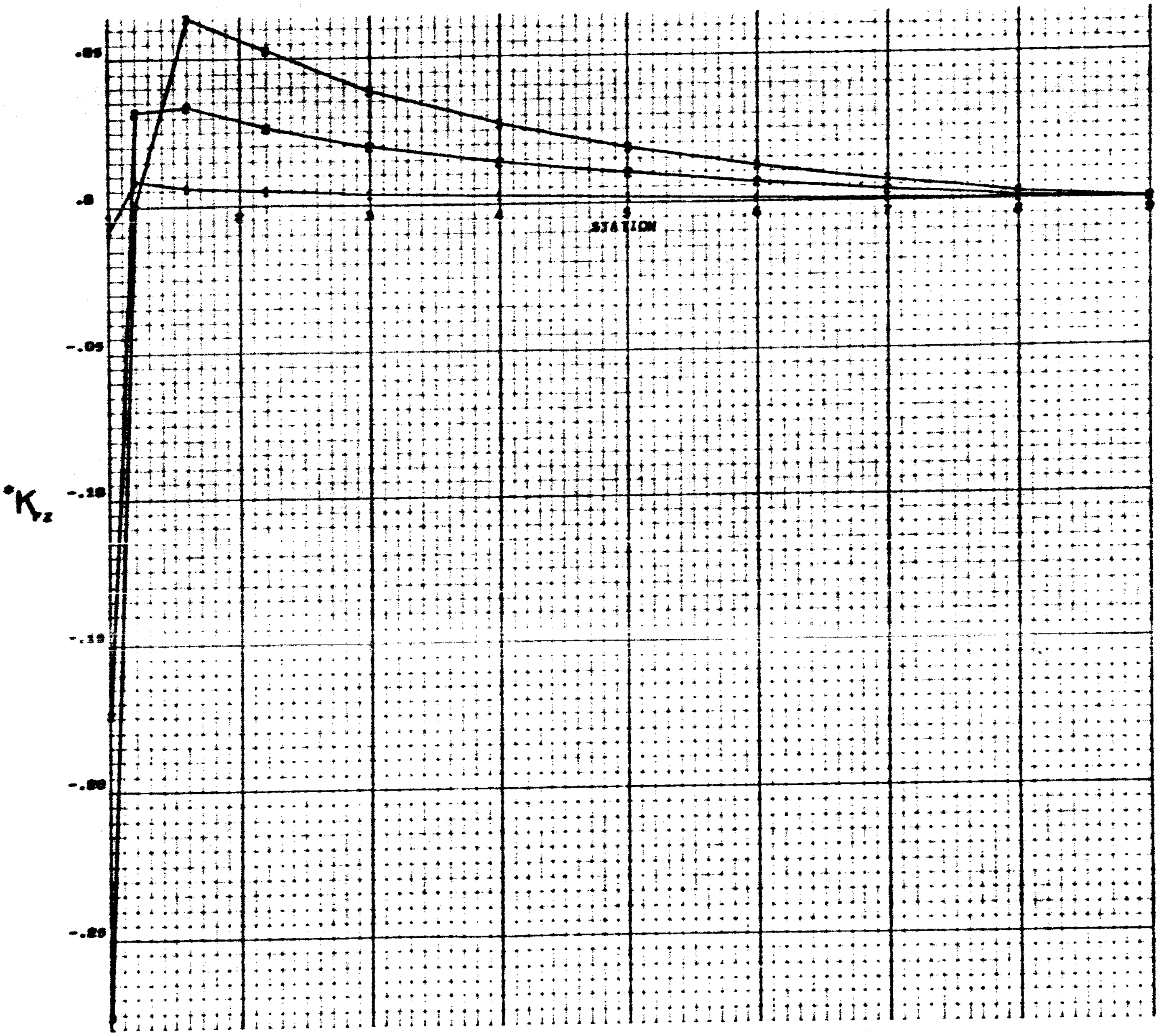


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

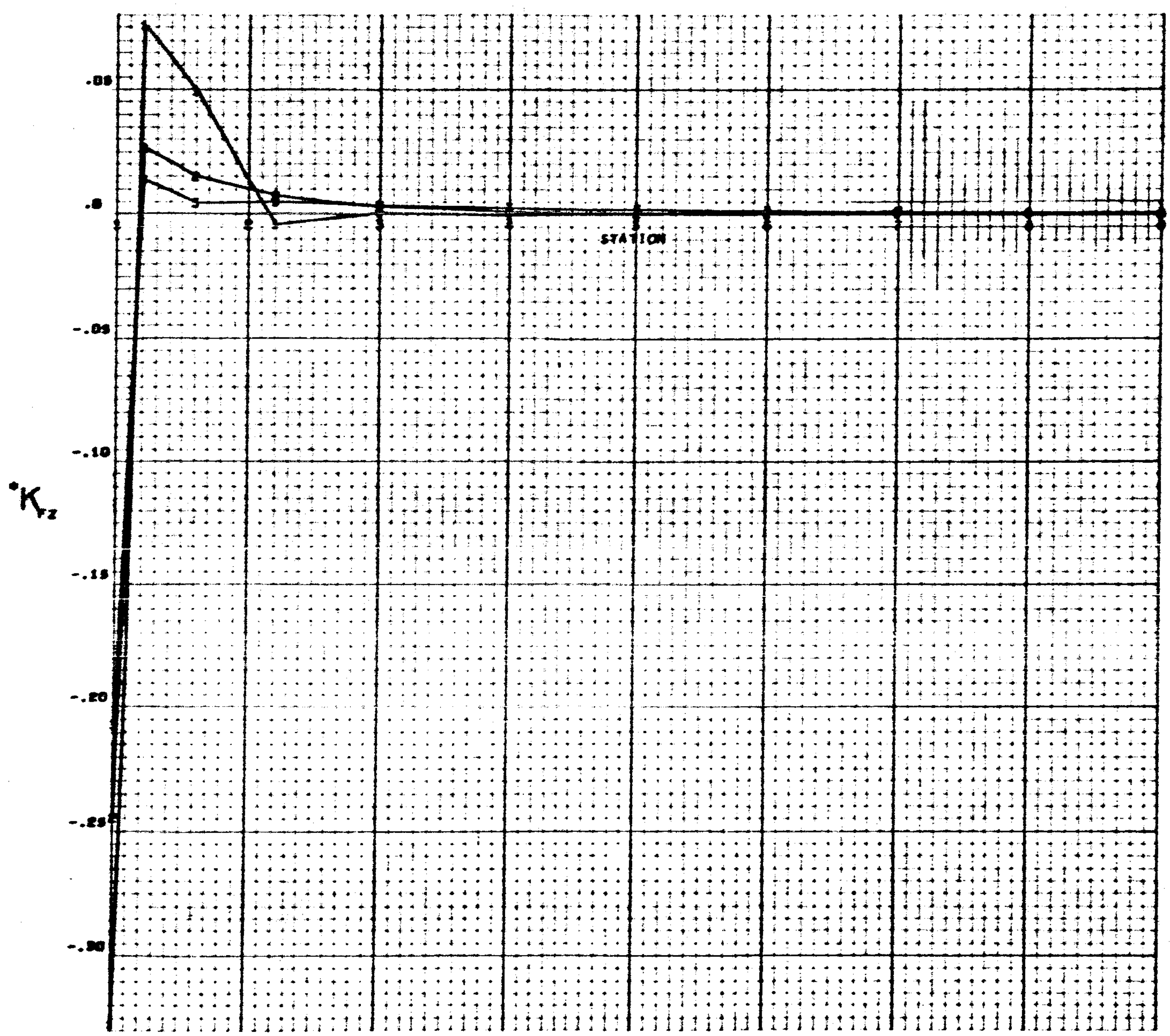
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

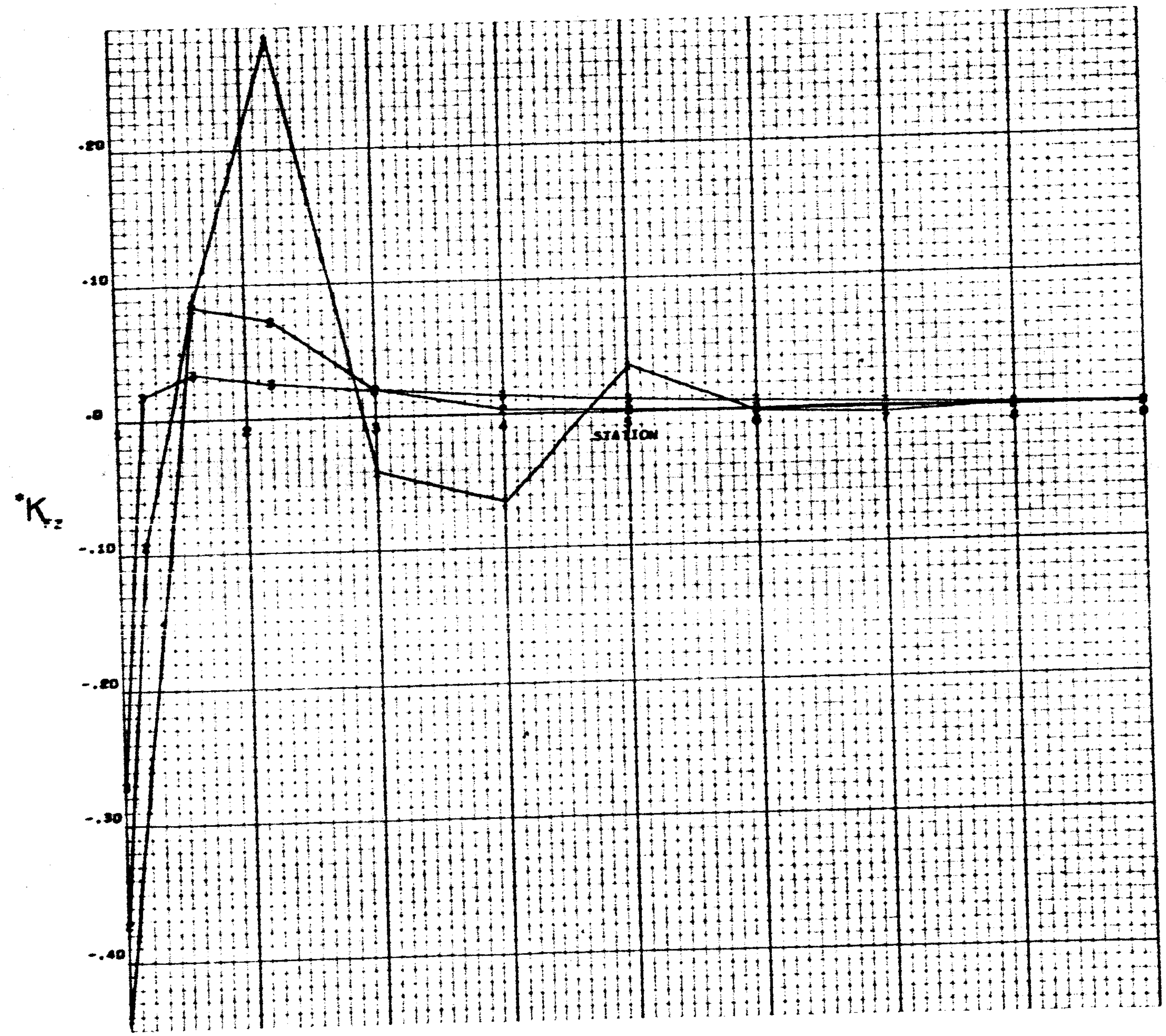


CURVE	GJ/EI
1	0.0[illegible]
2	0.[illegible]
3	2.[illegible]

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

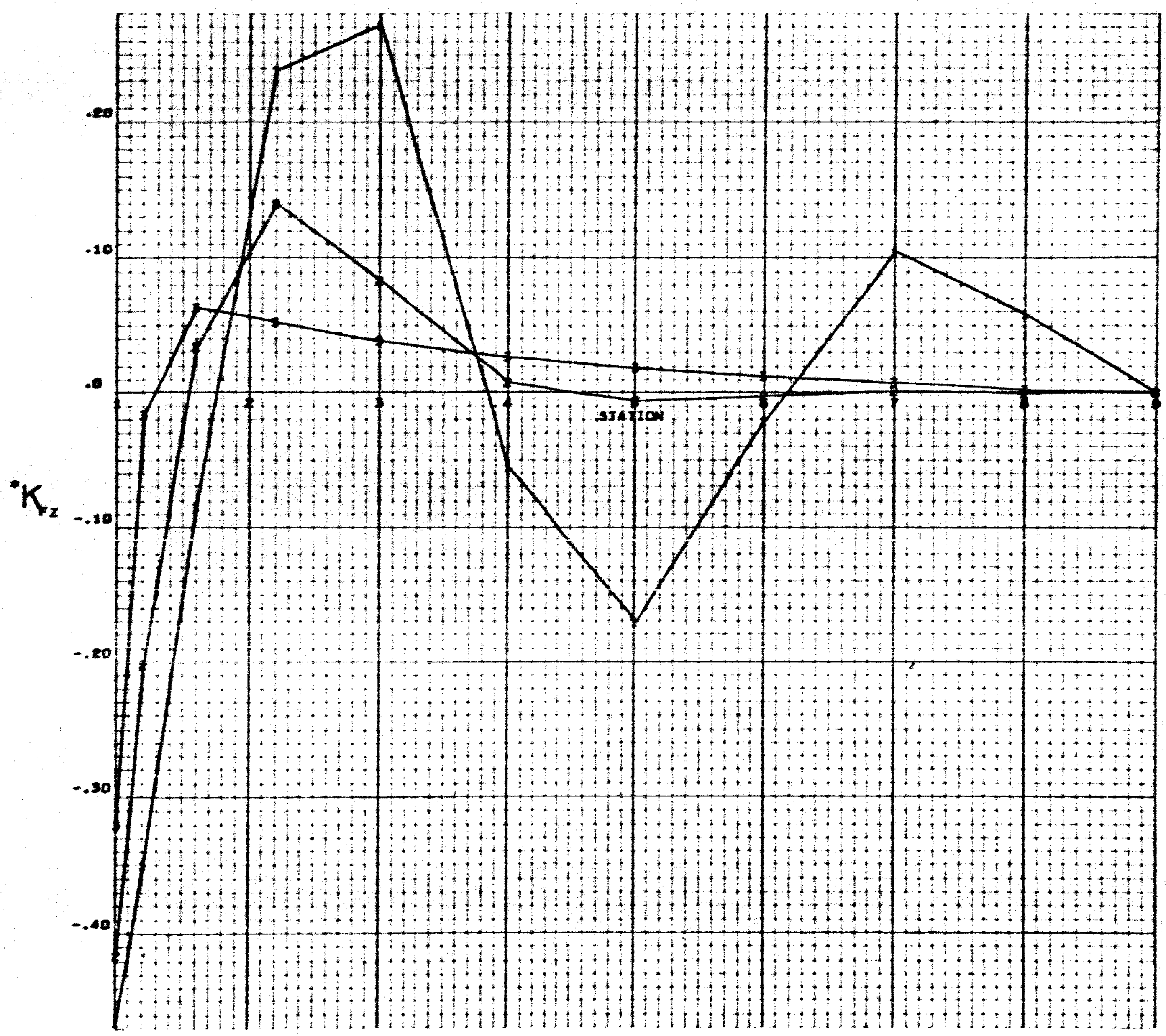
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

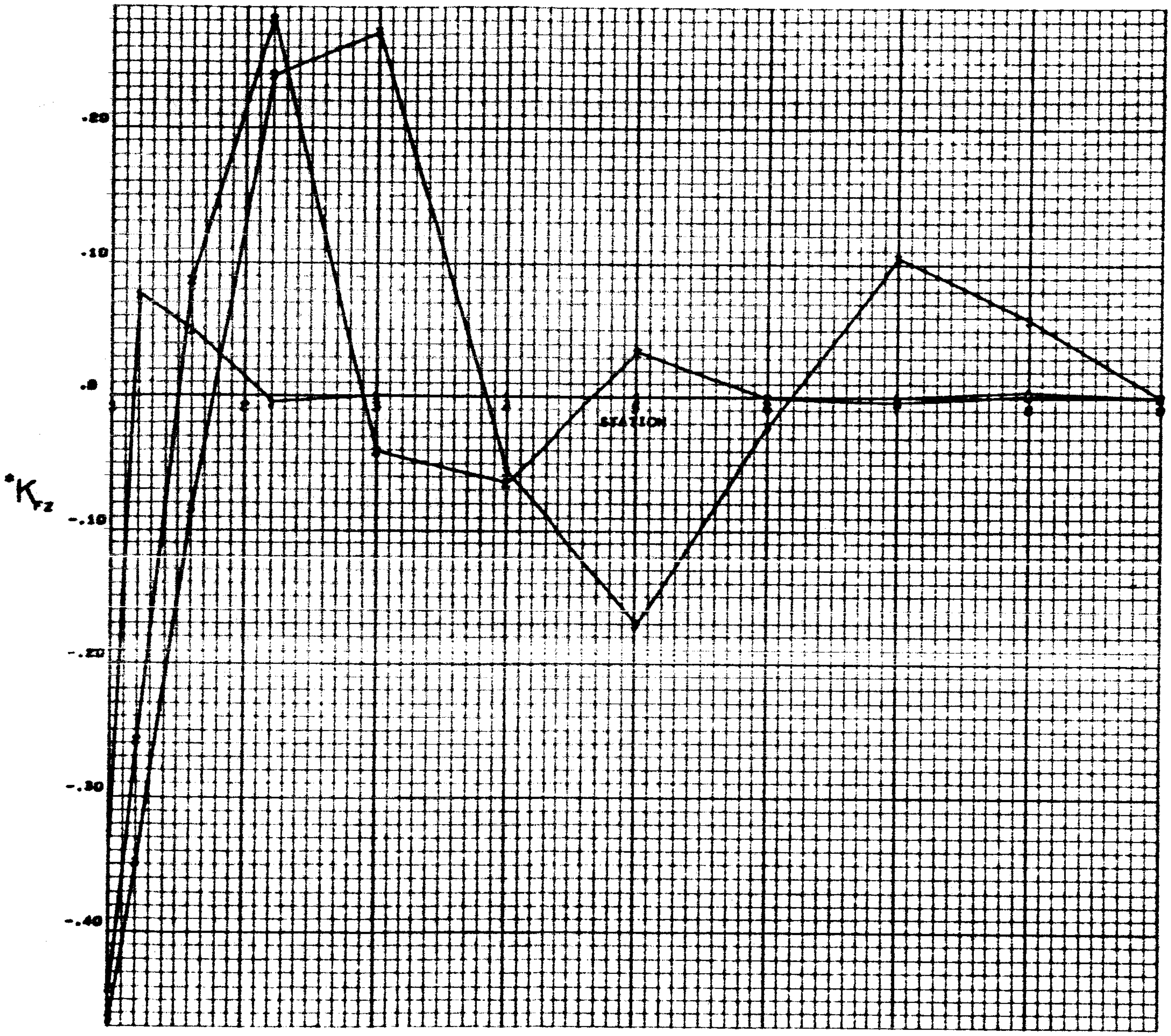
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{F_Z}$

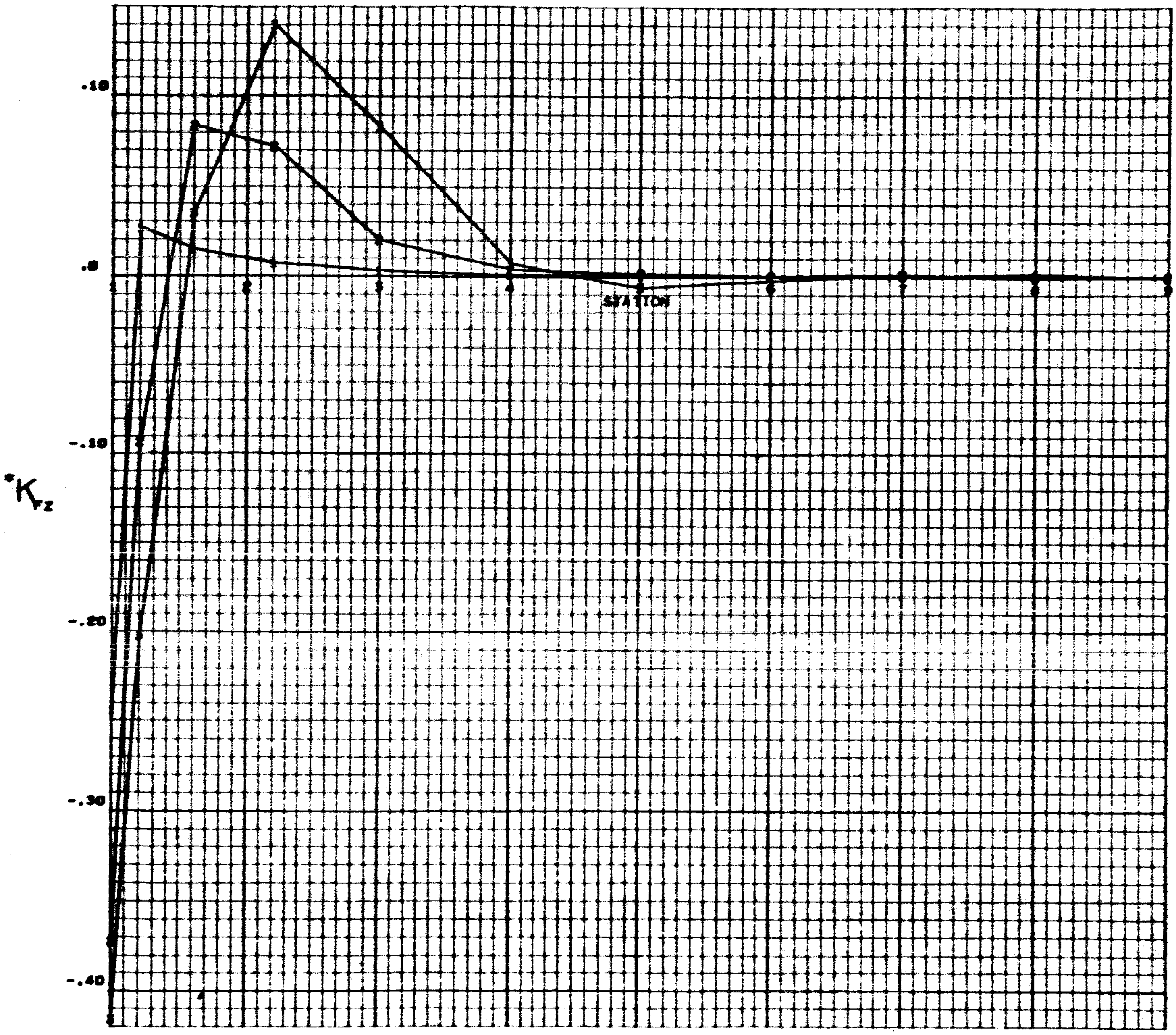
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

UNIT FORCE DISTRIBUTED OVER ELEMENT ! ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

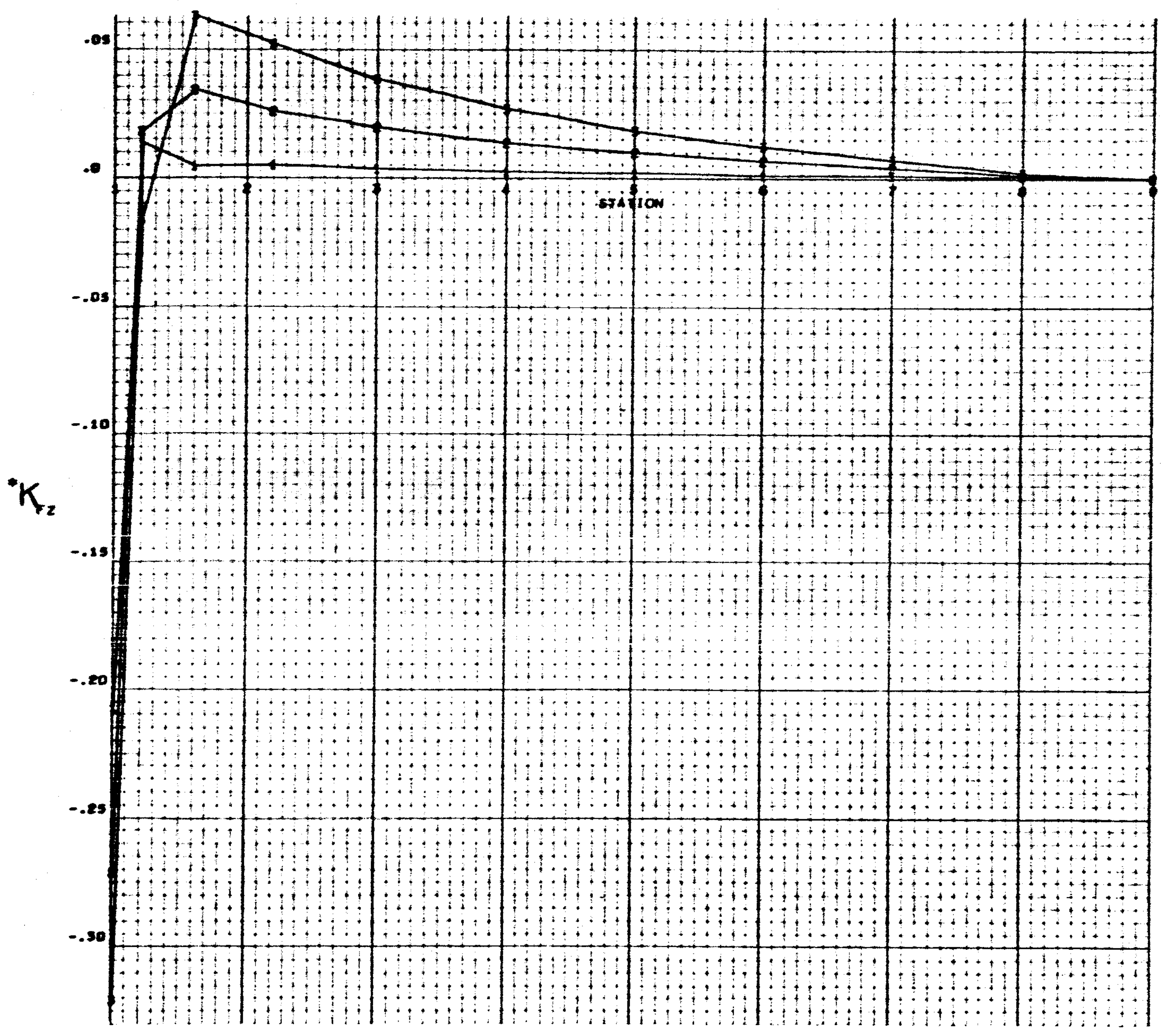


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{F_Z}

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

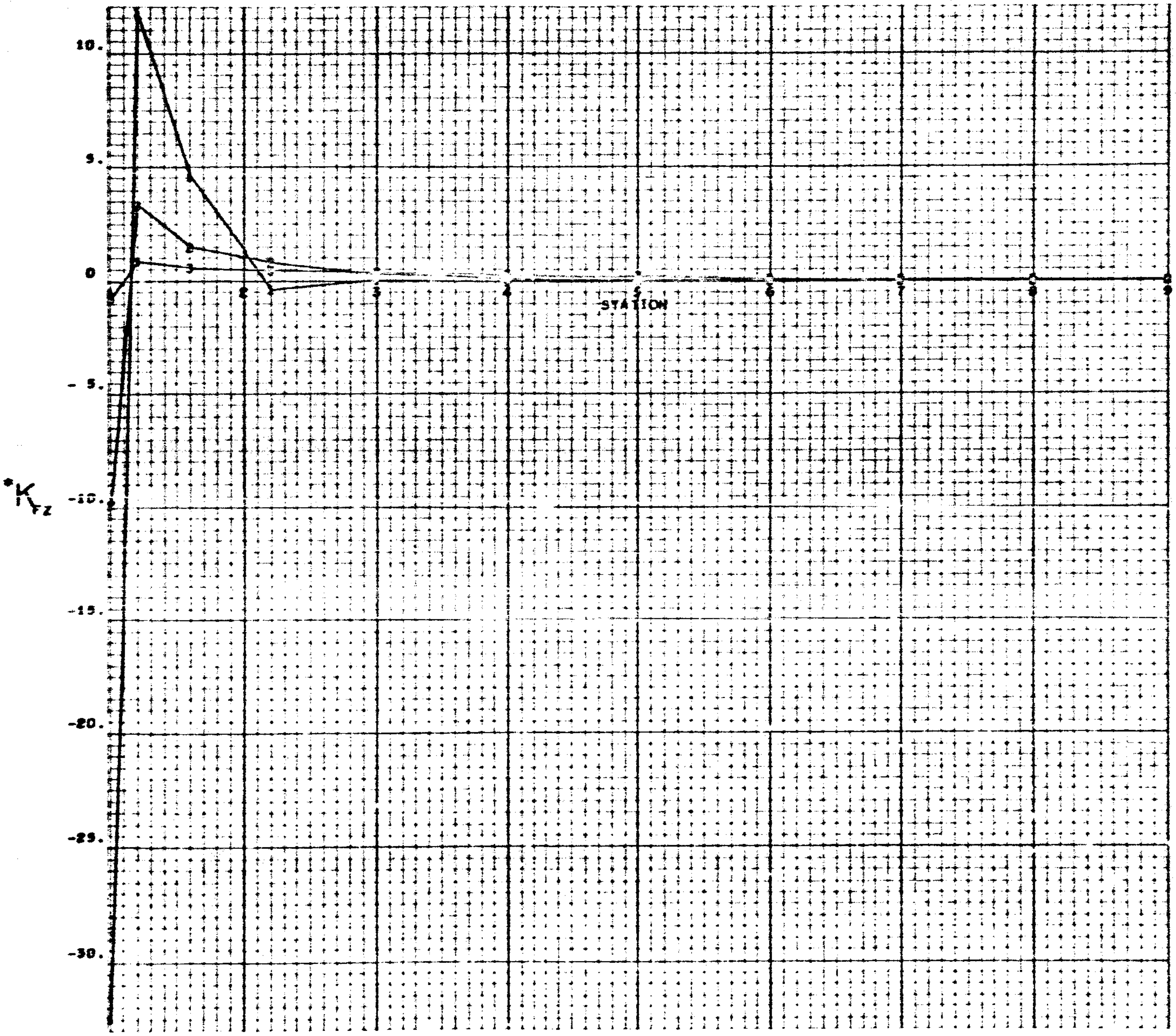


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

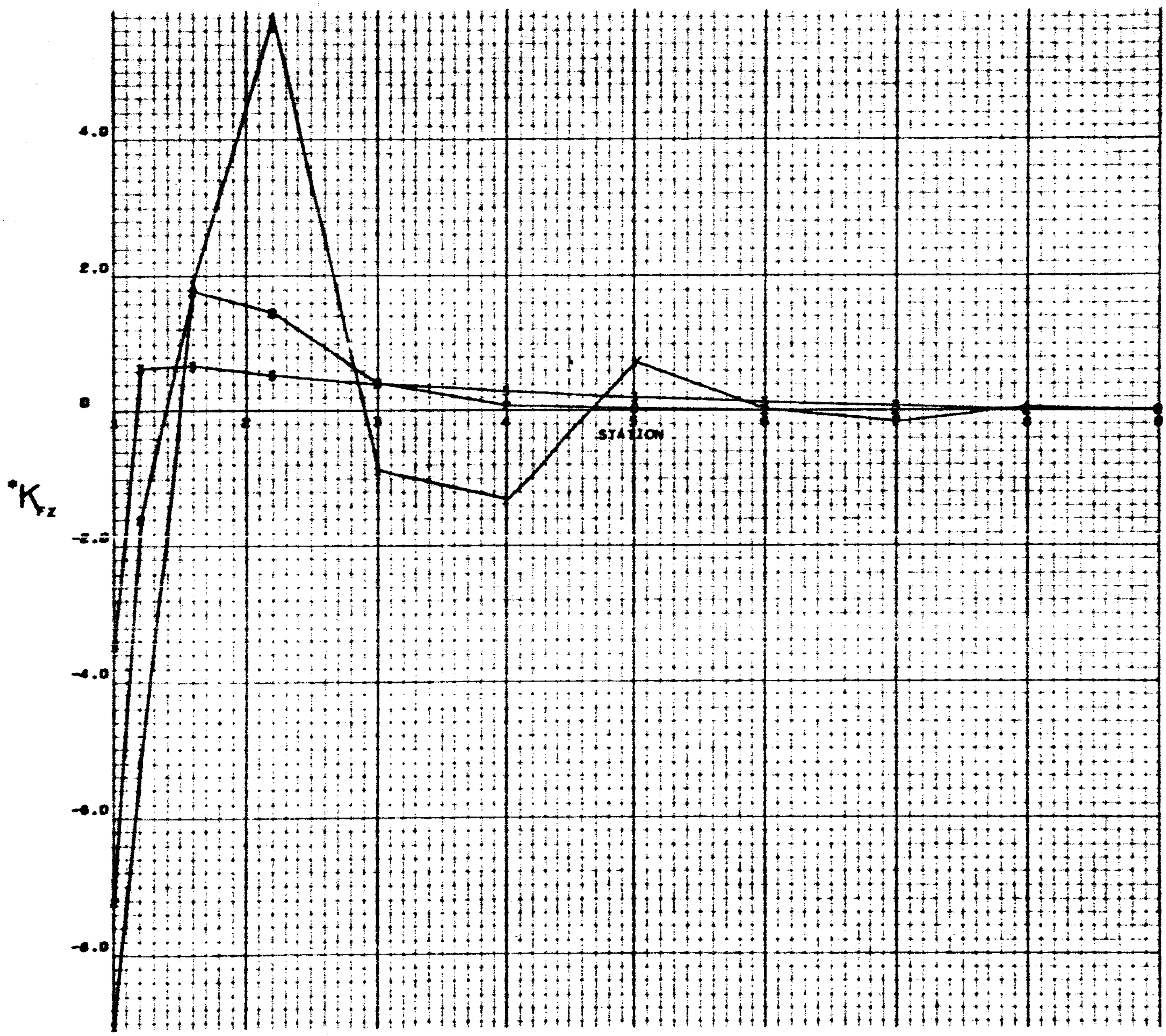
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE

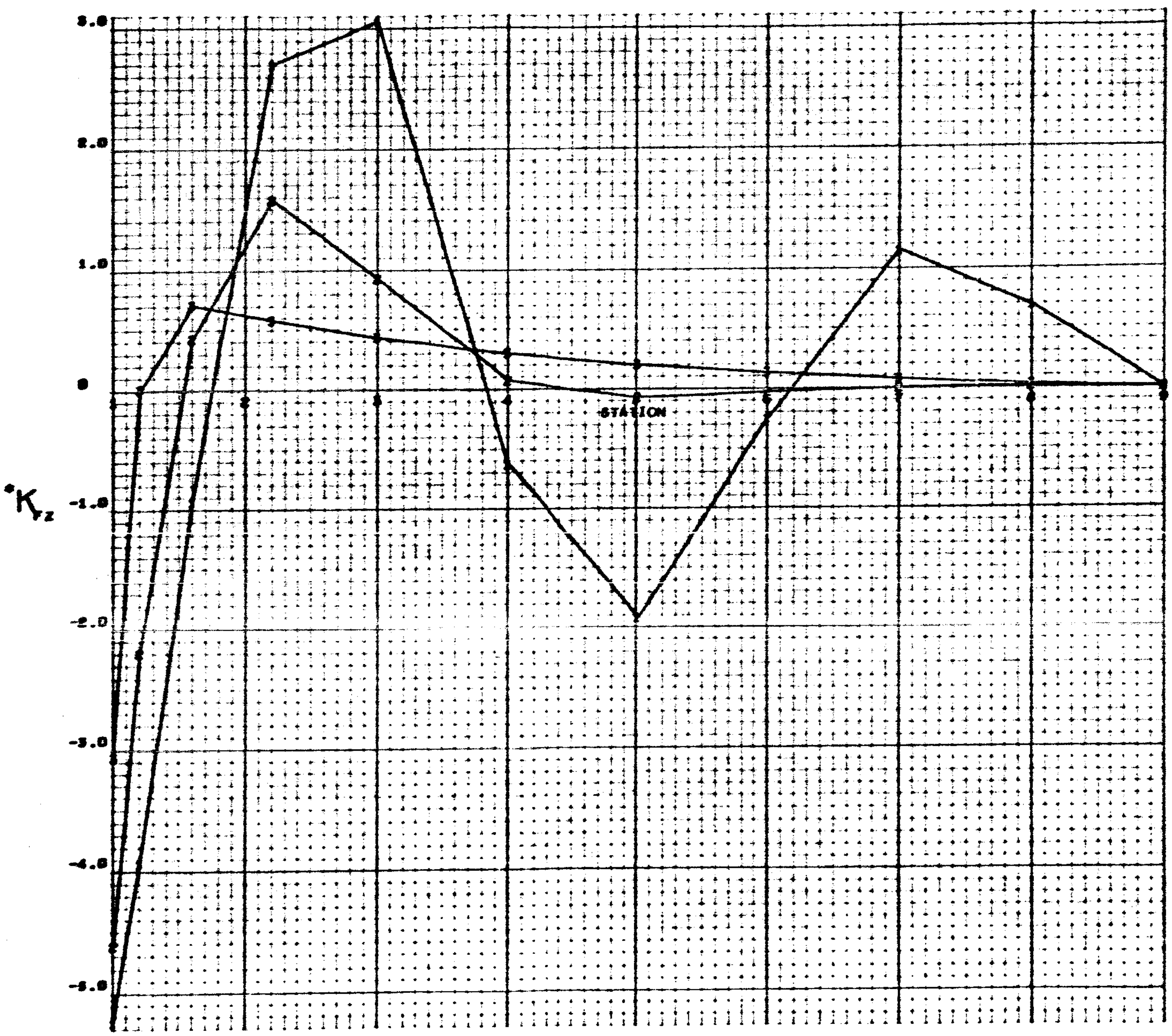


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE

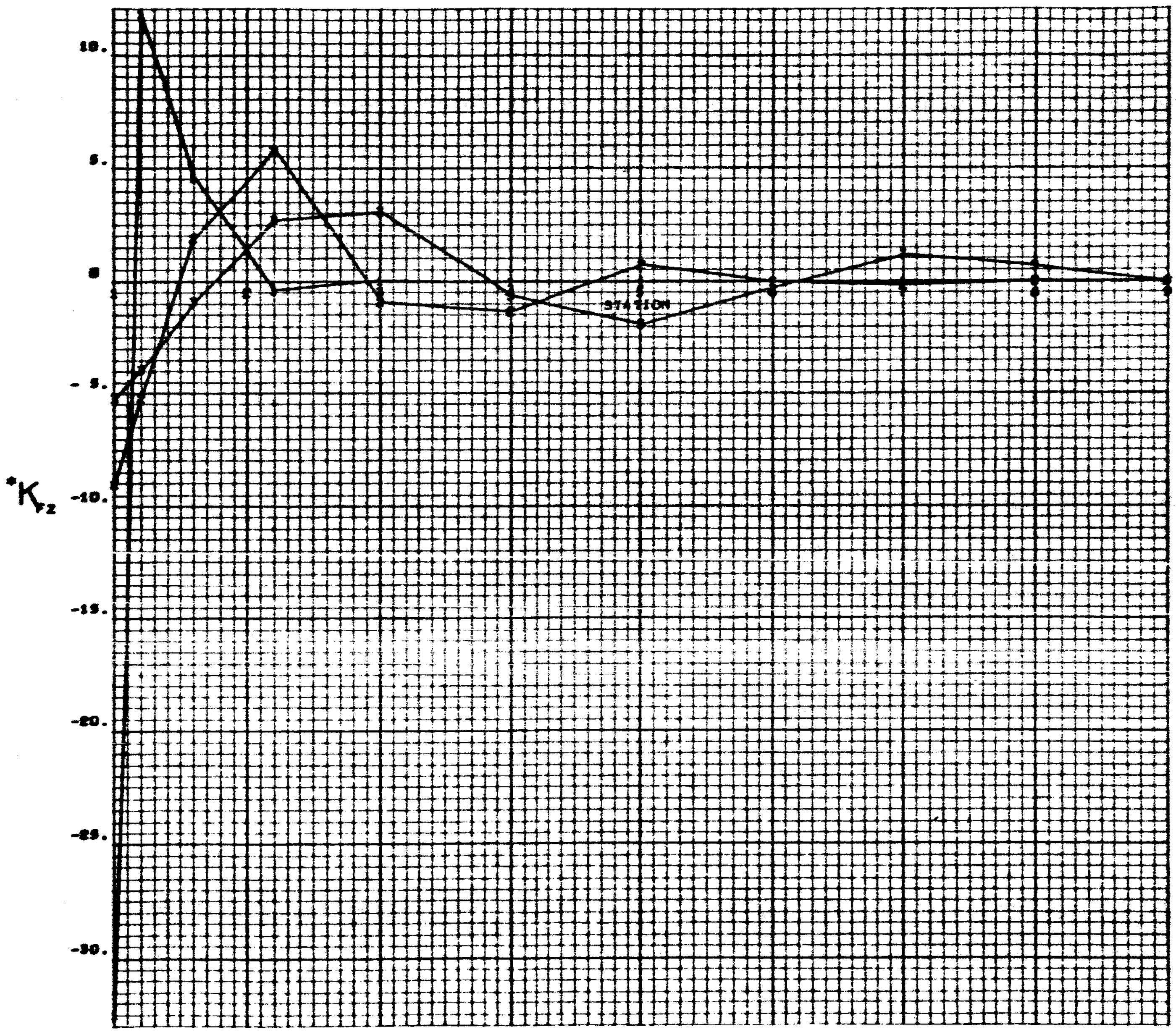


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{F_Z}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

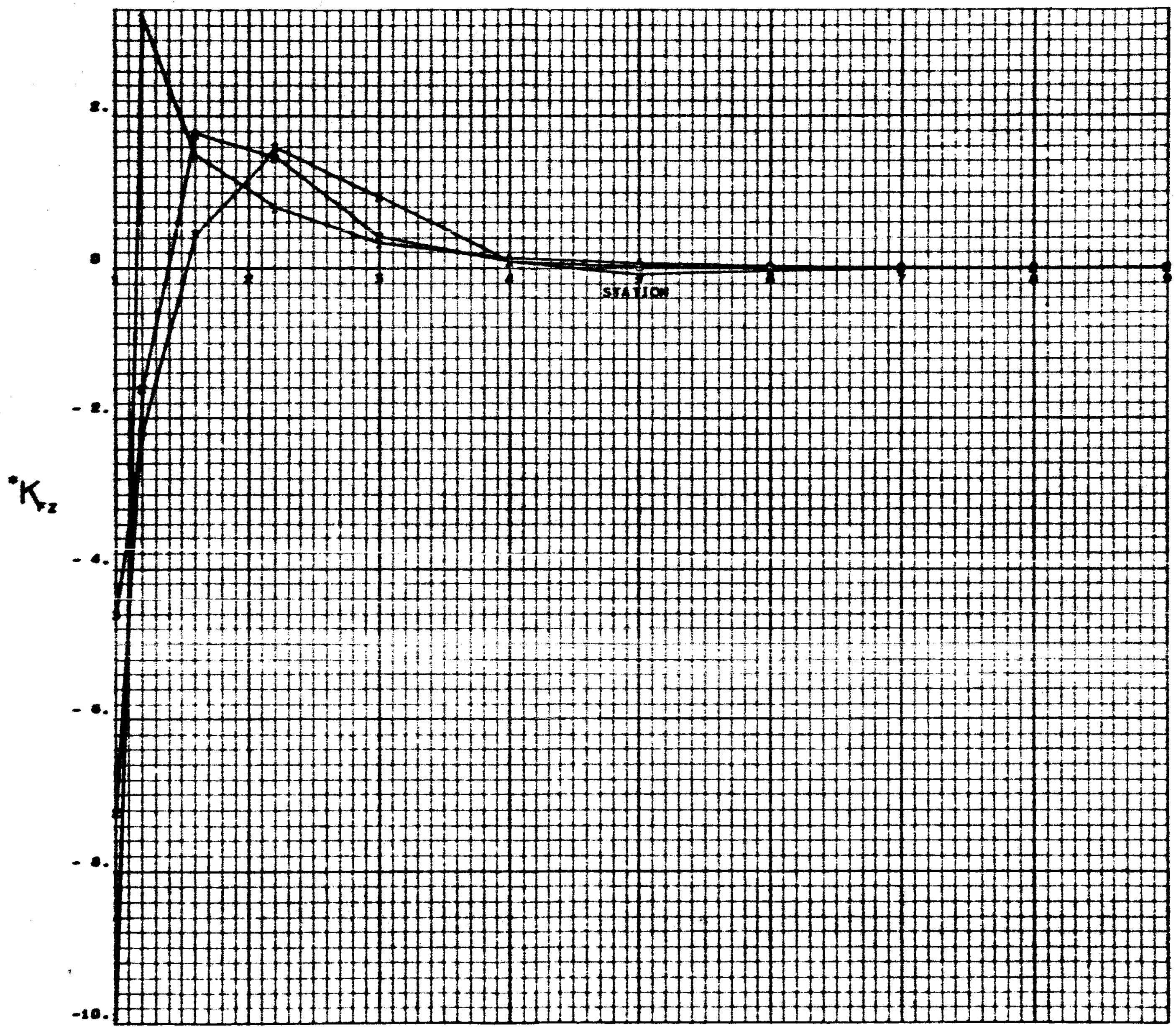
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.82, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{F_Z}

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

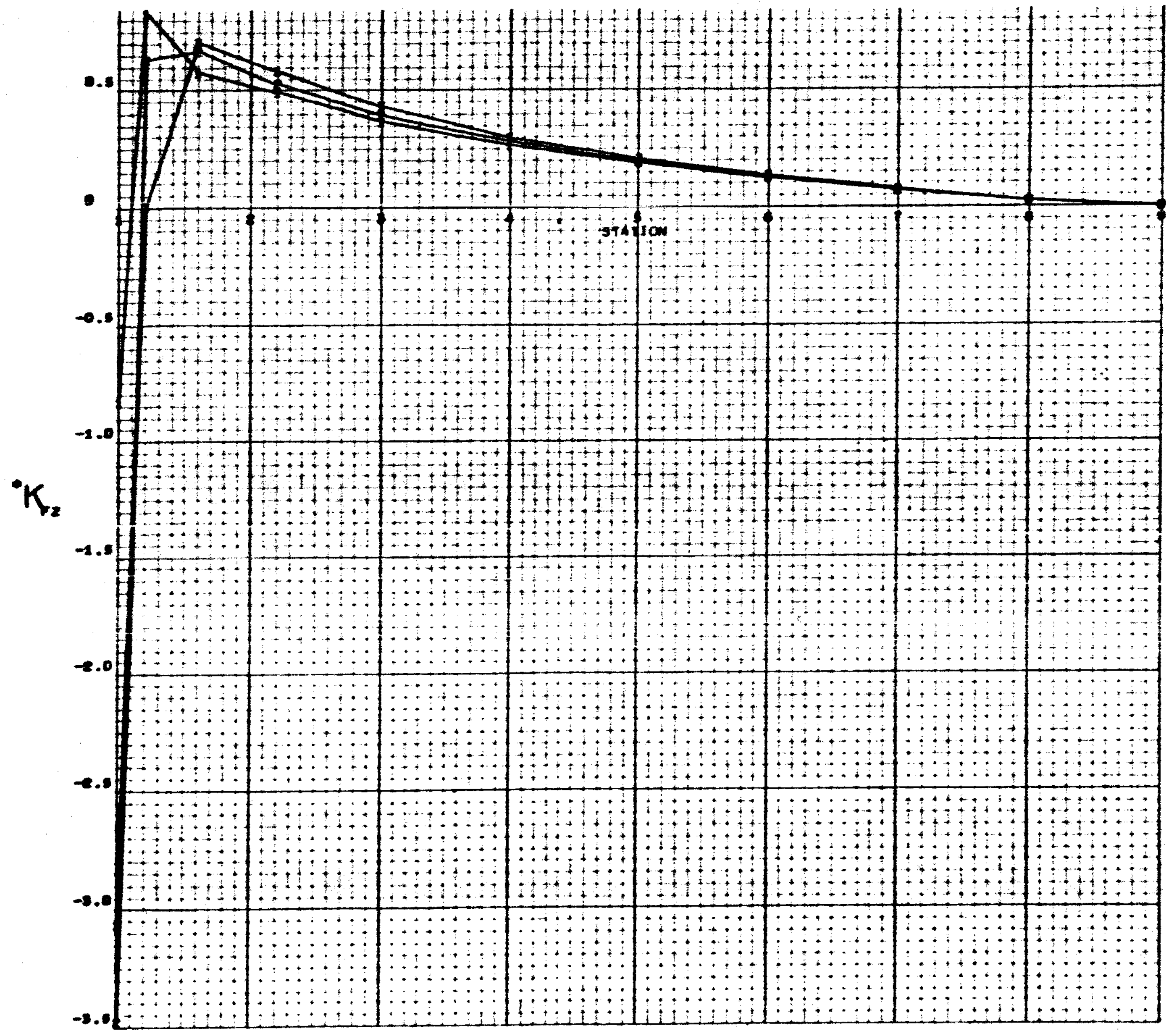


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

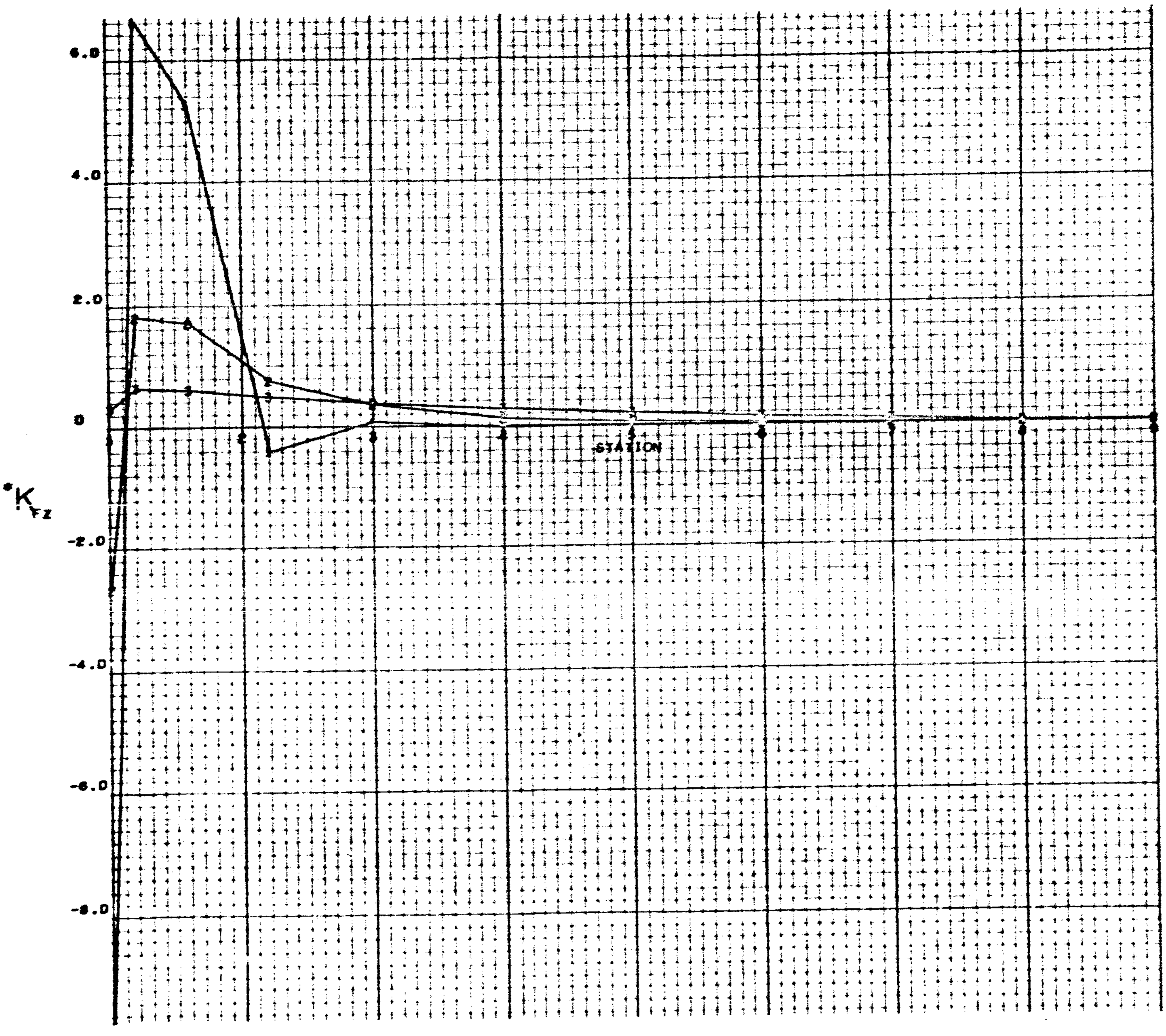


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

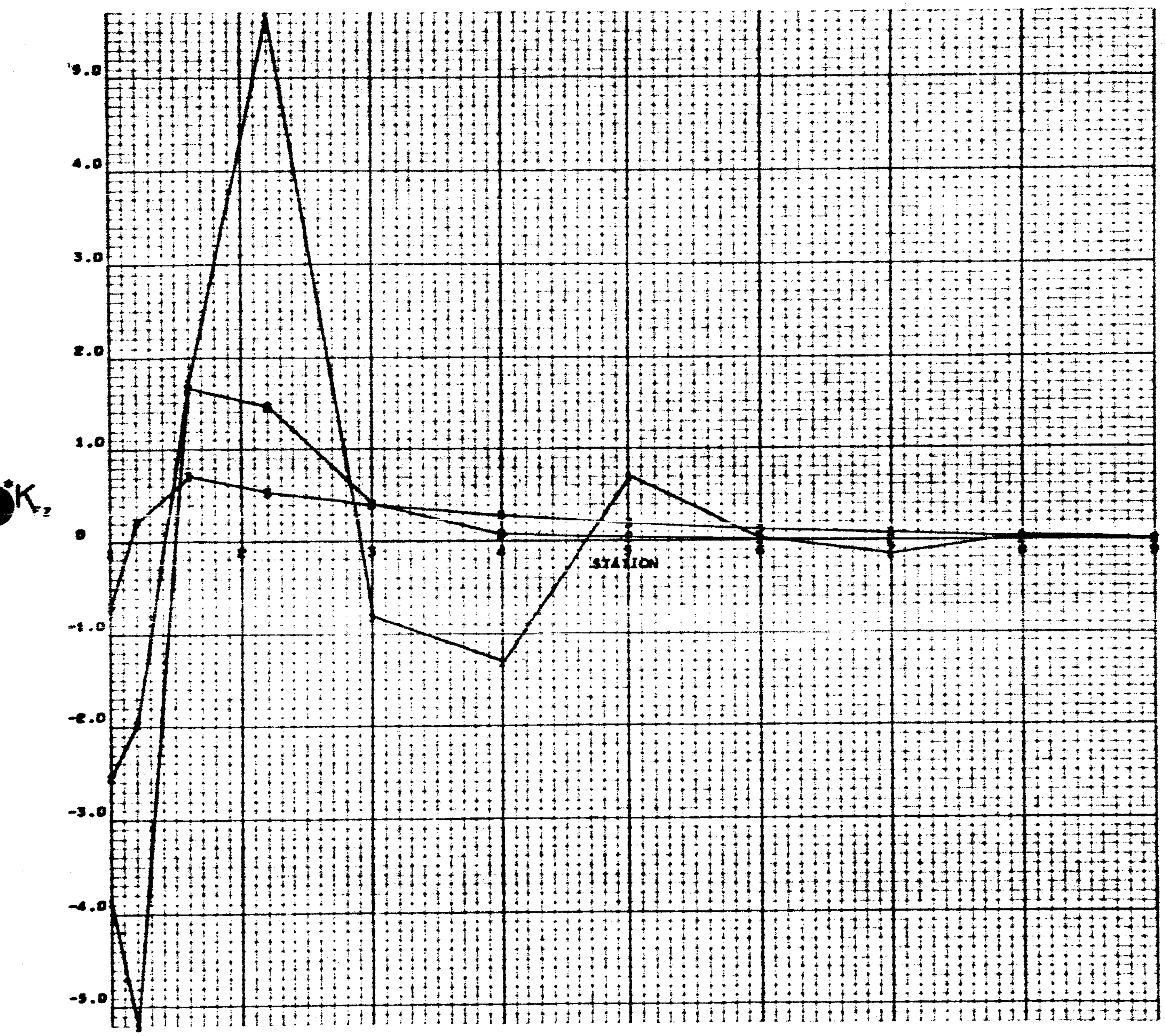


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

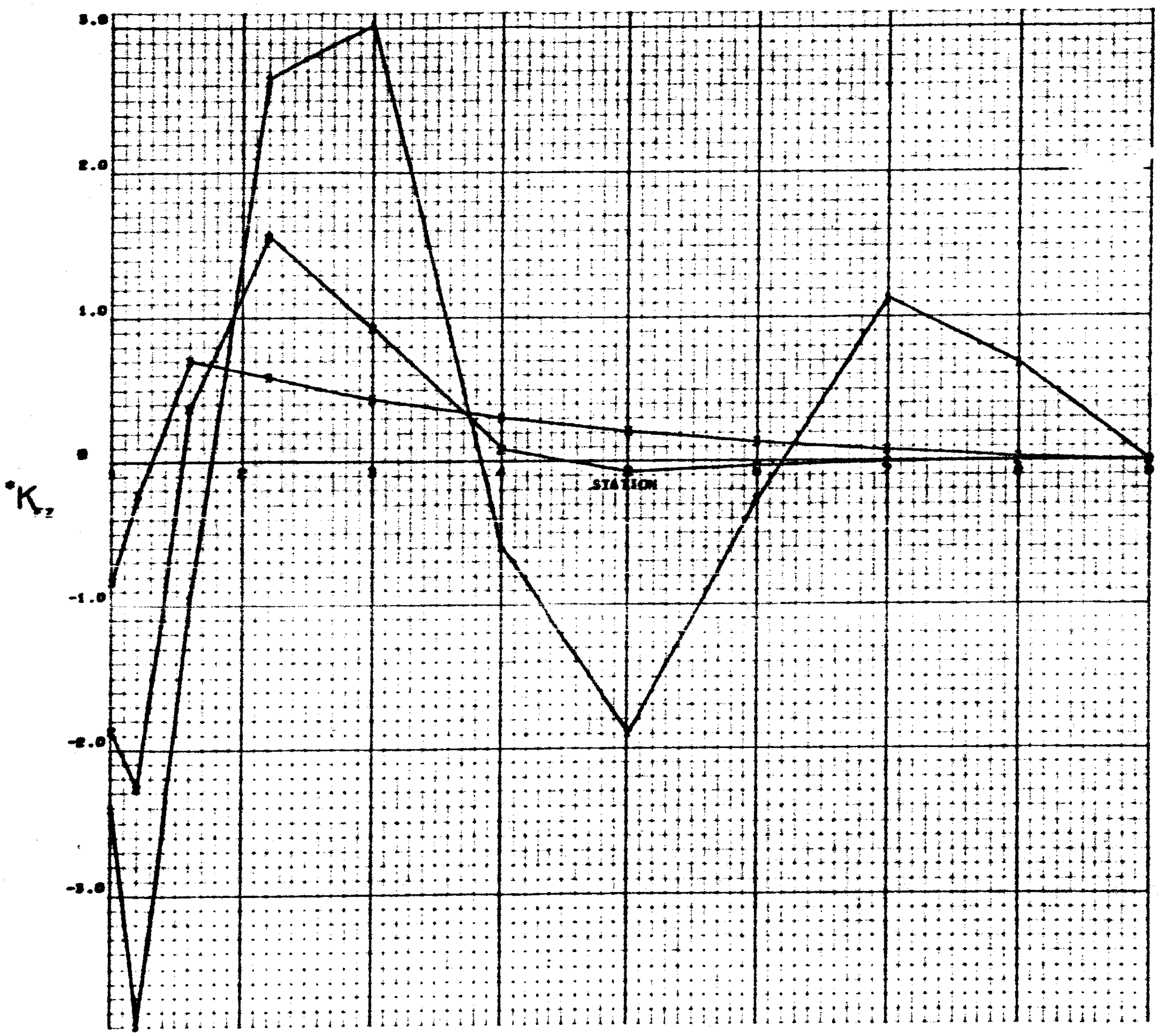
*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1

F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER

C/R = -0.09, GJ/EI VARIABLE

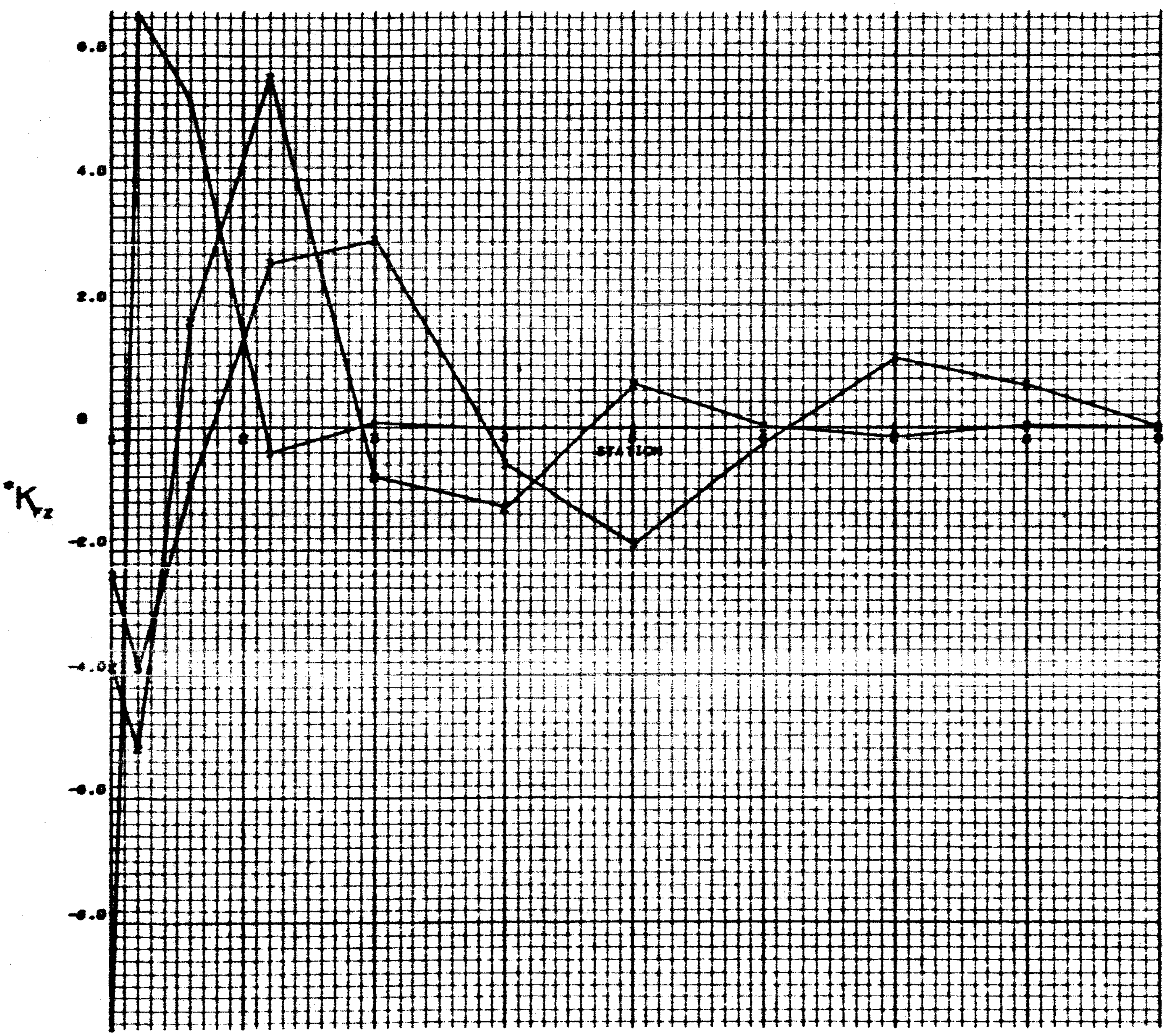


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

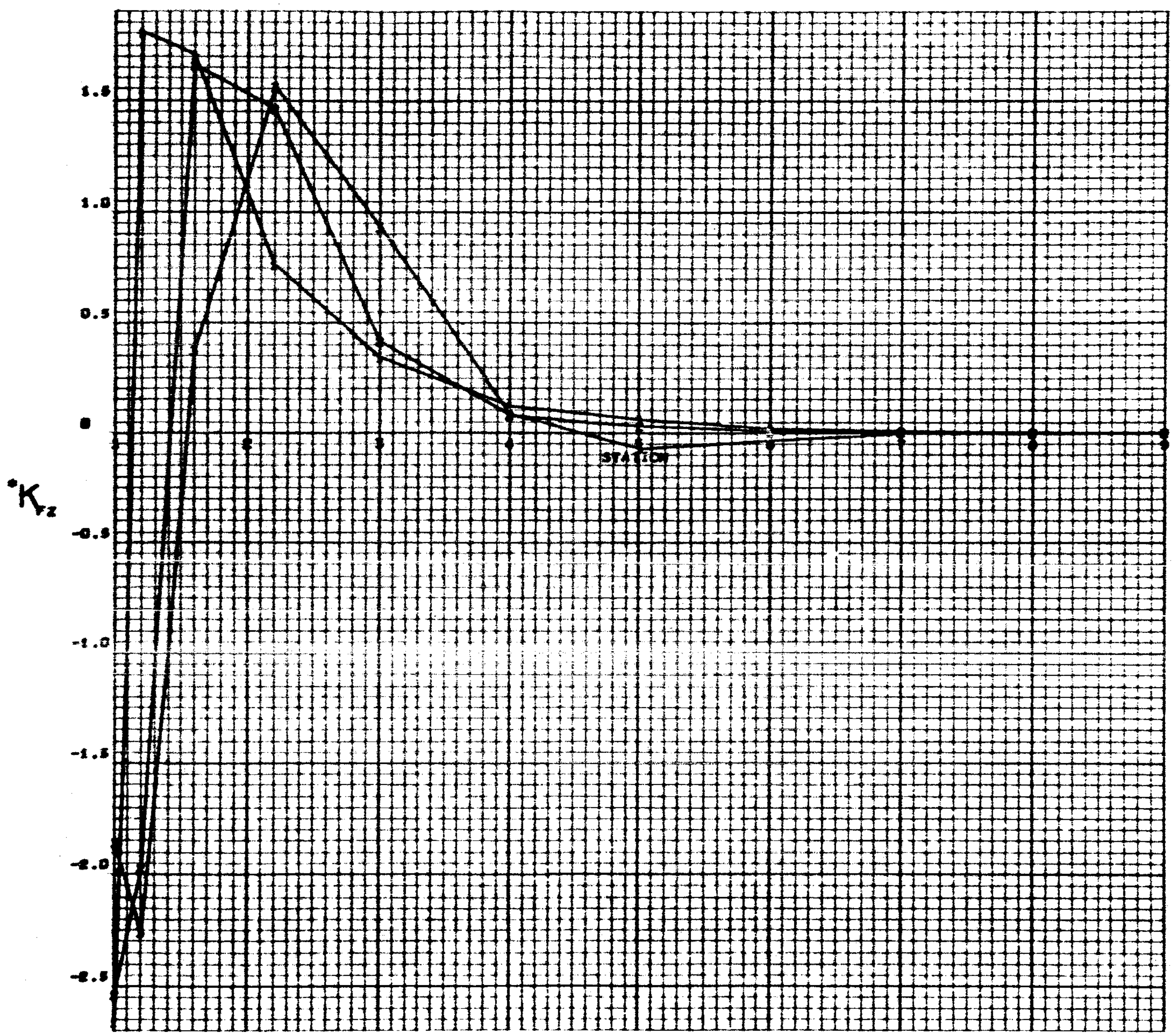
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

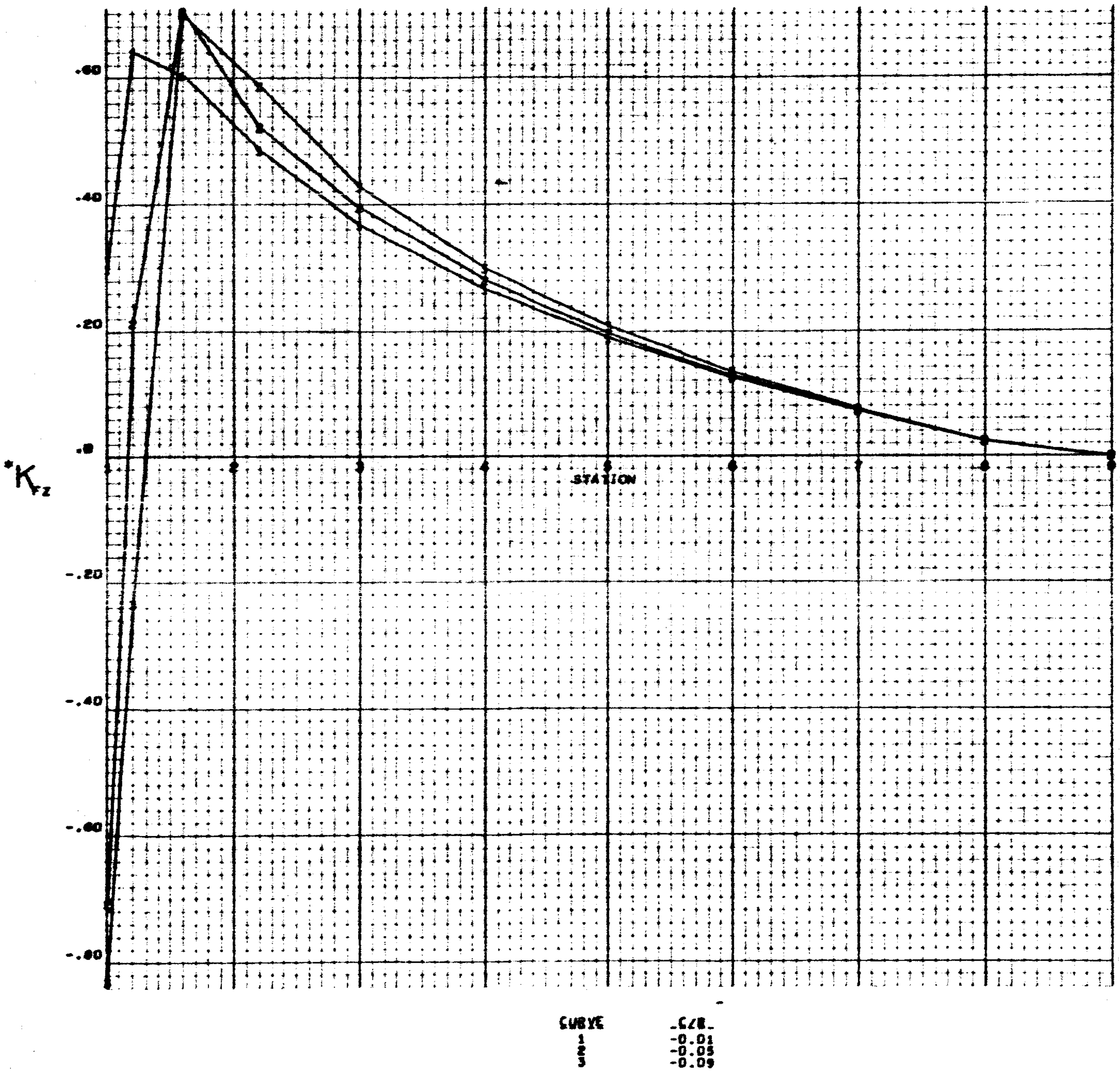
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
6J/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

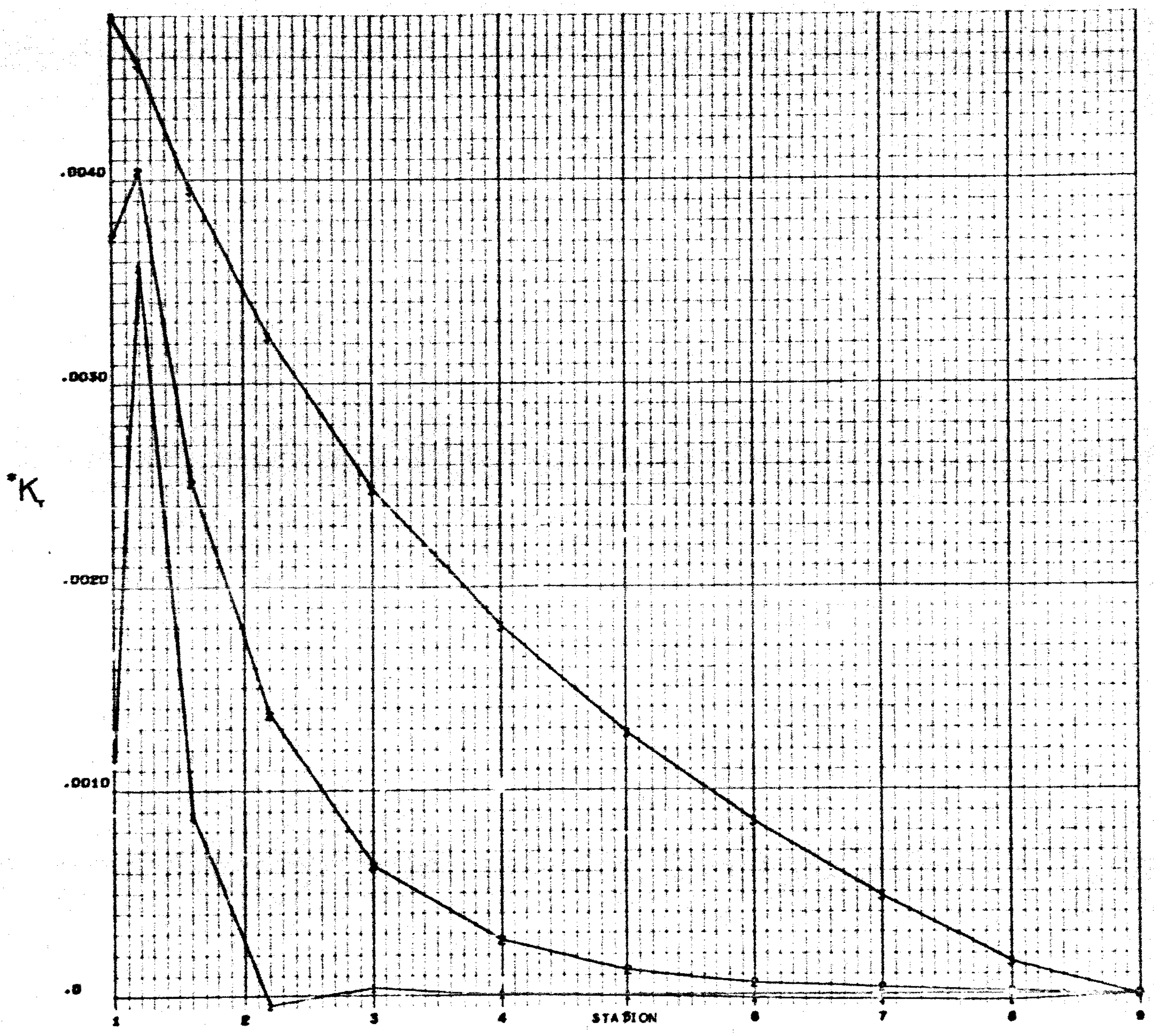
*NOTE . INTERNAL NORMAL FORCE, F_Z = K_{FZ}

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
F_Z, INTERNAL NORMAL FORCE AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



*NOTE . INTERNAL NORMAL FORCE, $F_Z = K_{FZ}$

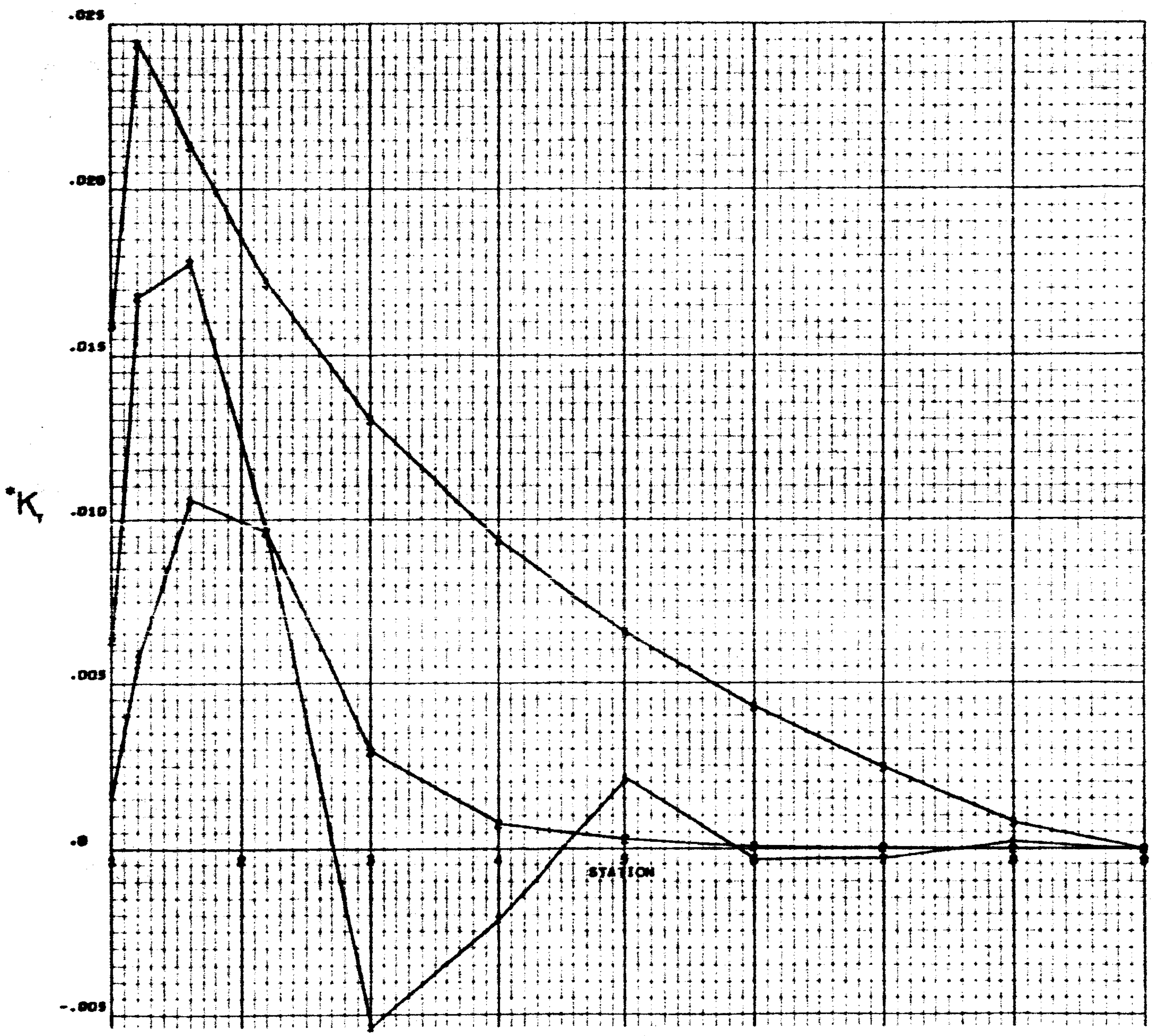
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

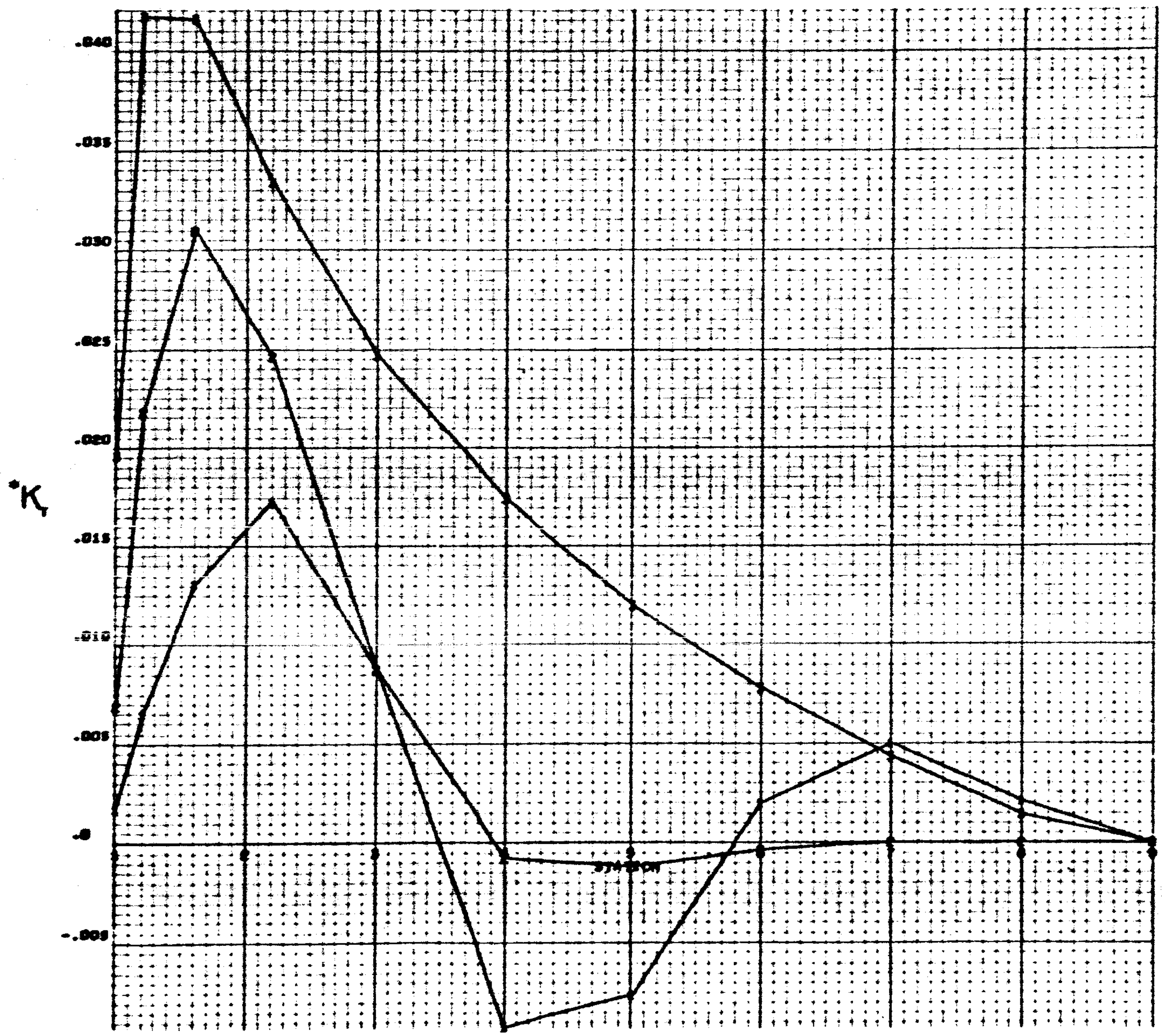
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE

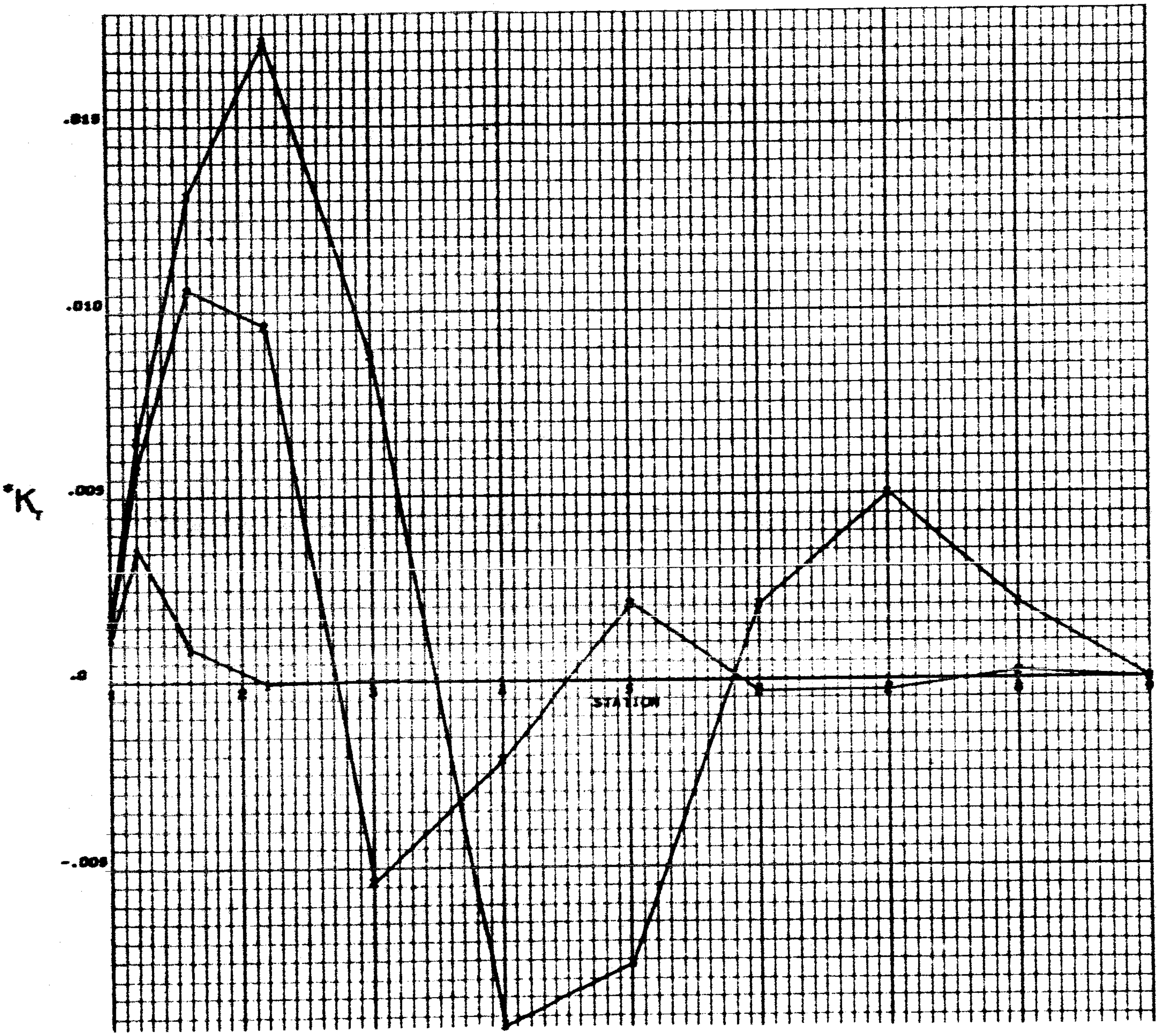


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

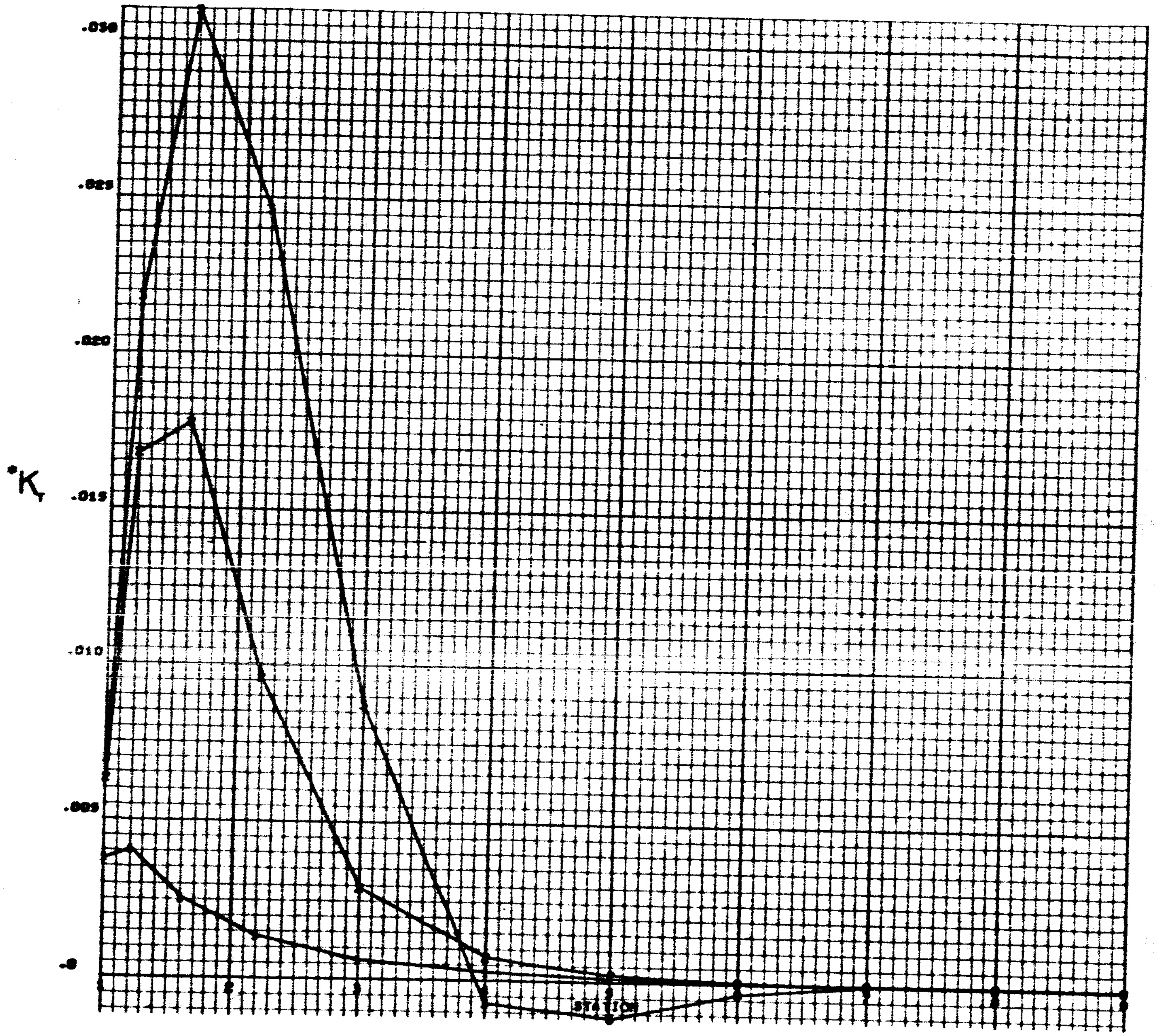


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

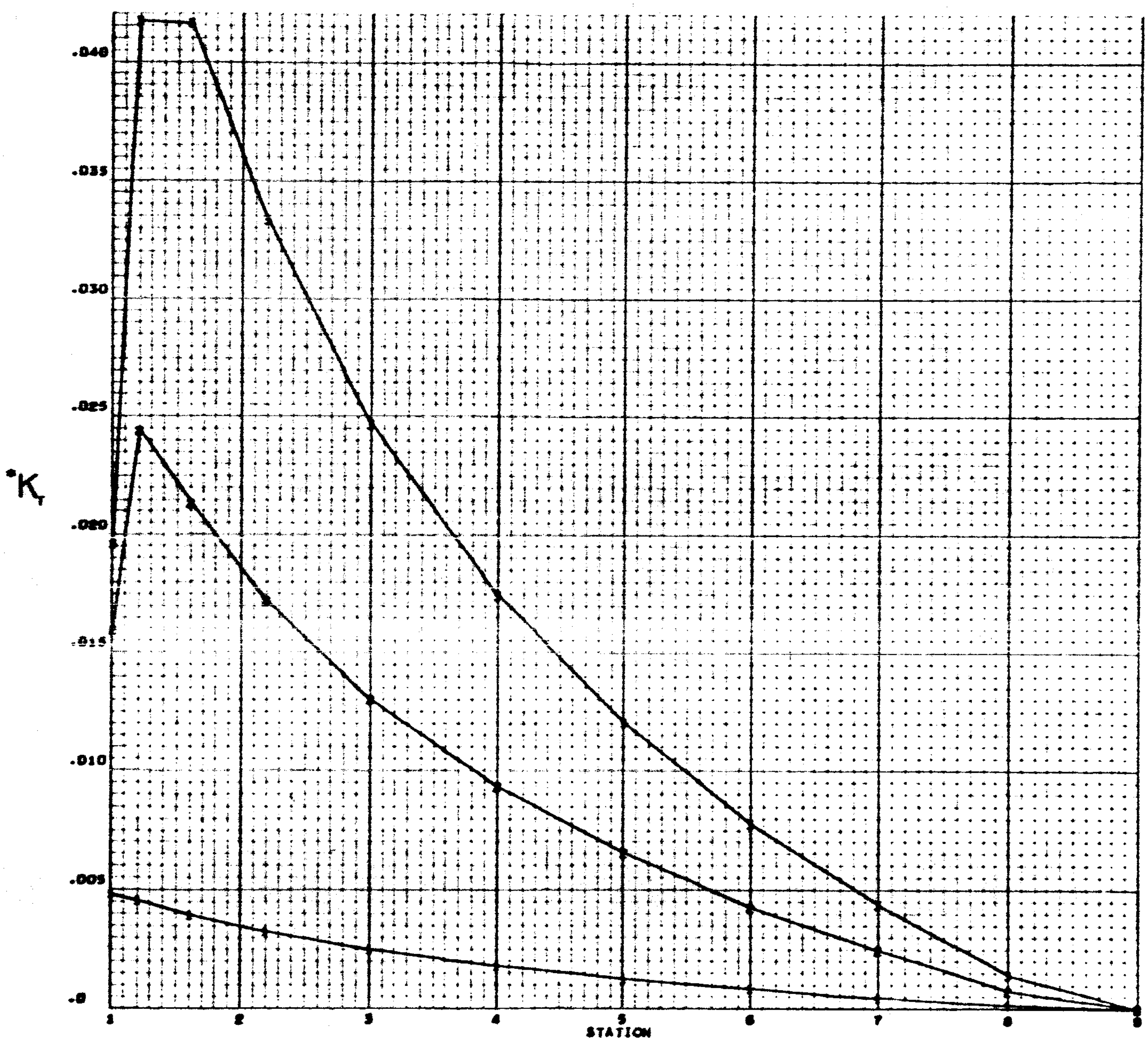
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.03
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

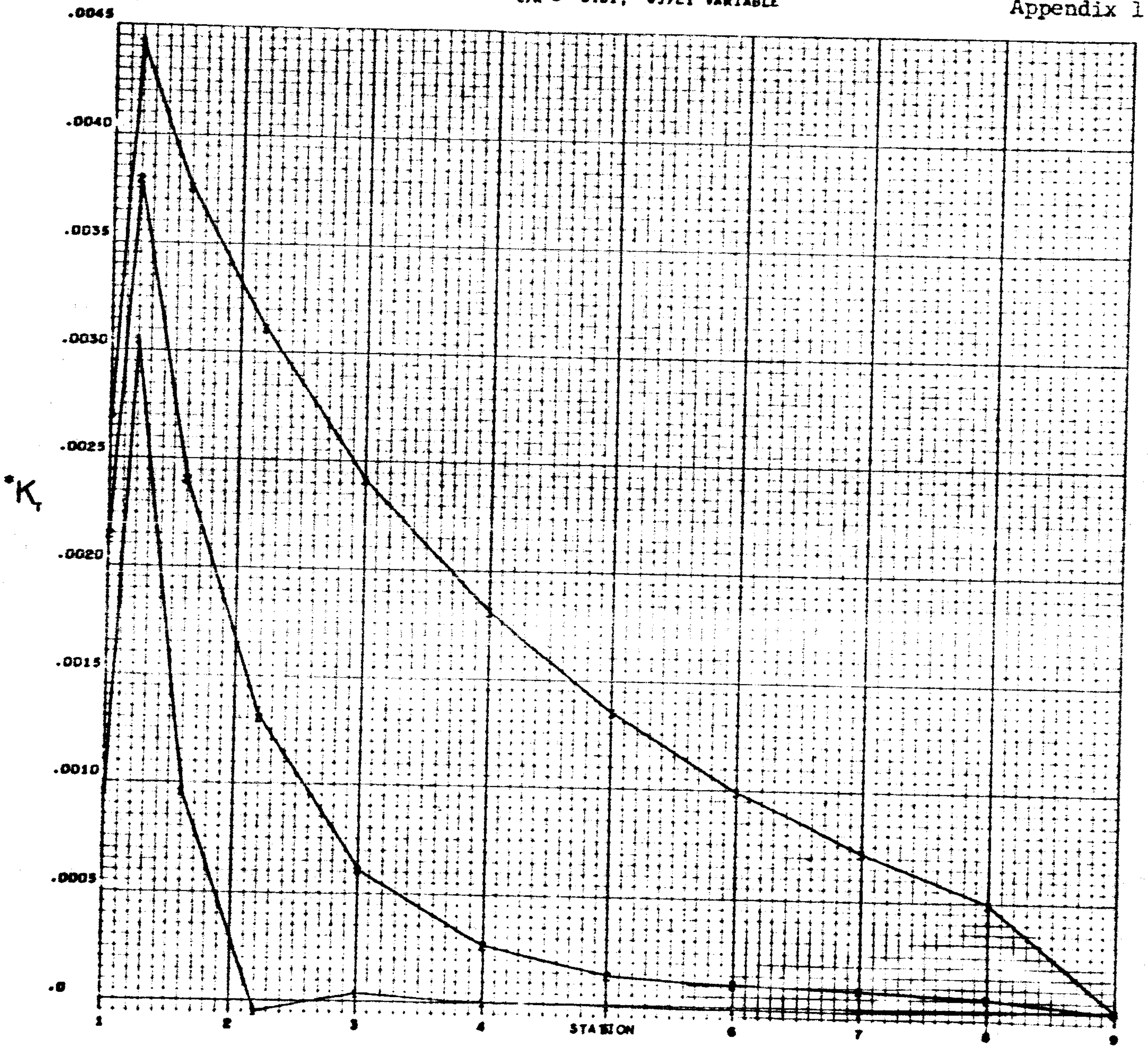
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

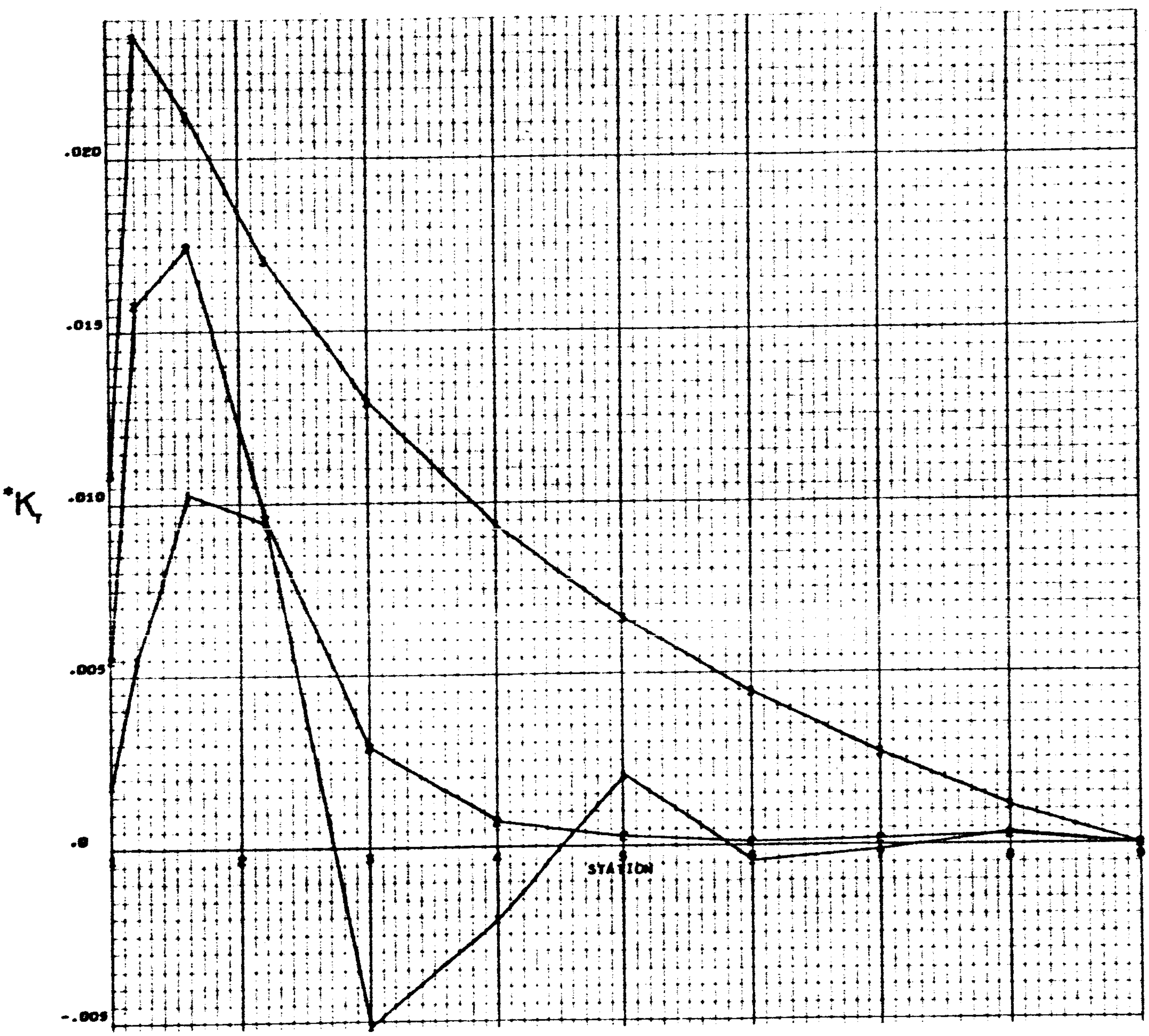


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

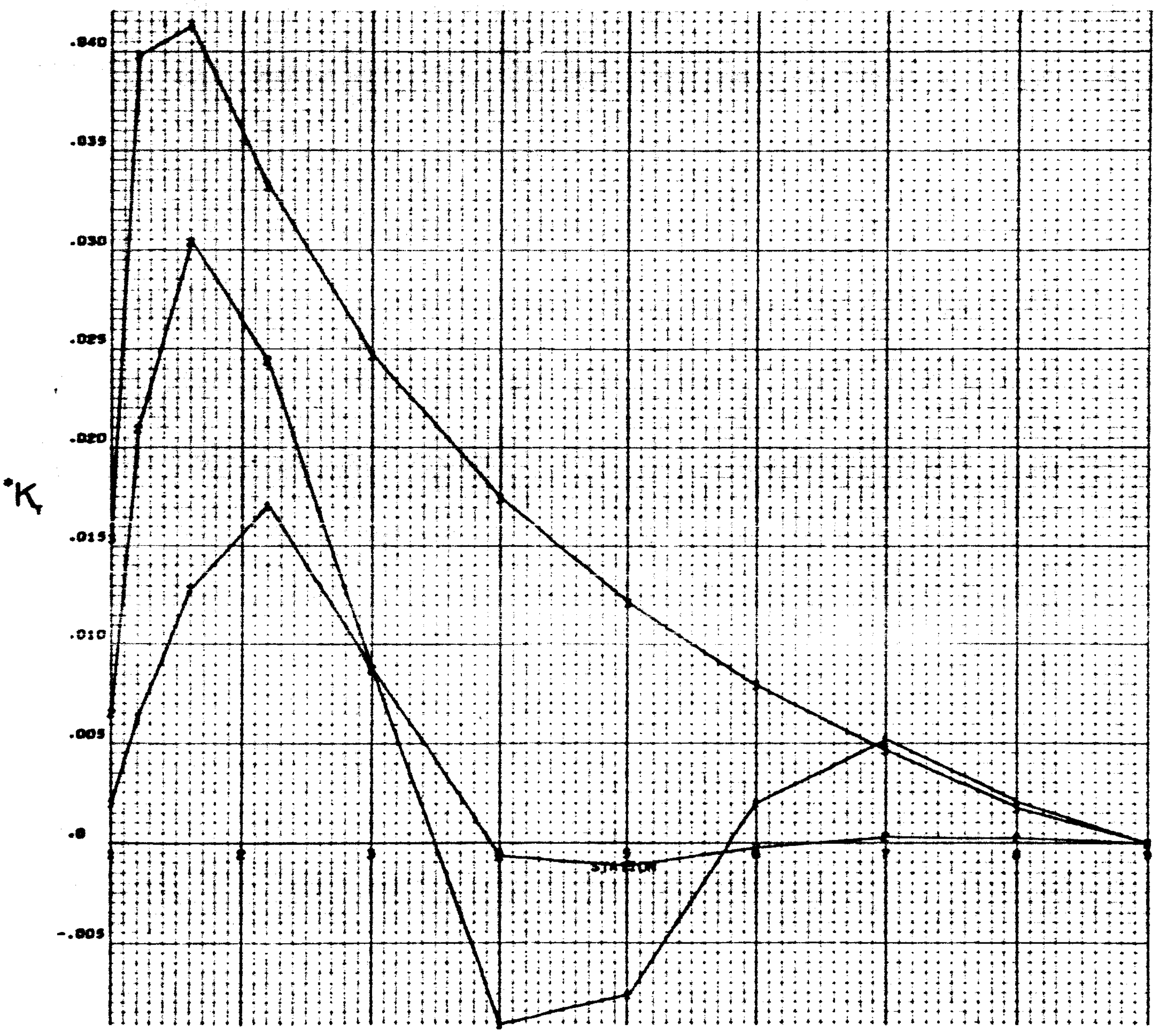
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

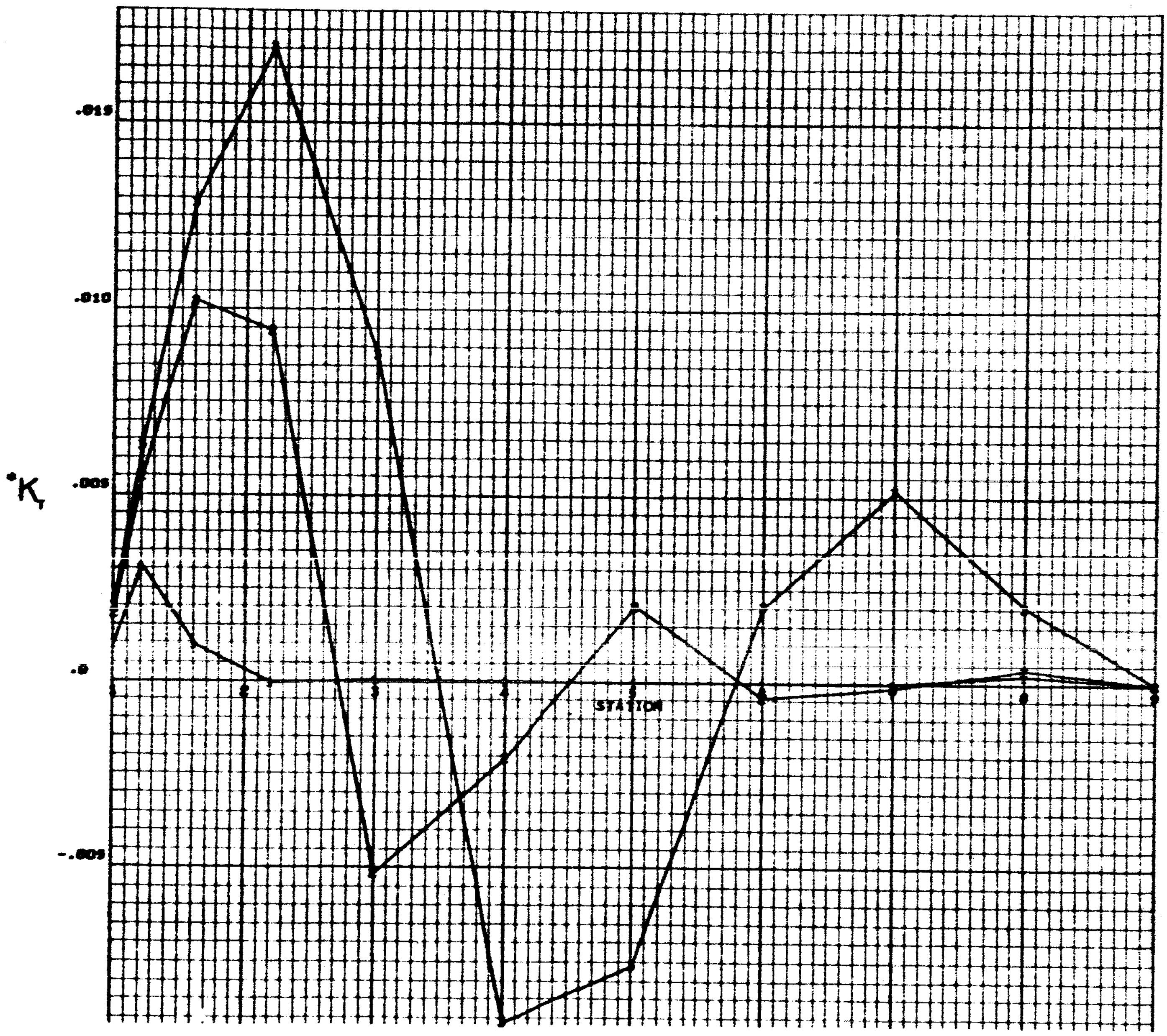
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

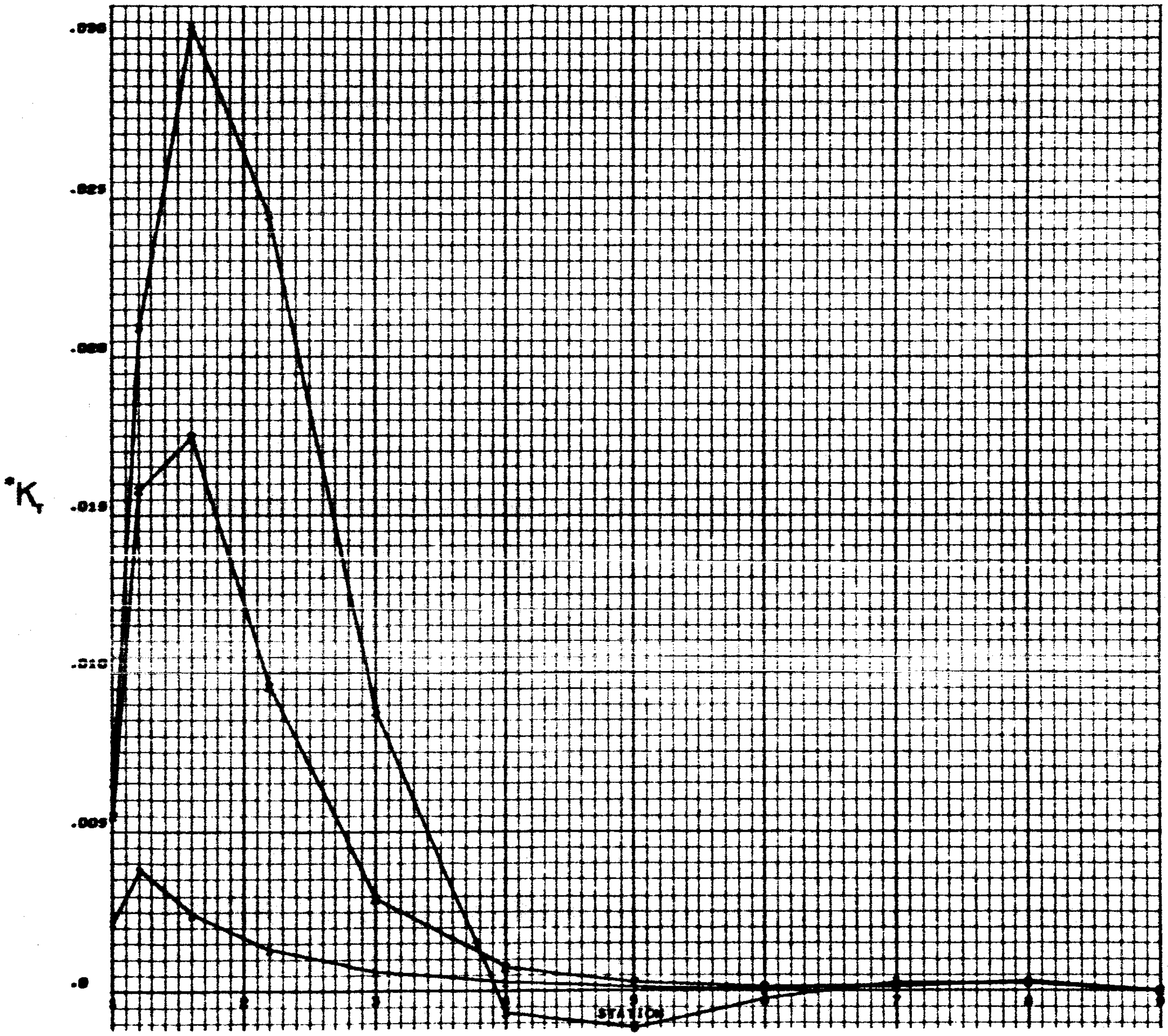
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

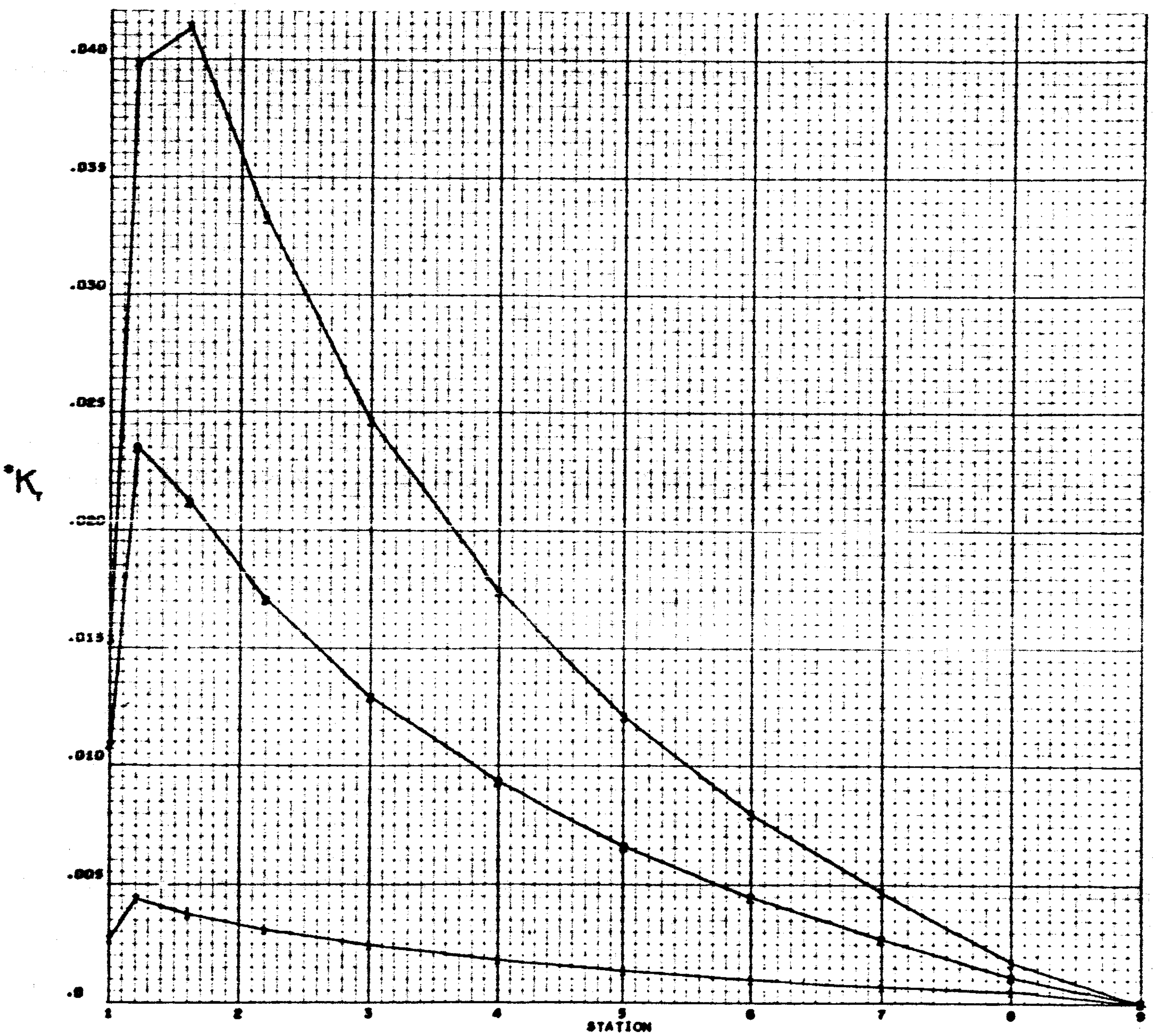
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

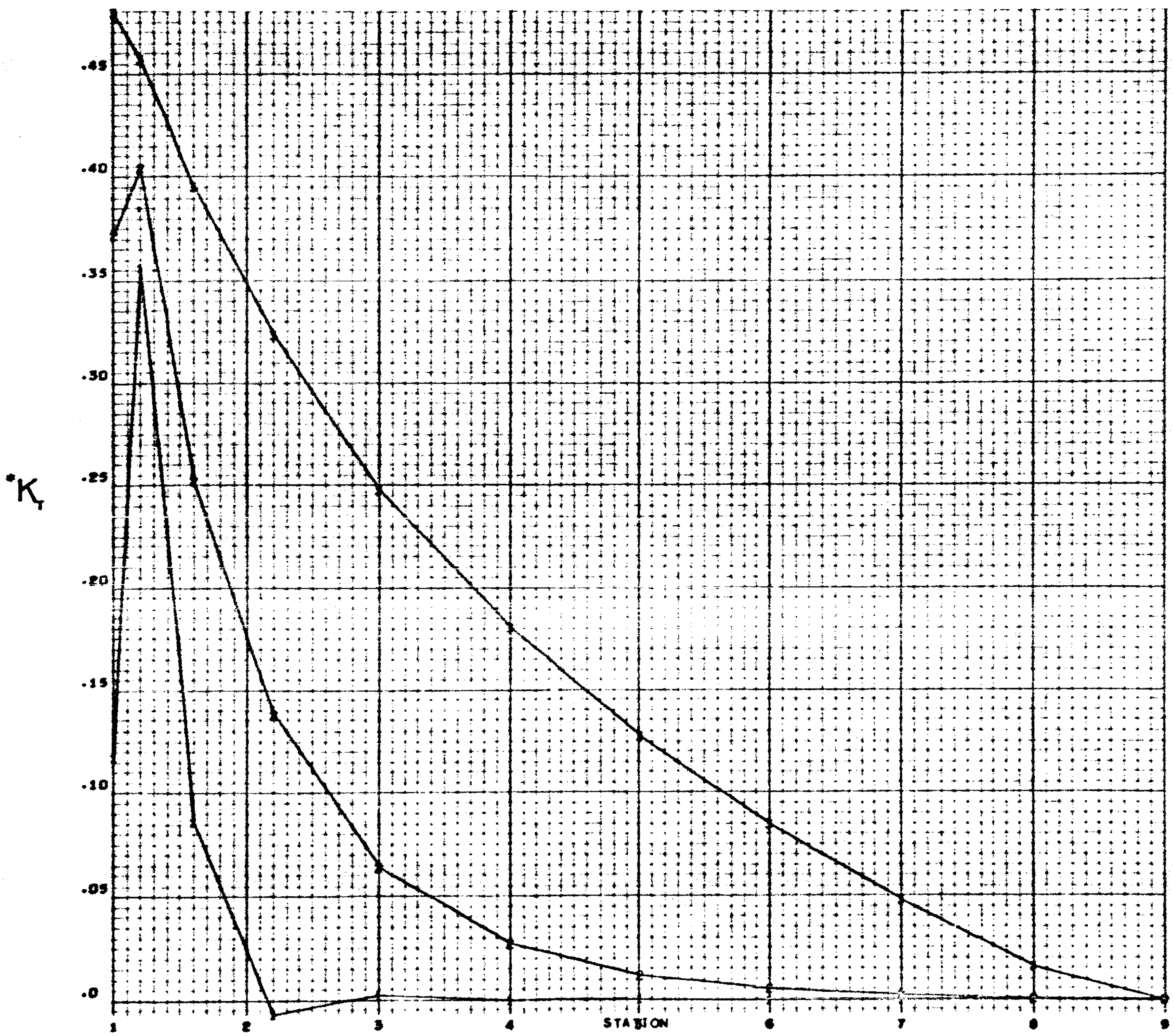
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T R$

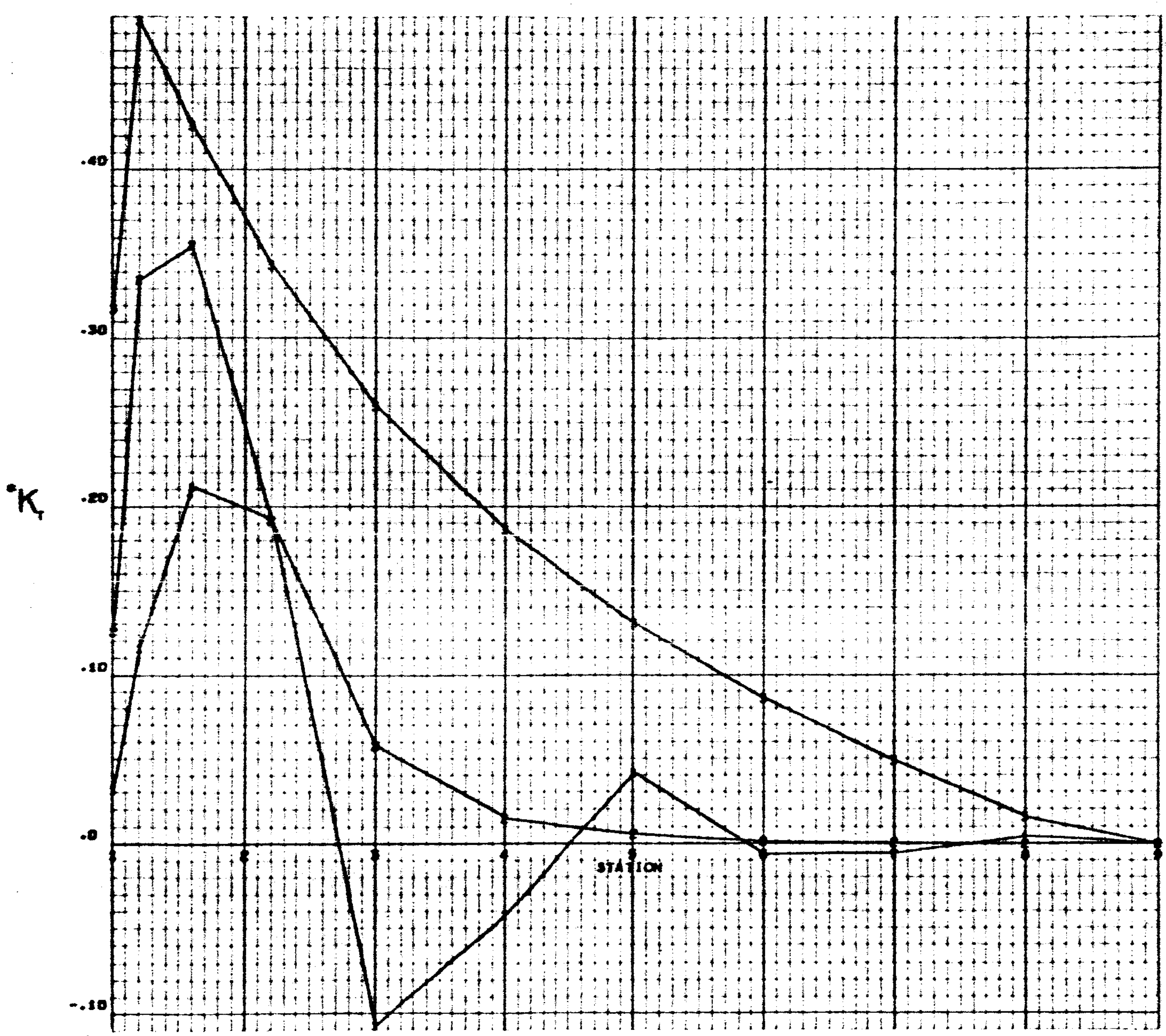
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

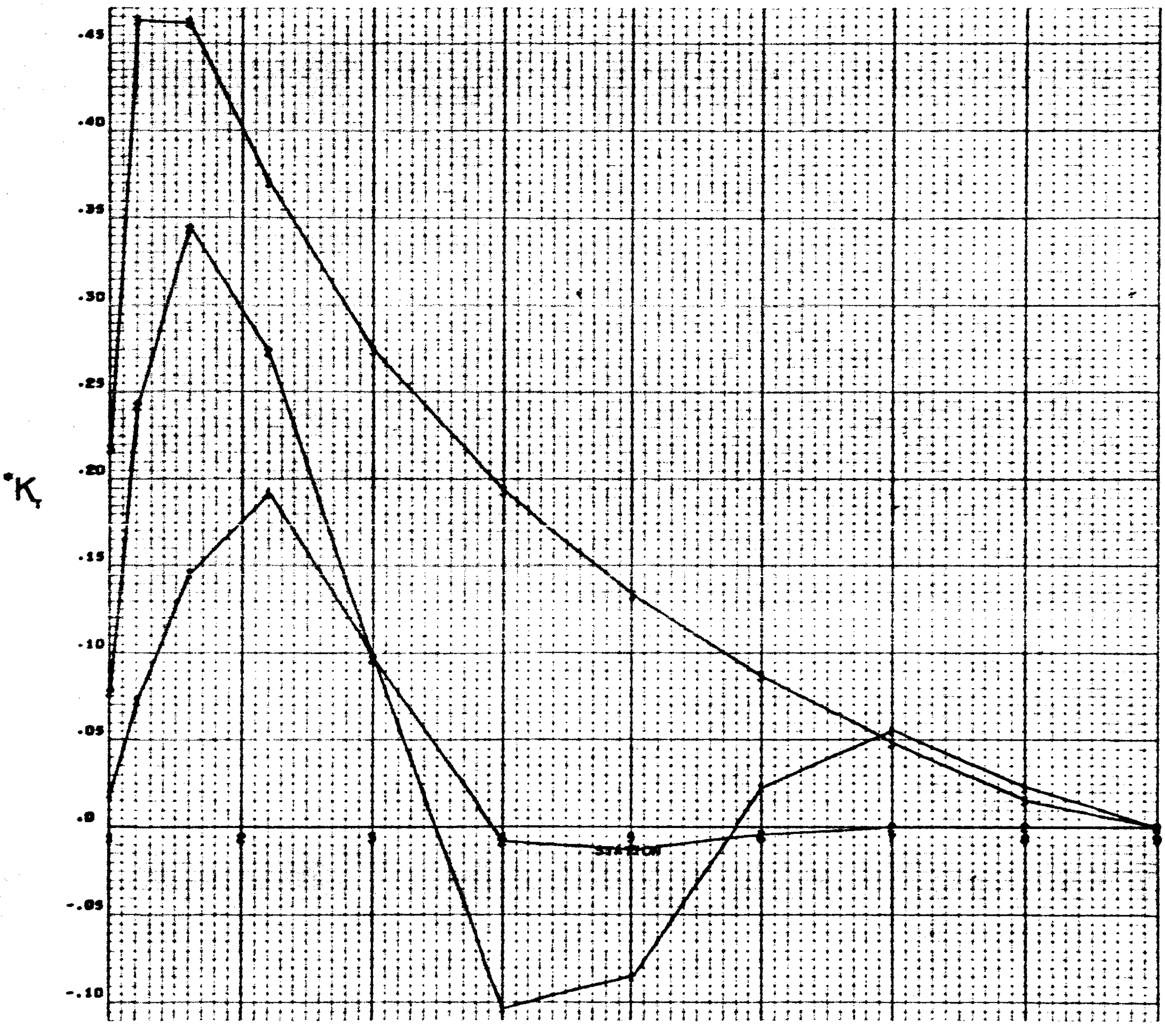
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

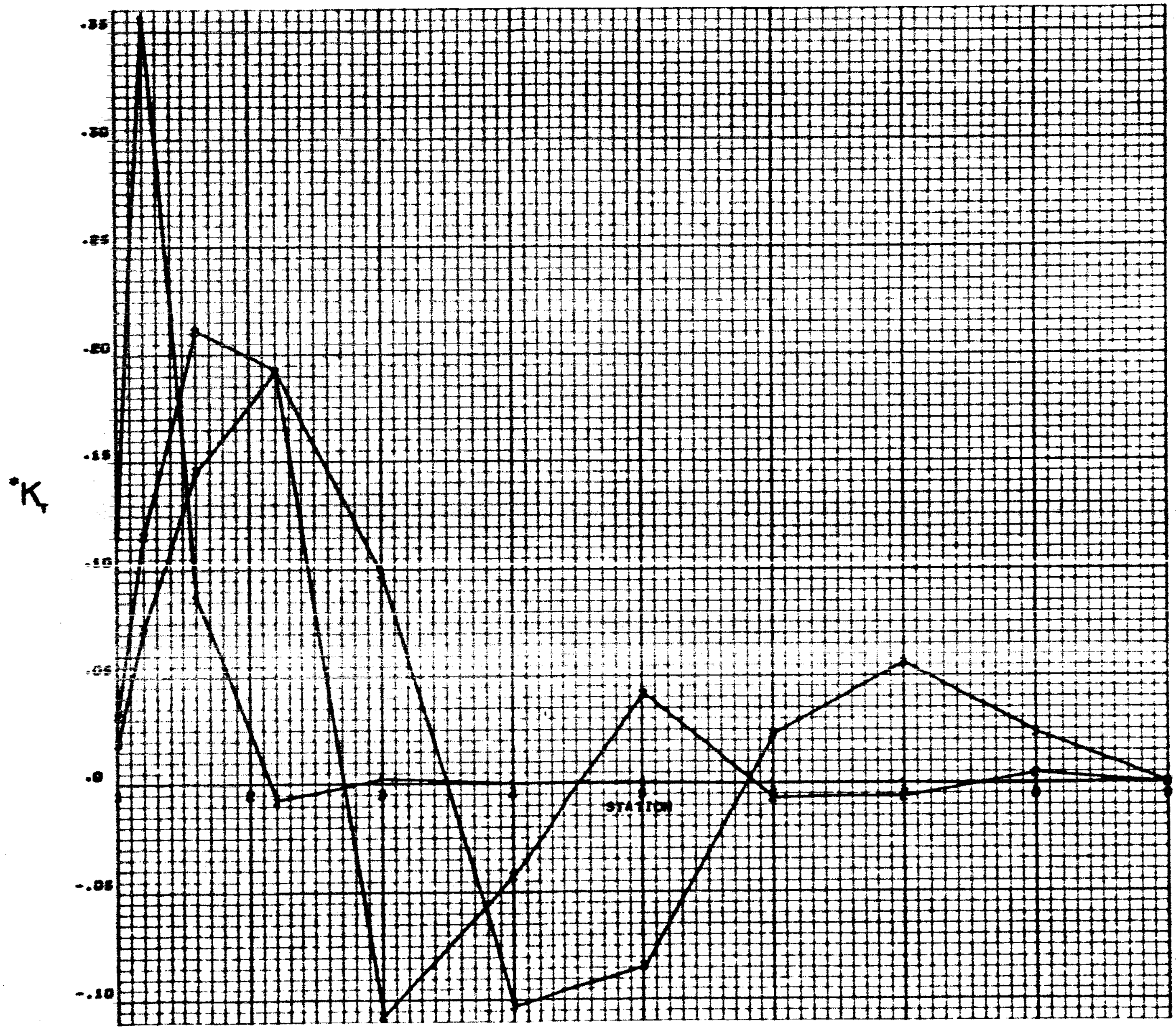
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

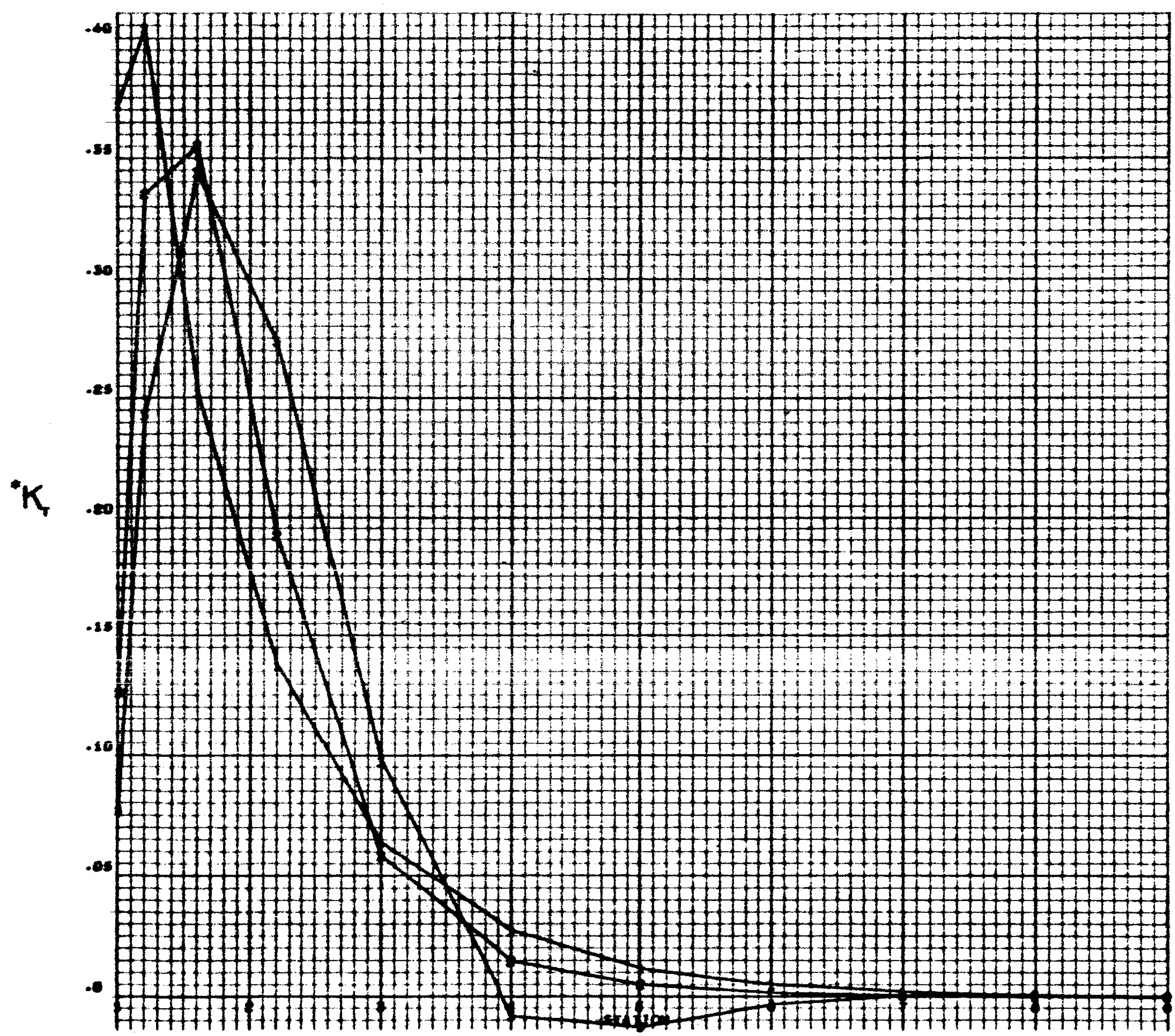


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

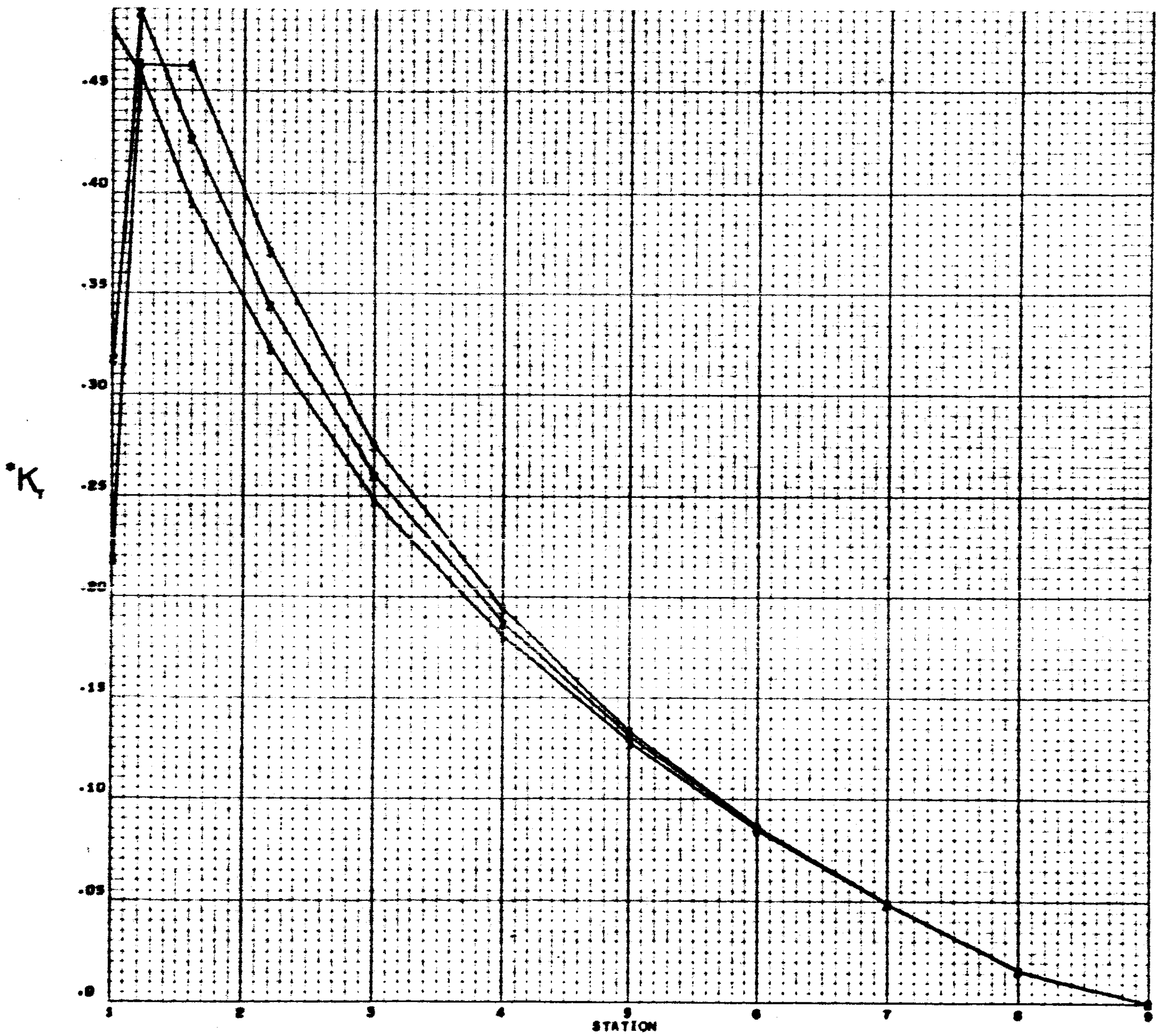
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

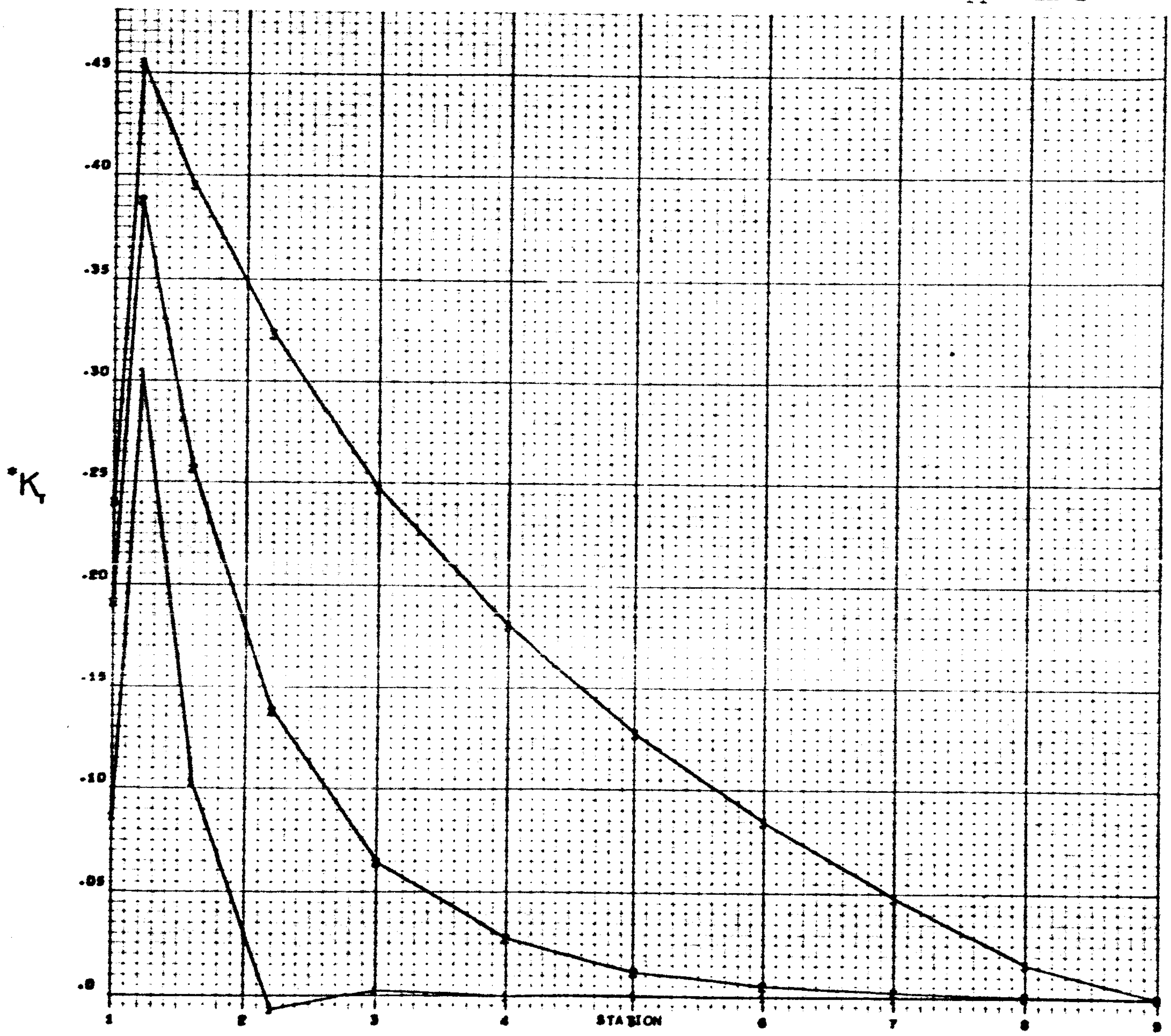
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

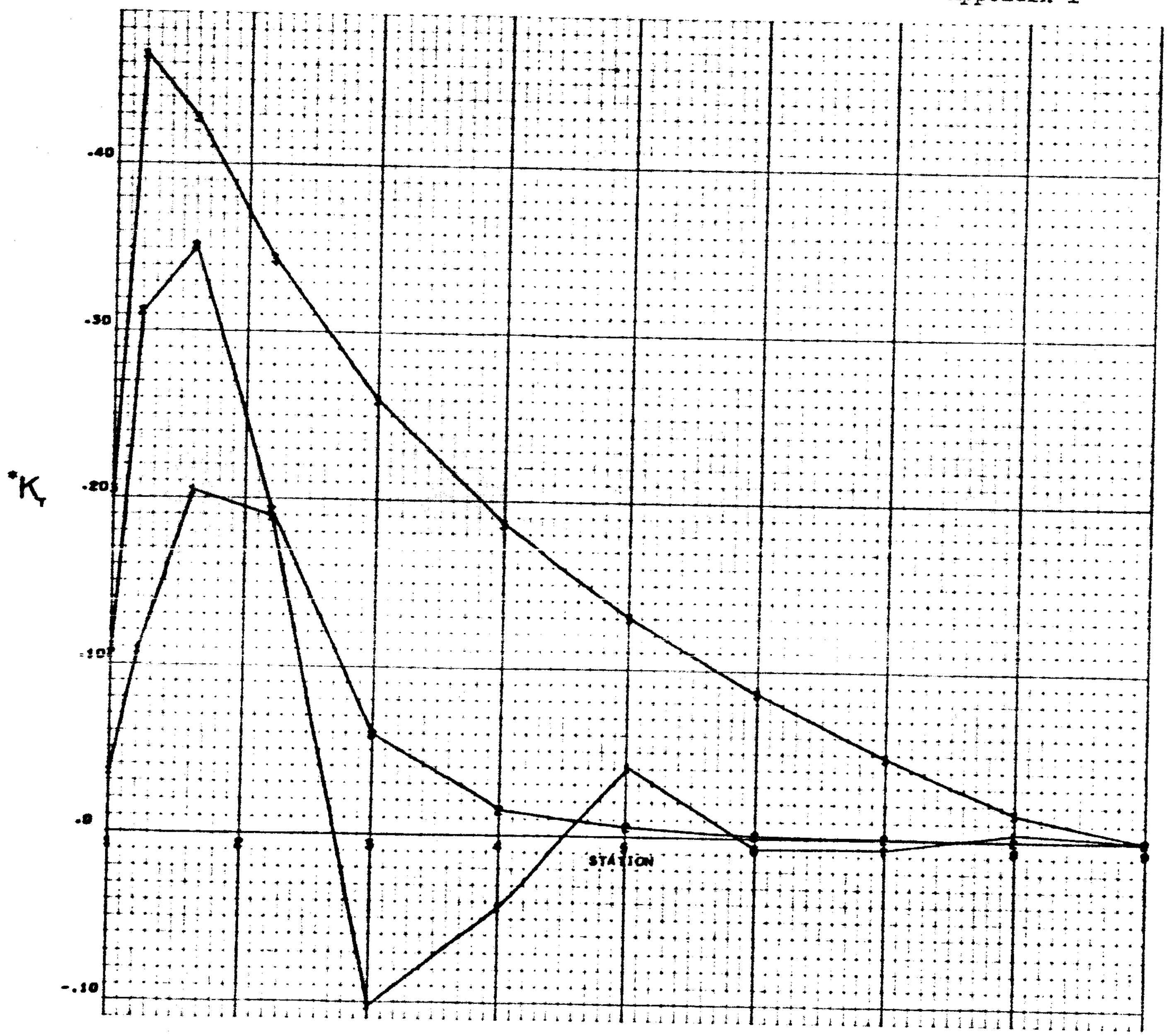
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

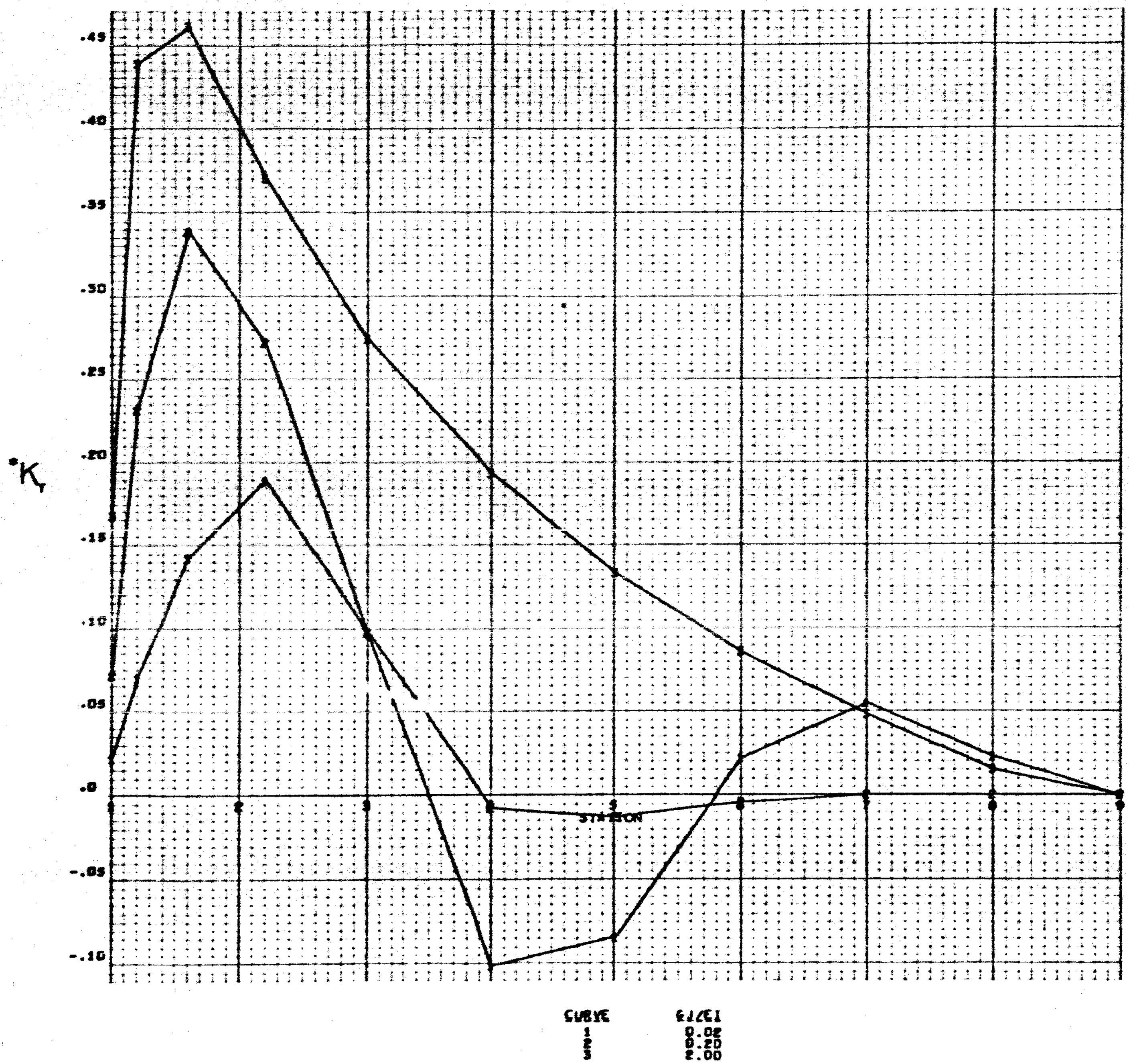
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

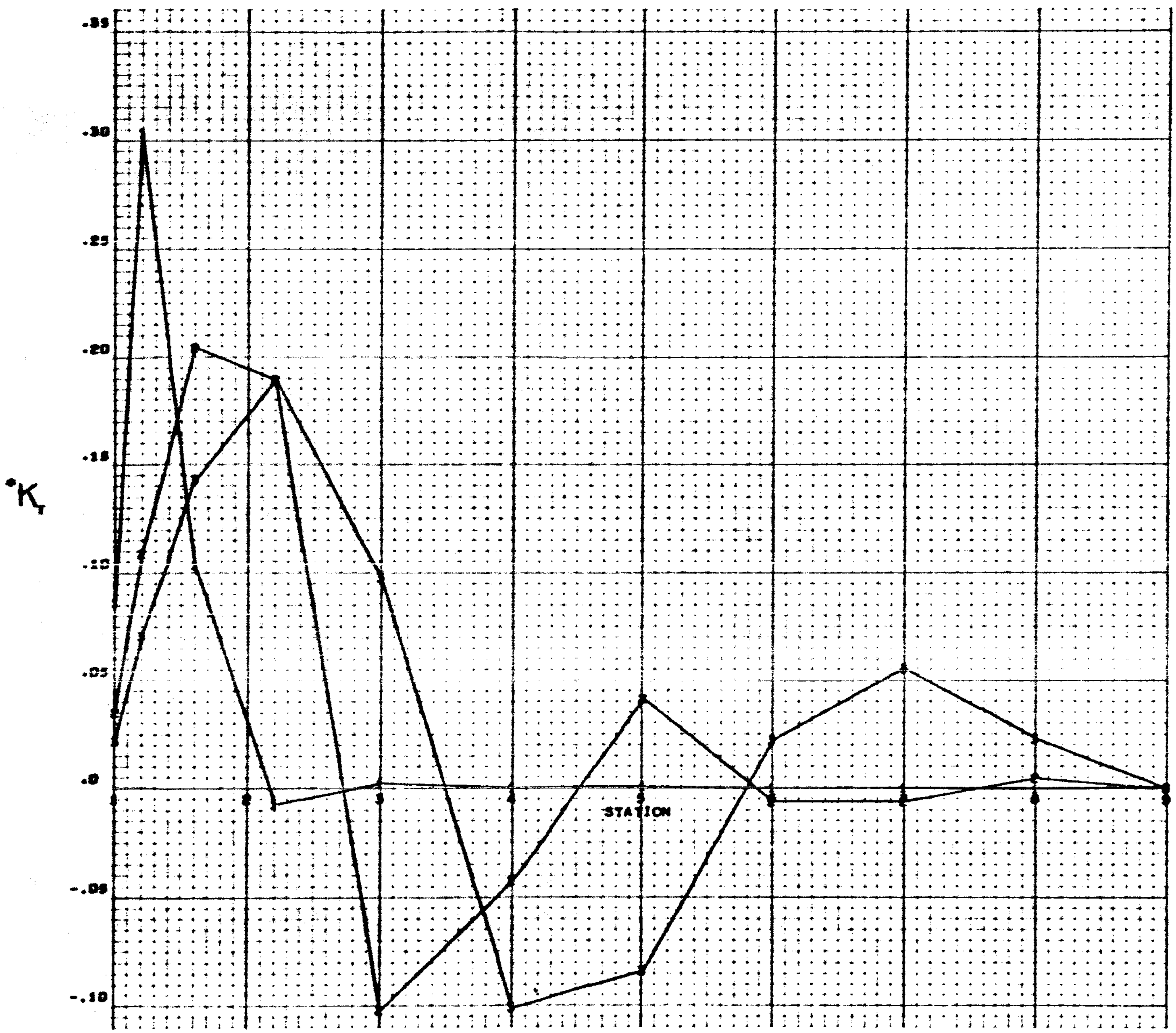
*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, T = K_T

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

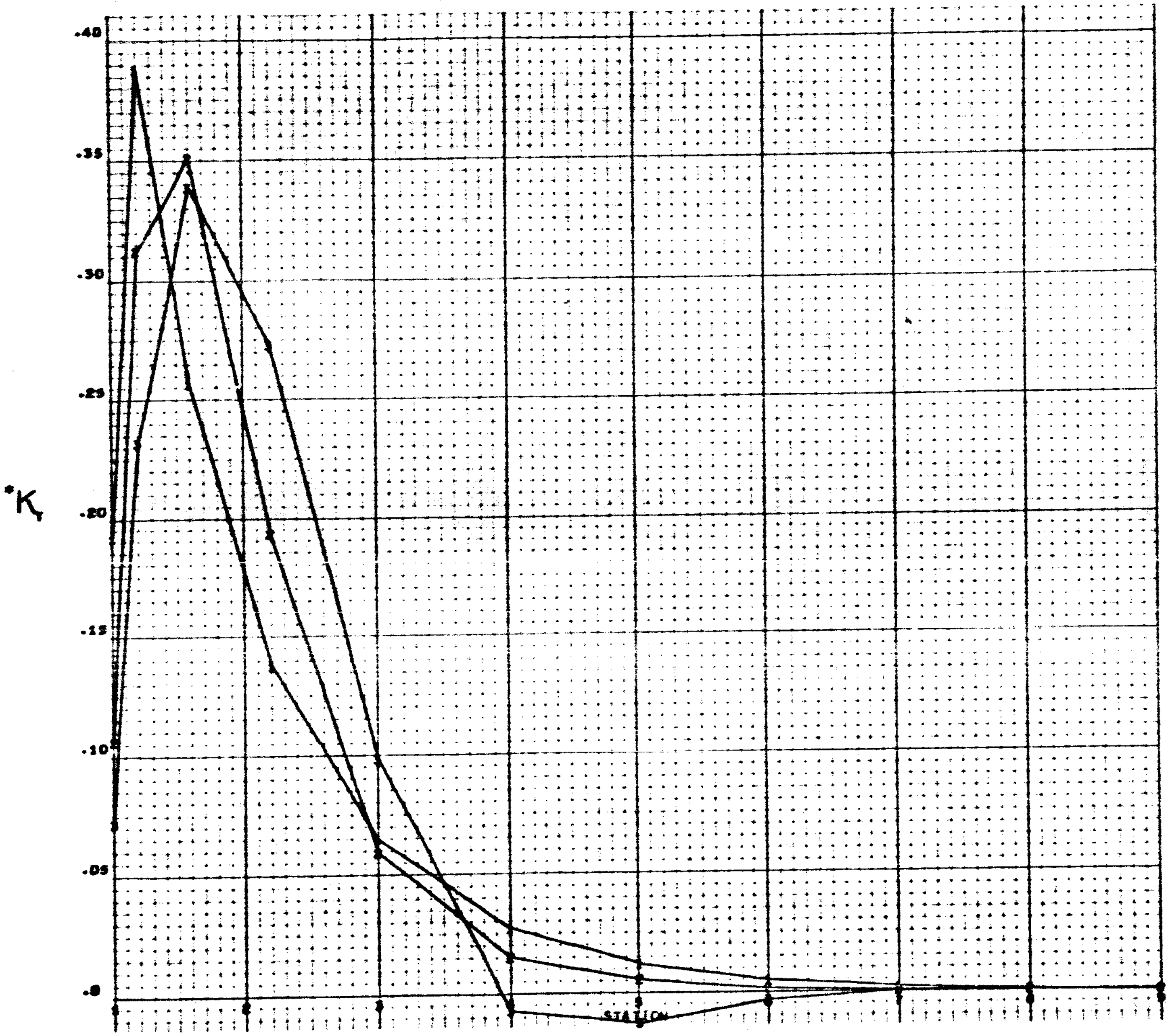


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

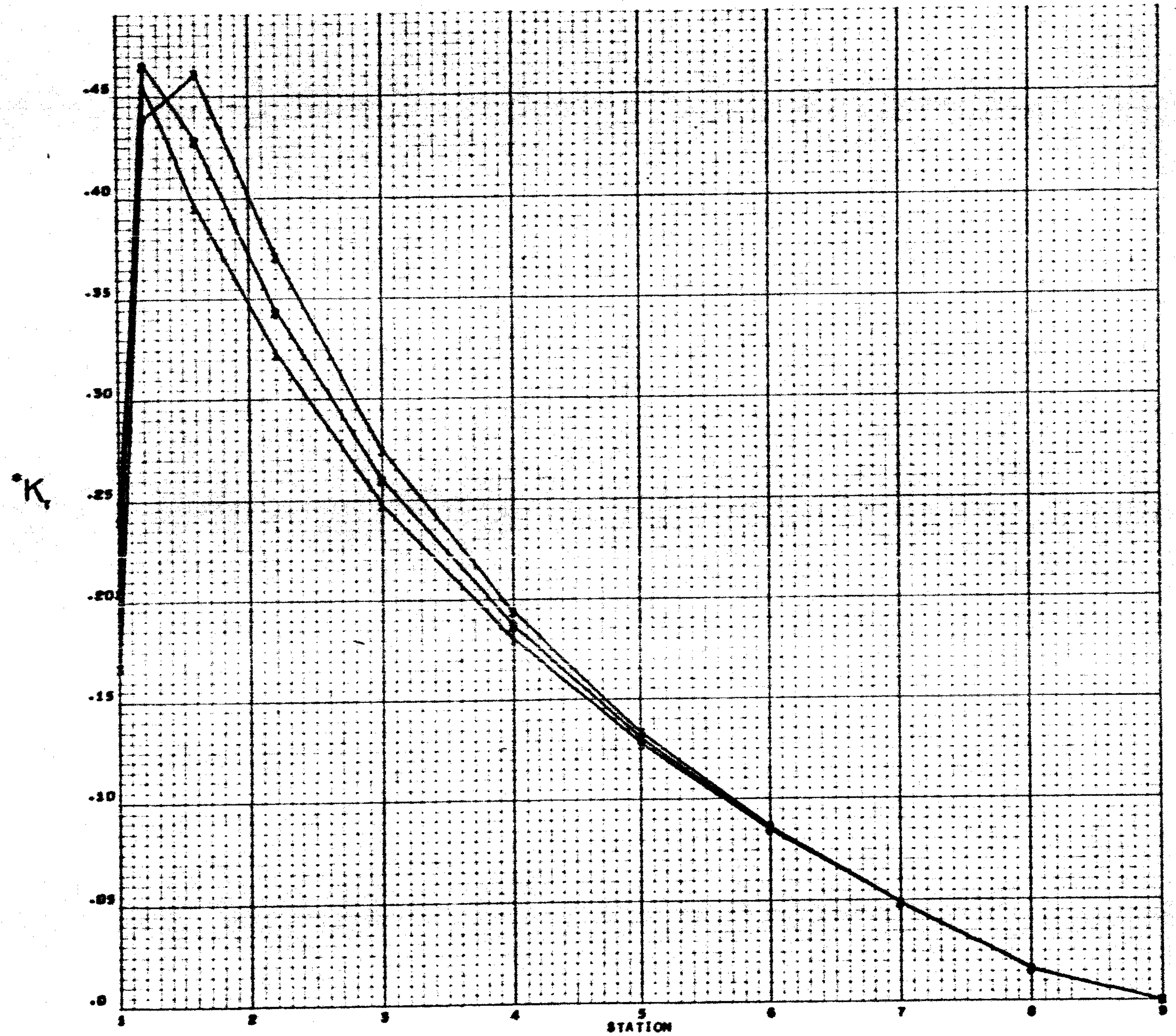


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
T, INTERNAL MOMENT ABOUT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

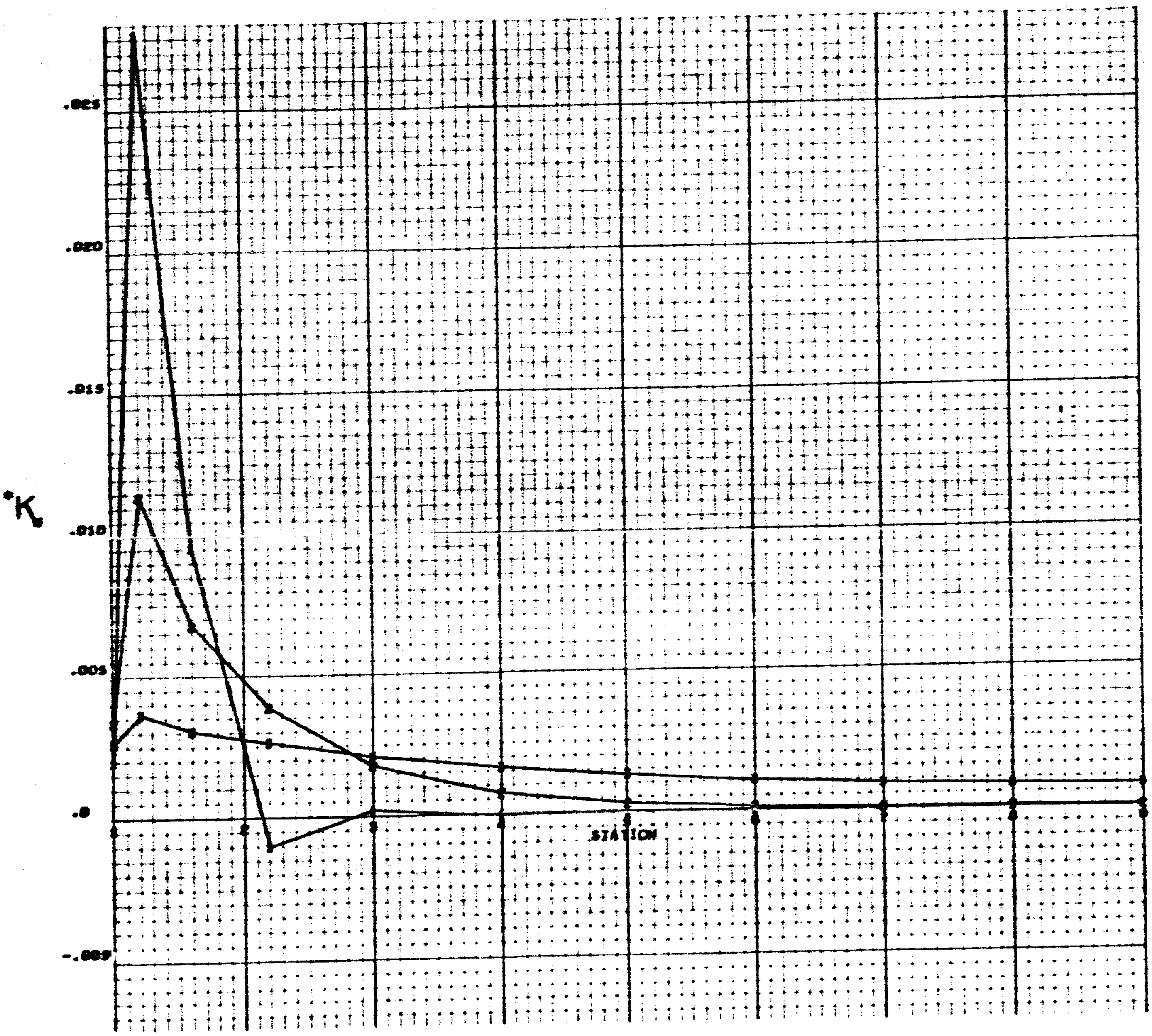


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT ELASTIC CENTER, $T = K_T$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

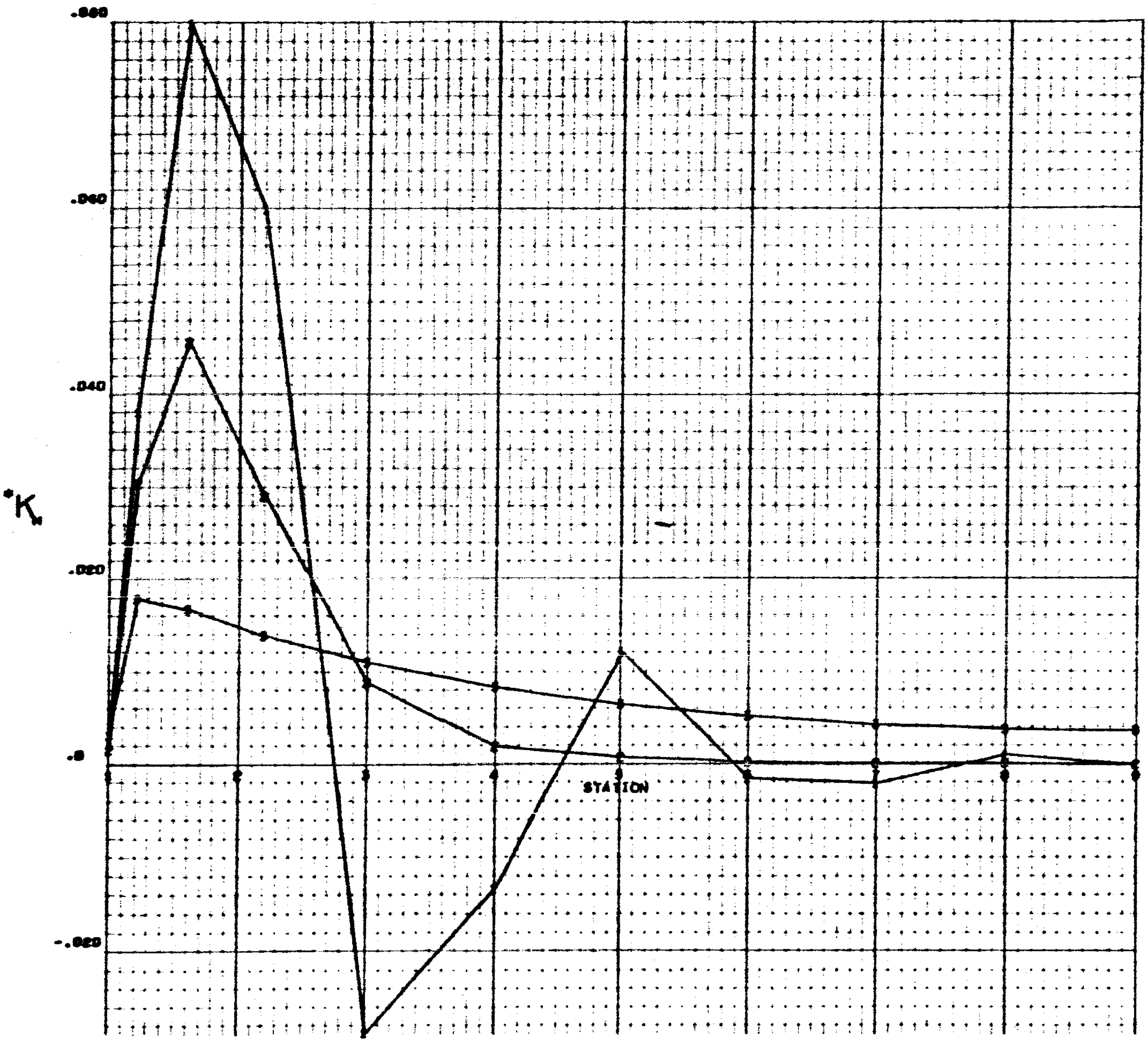
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE

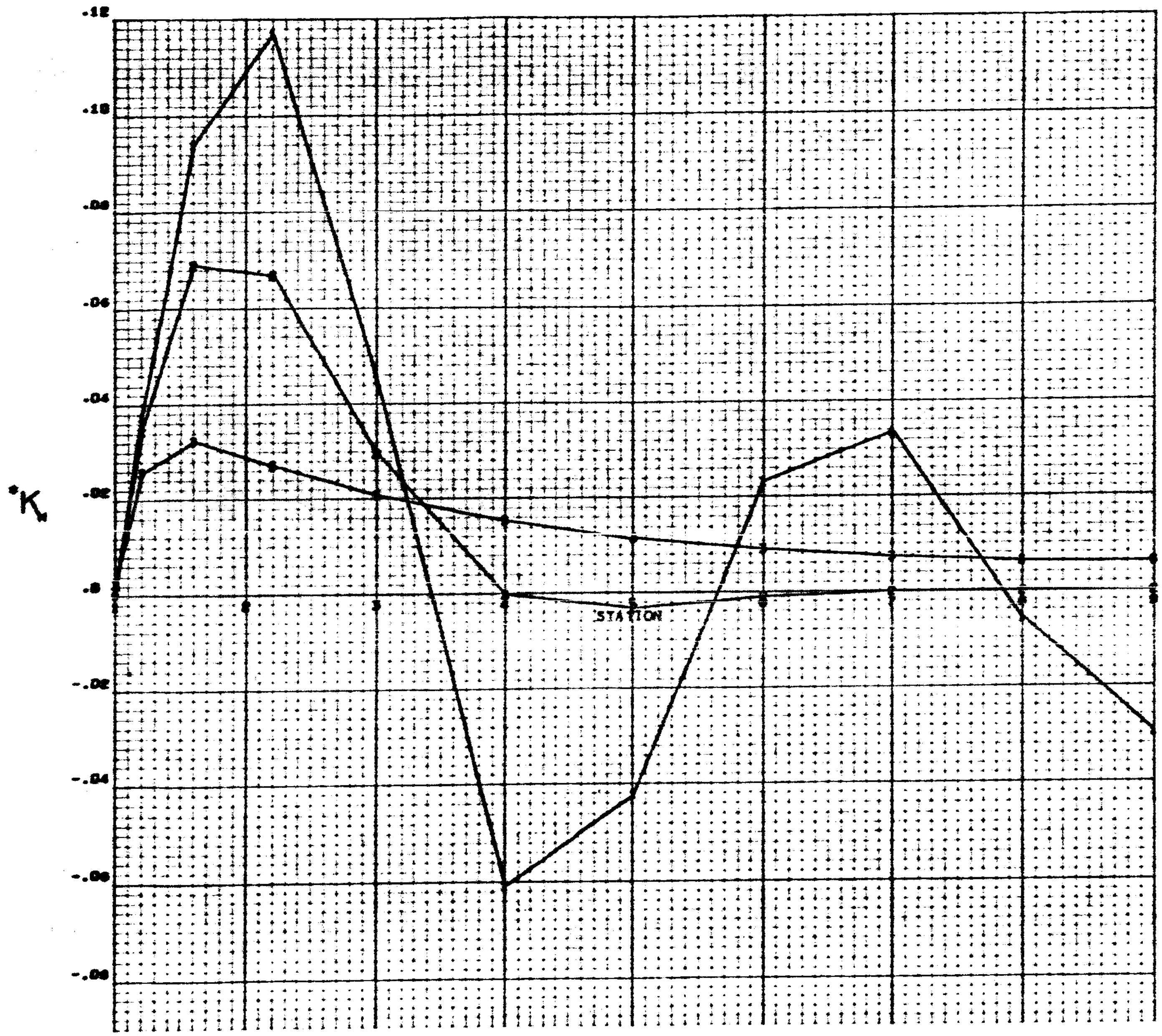


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

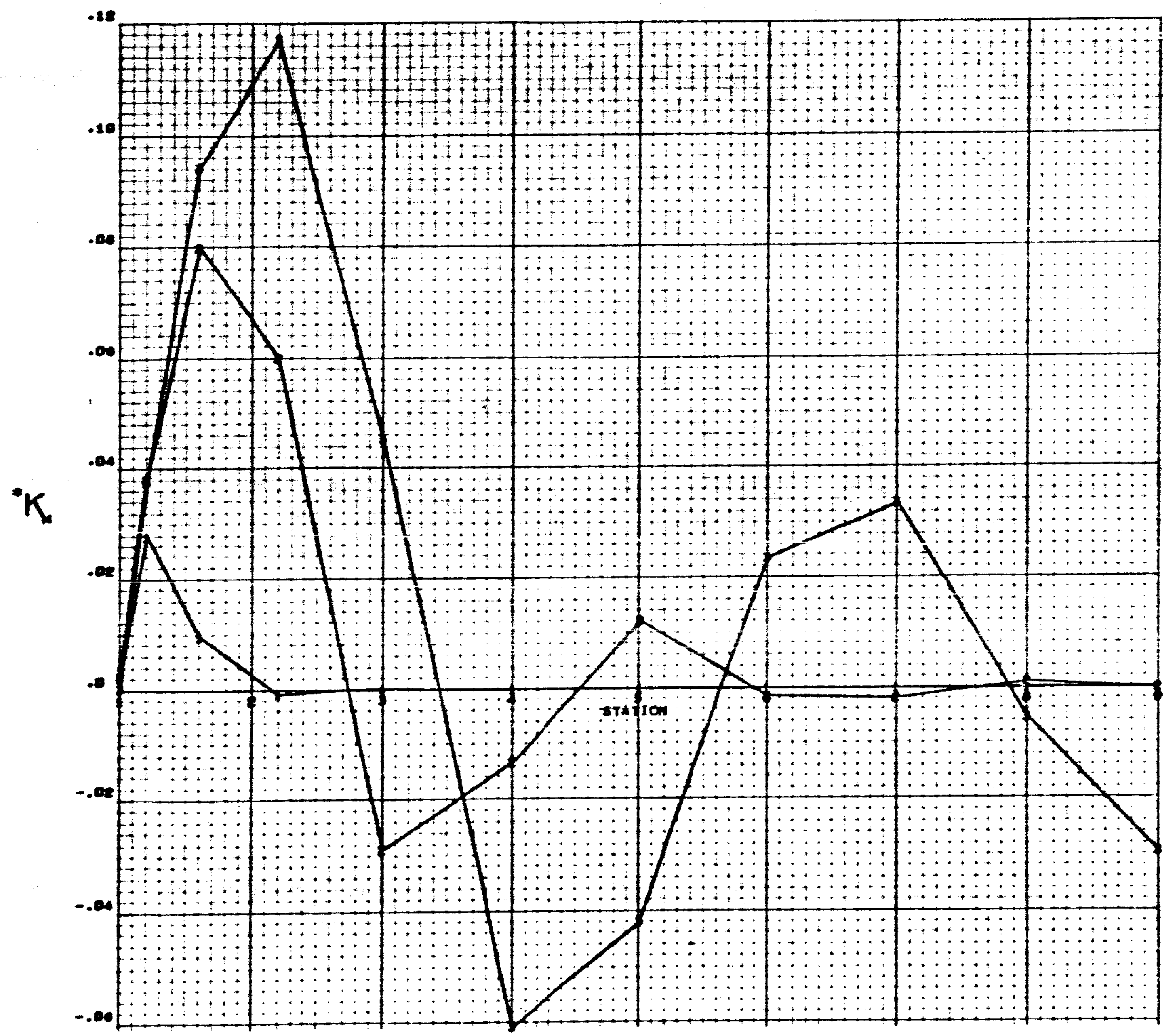
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

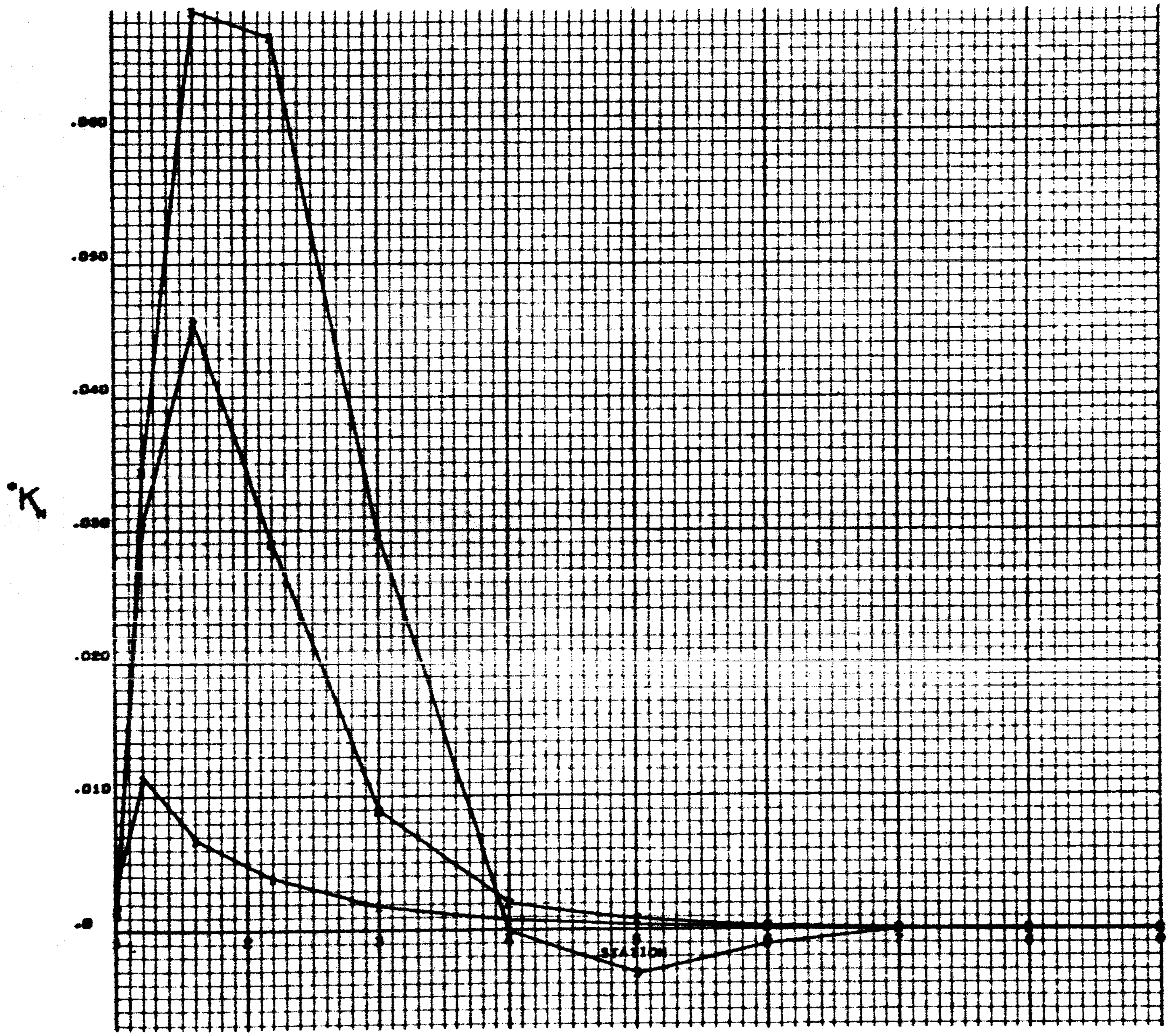


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

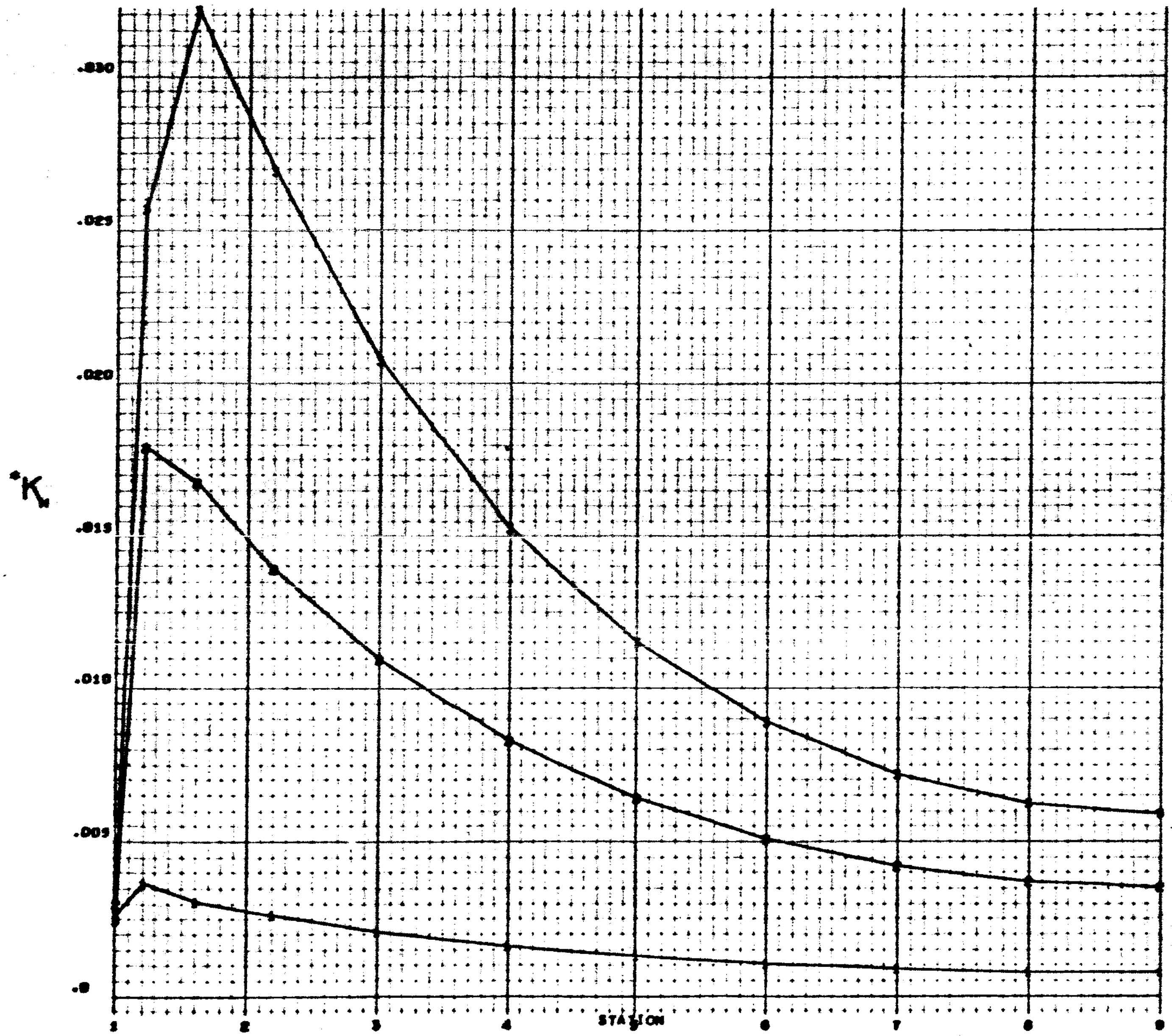
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

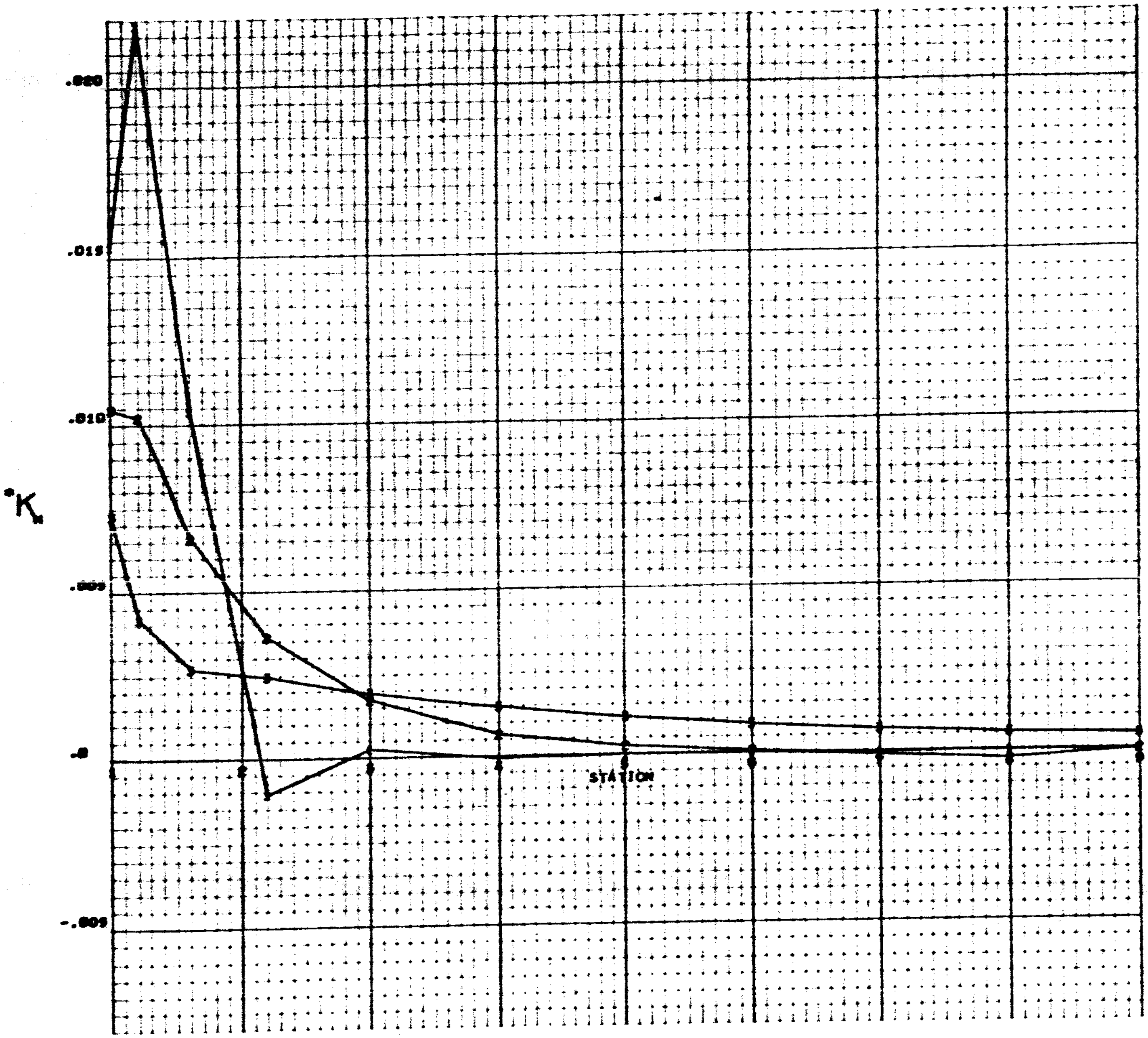


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

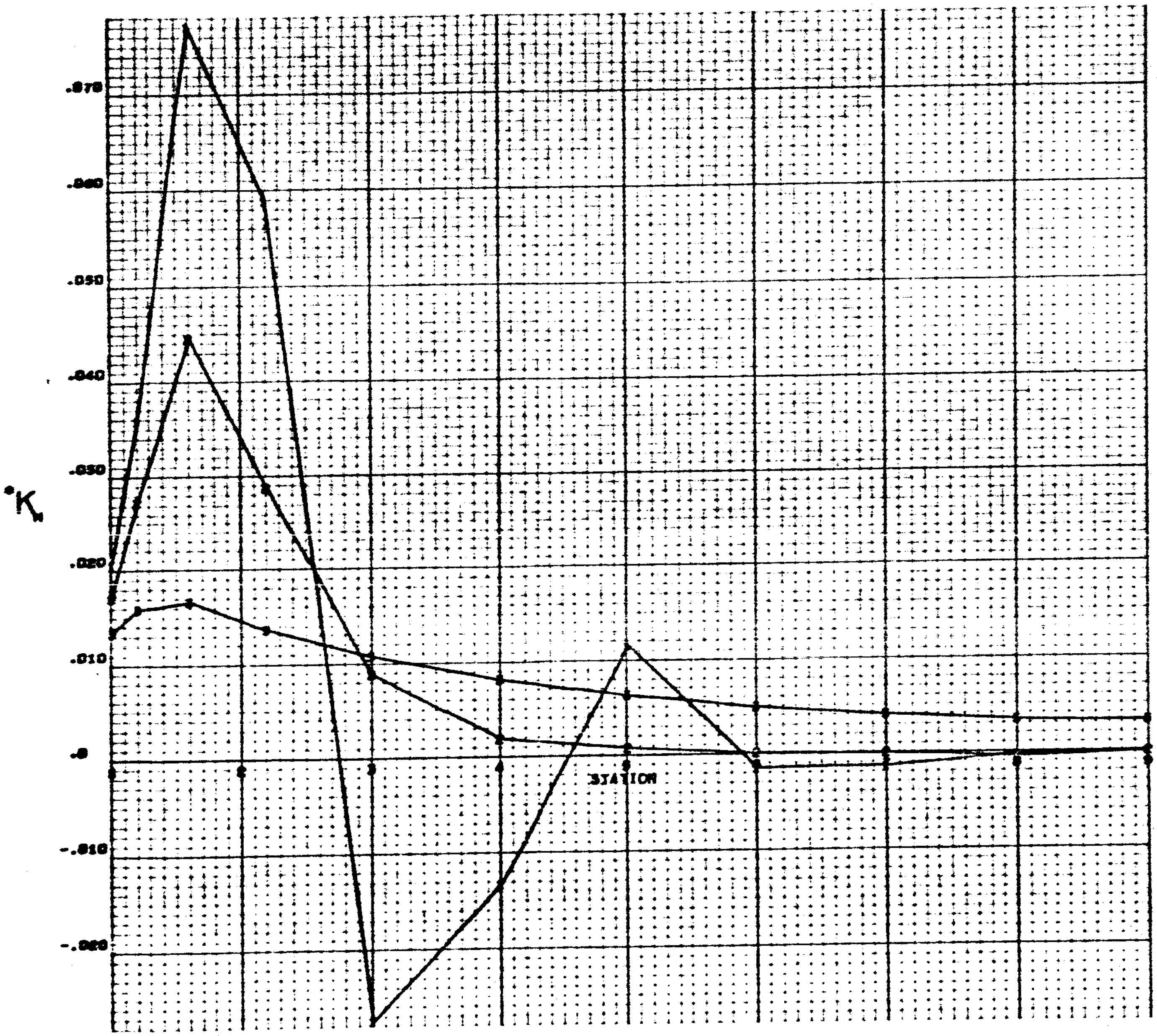


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

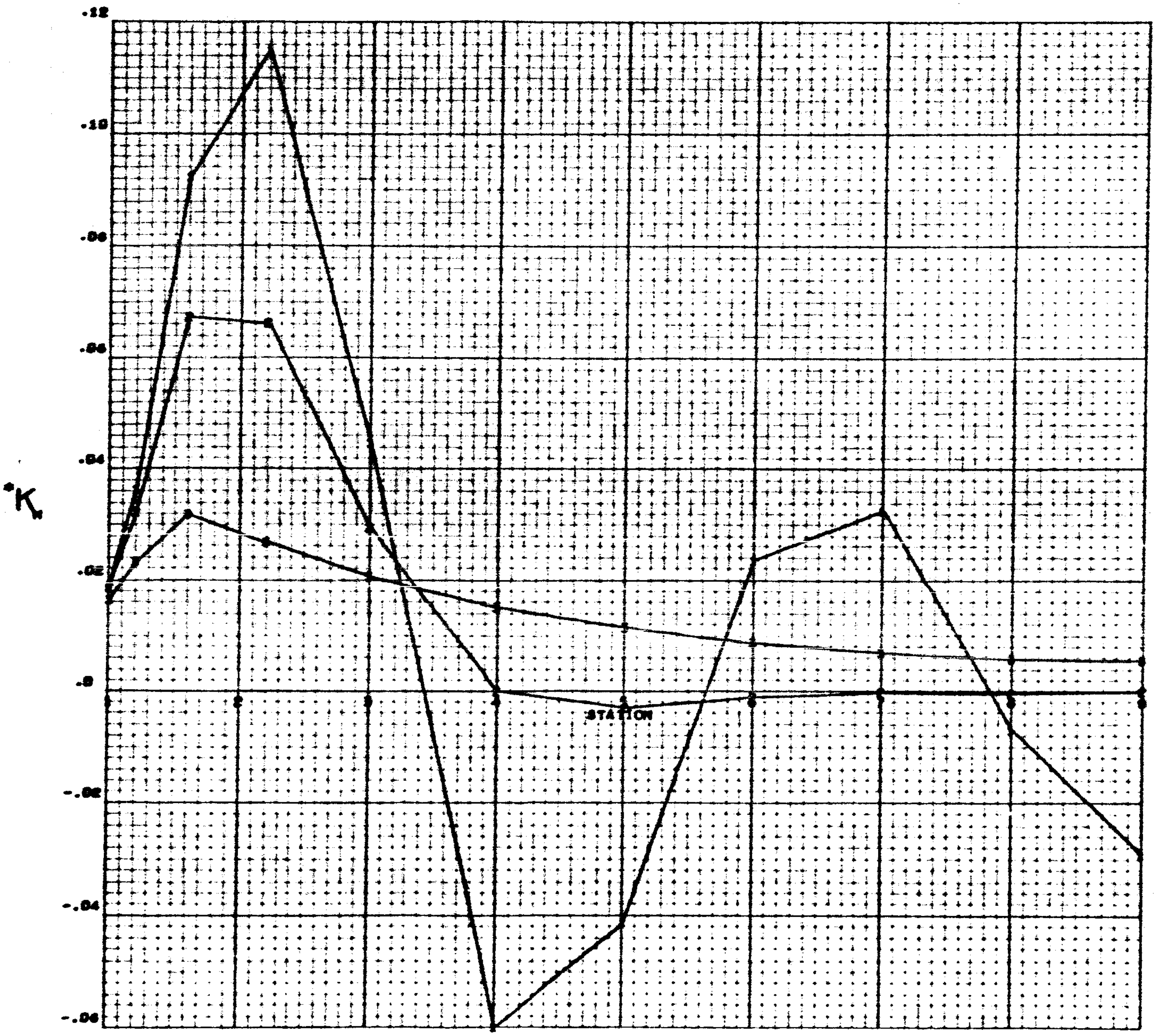
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

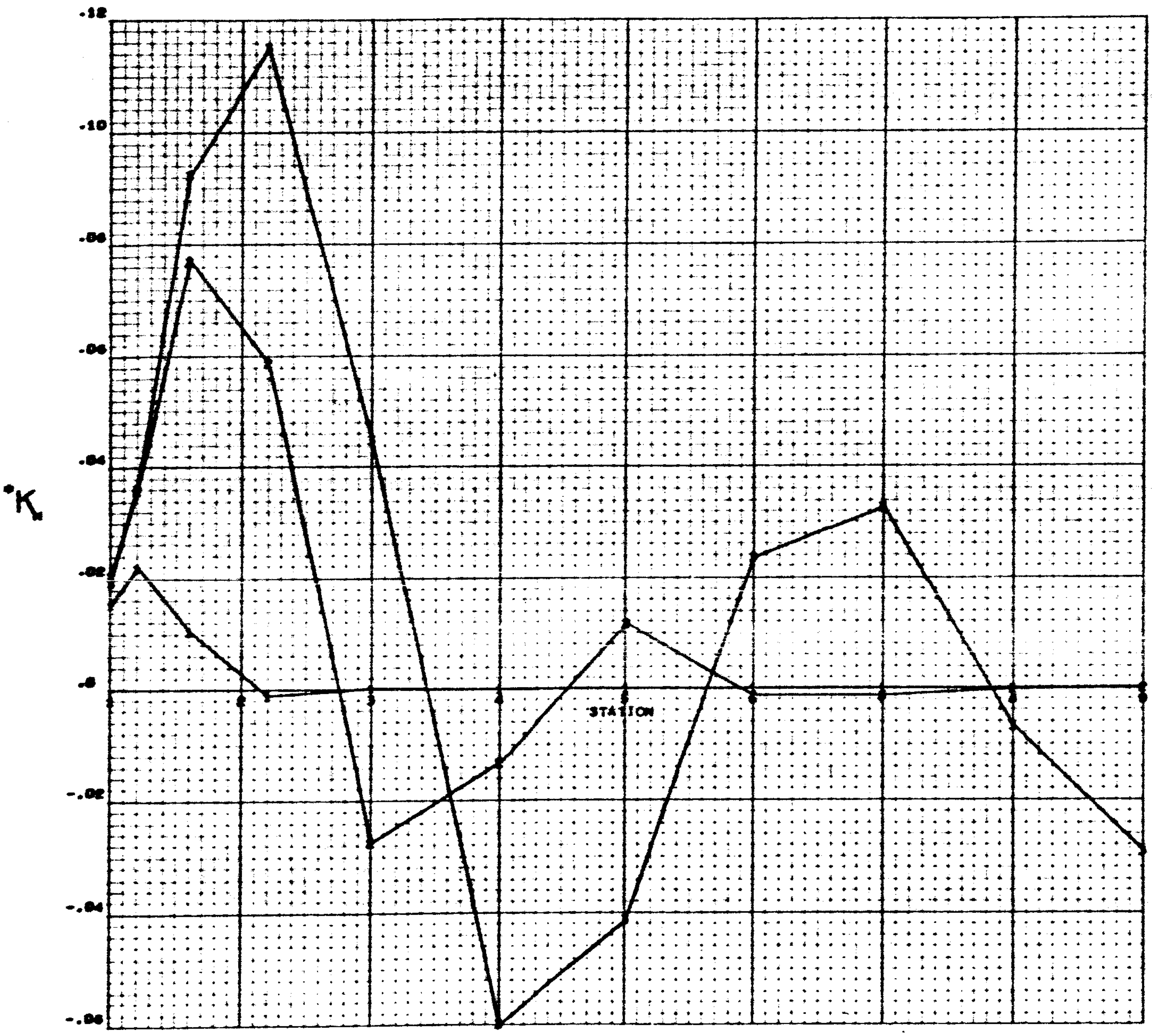
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

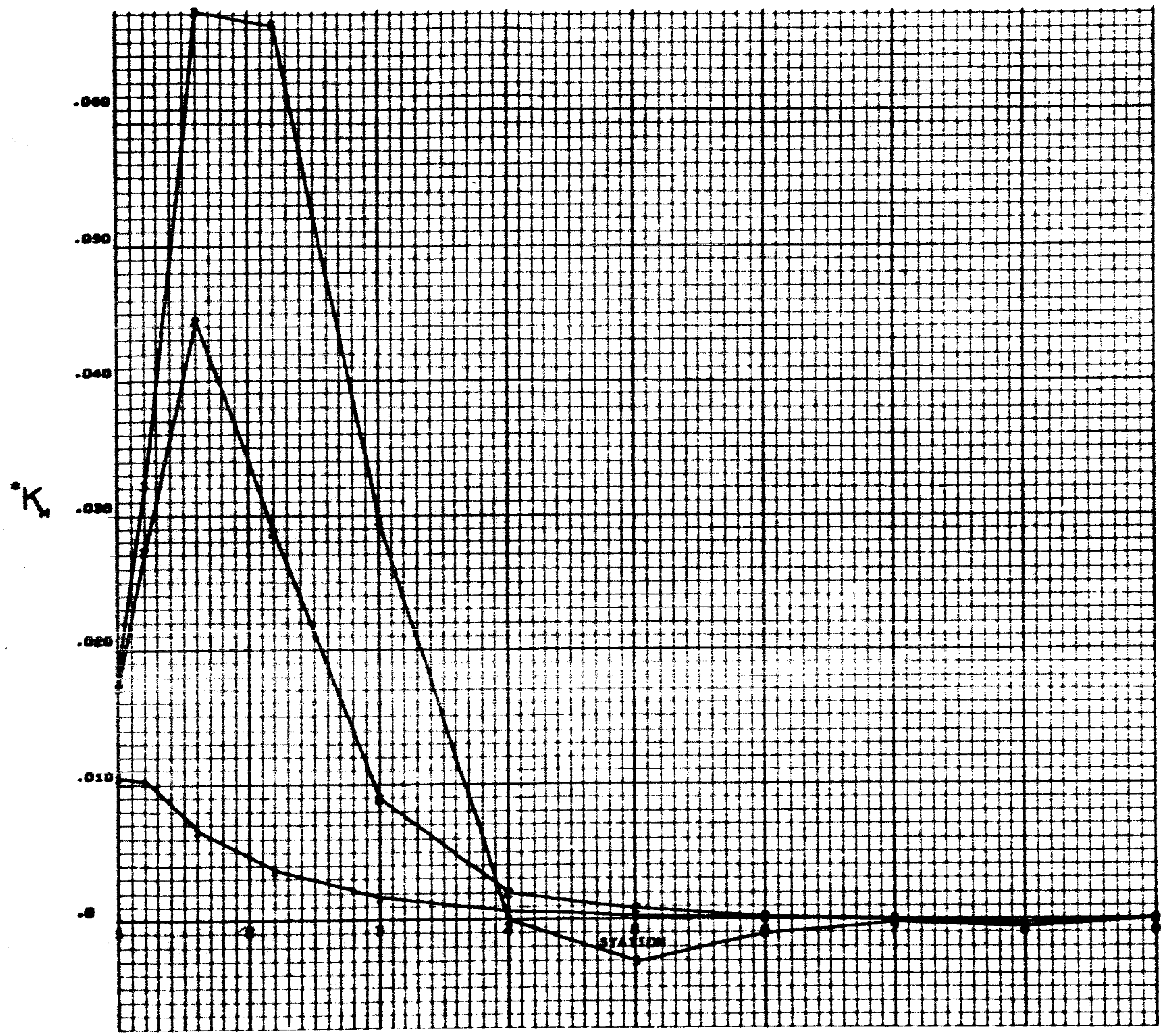
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE

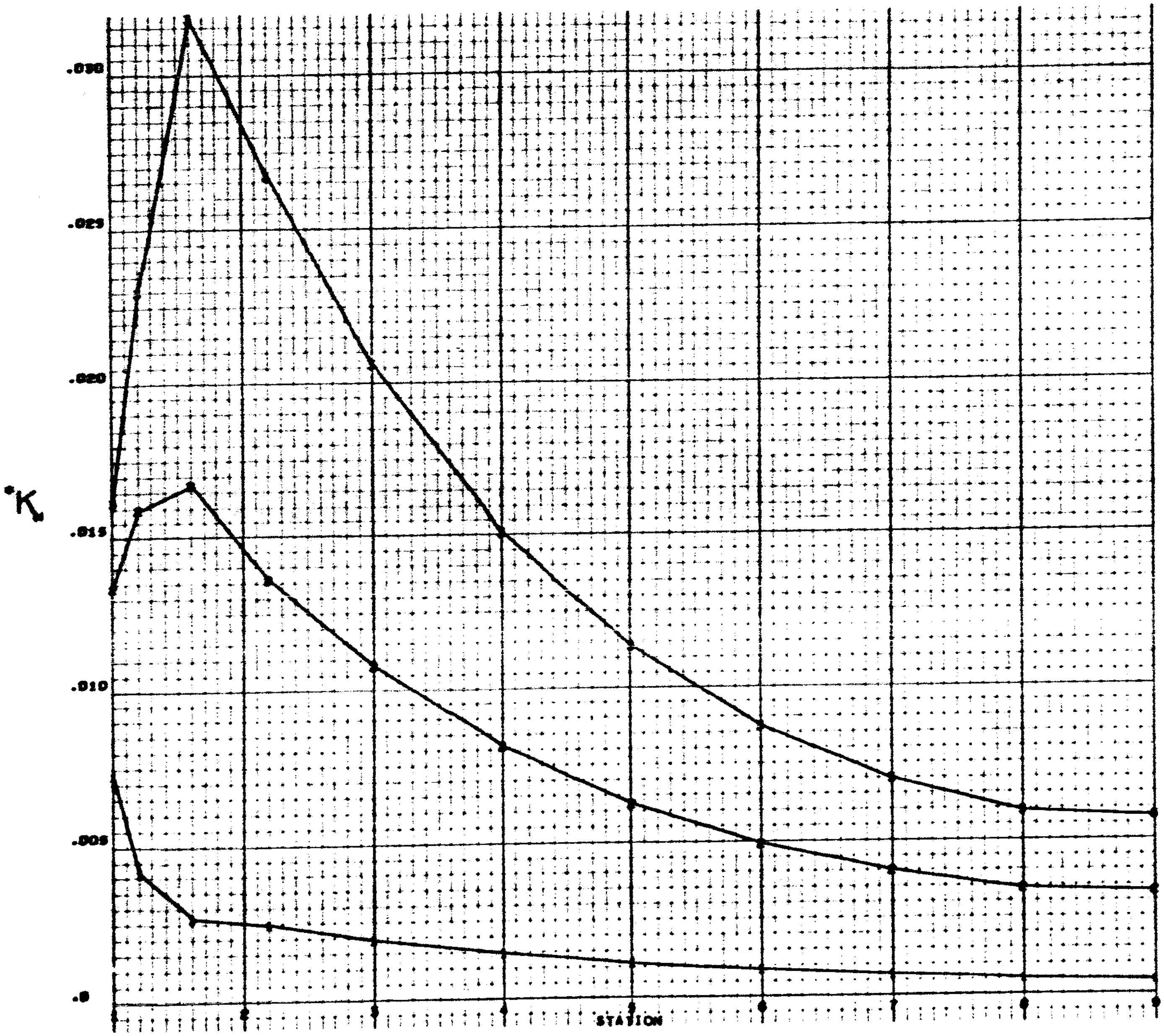


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

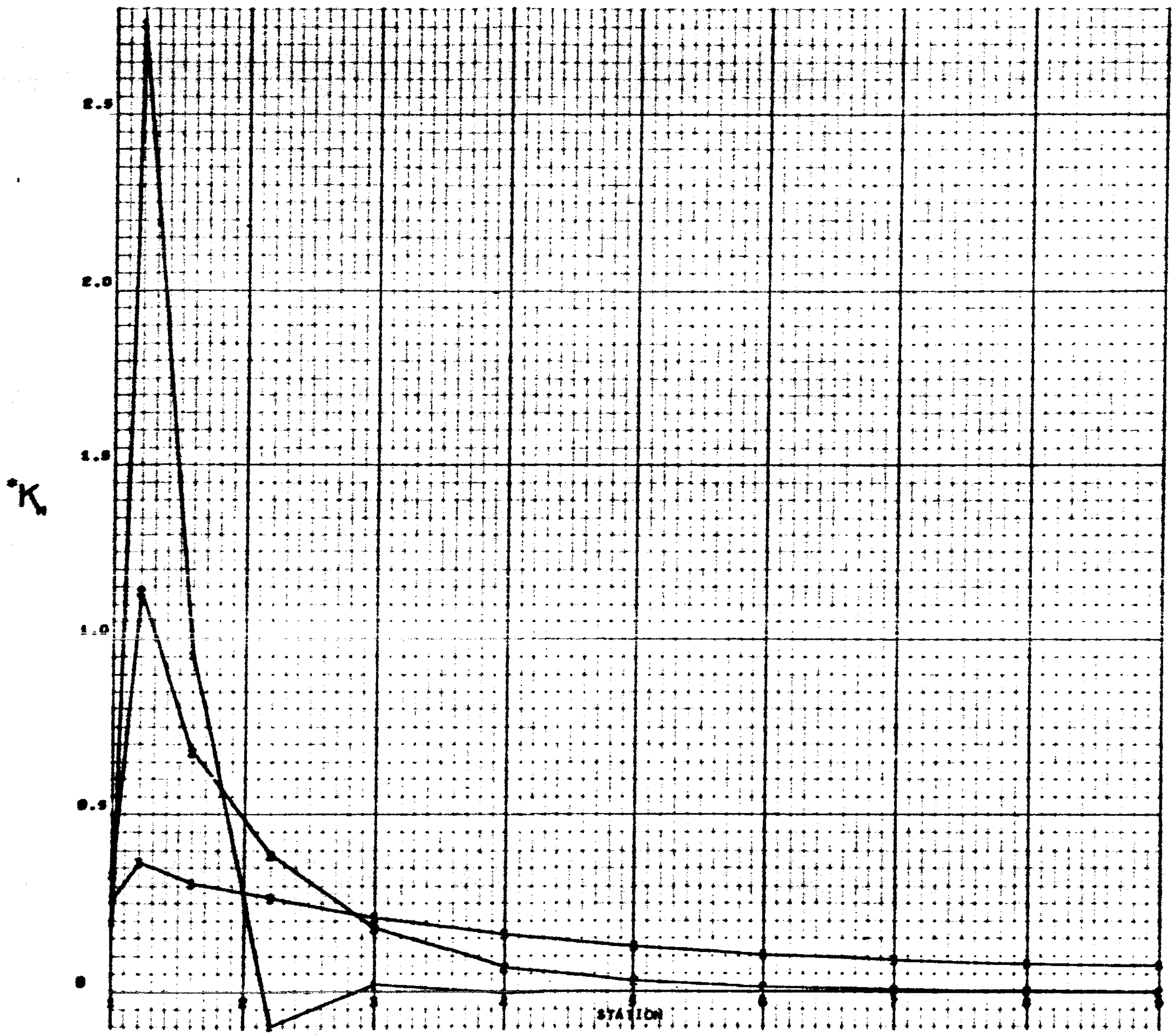


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M R$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

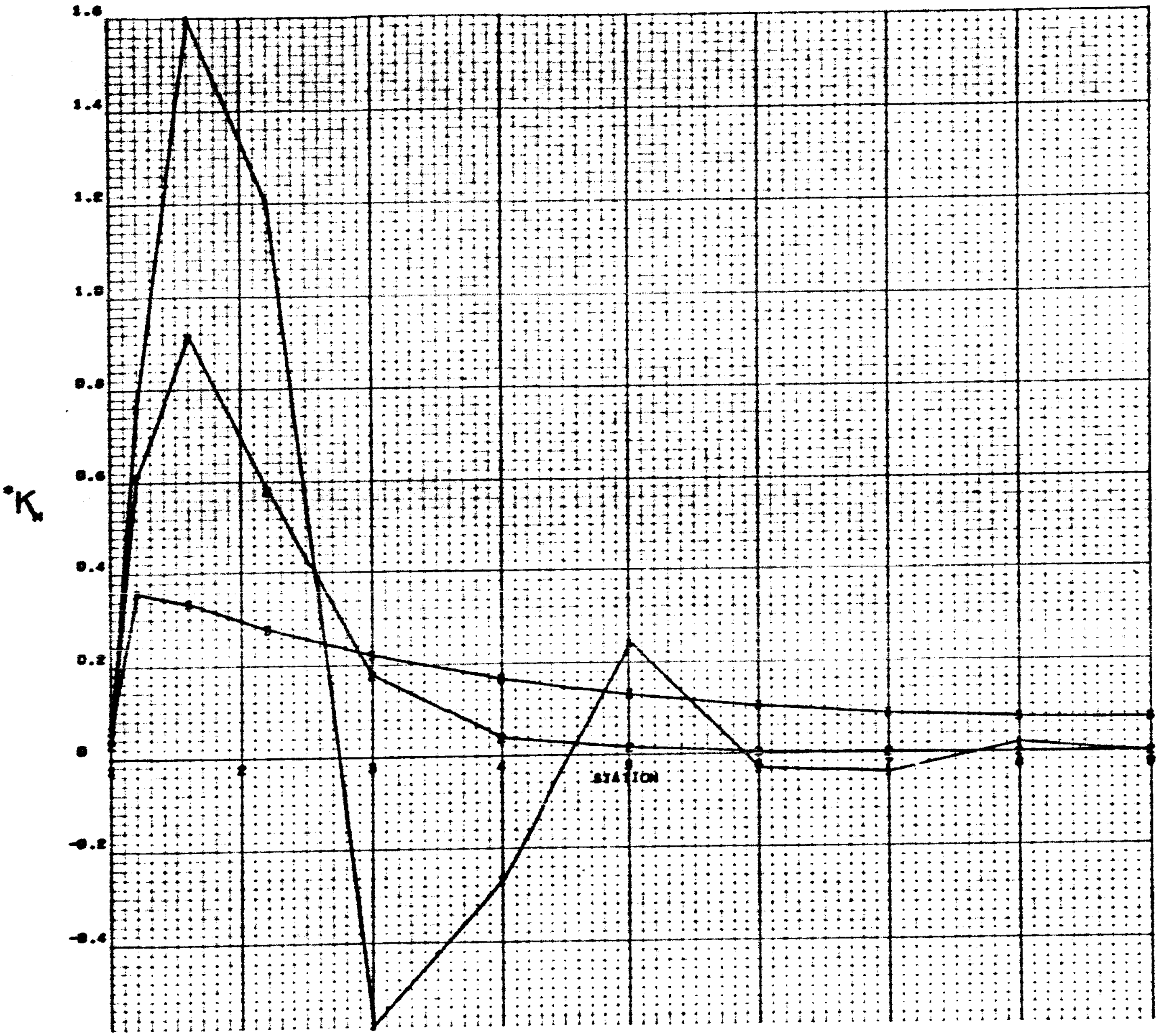


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

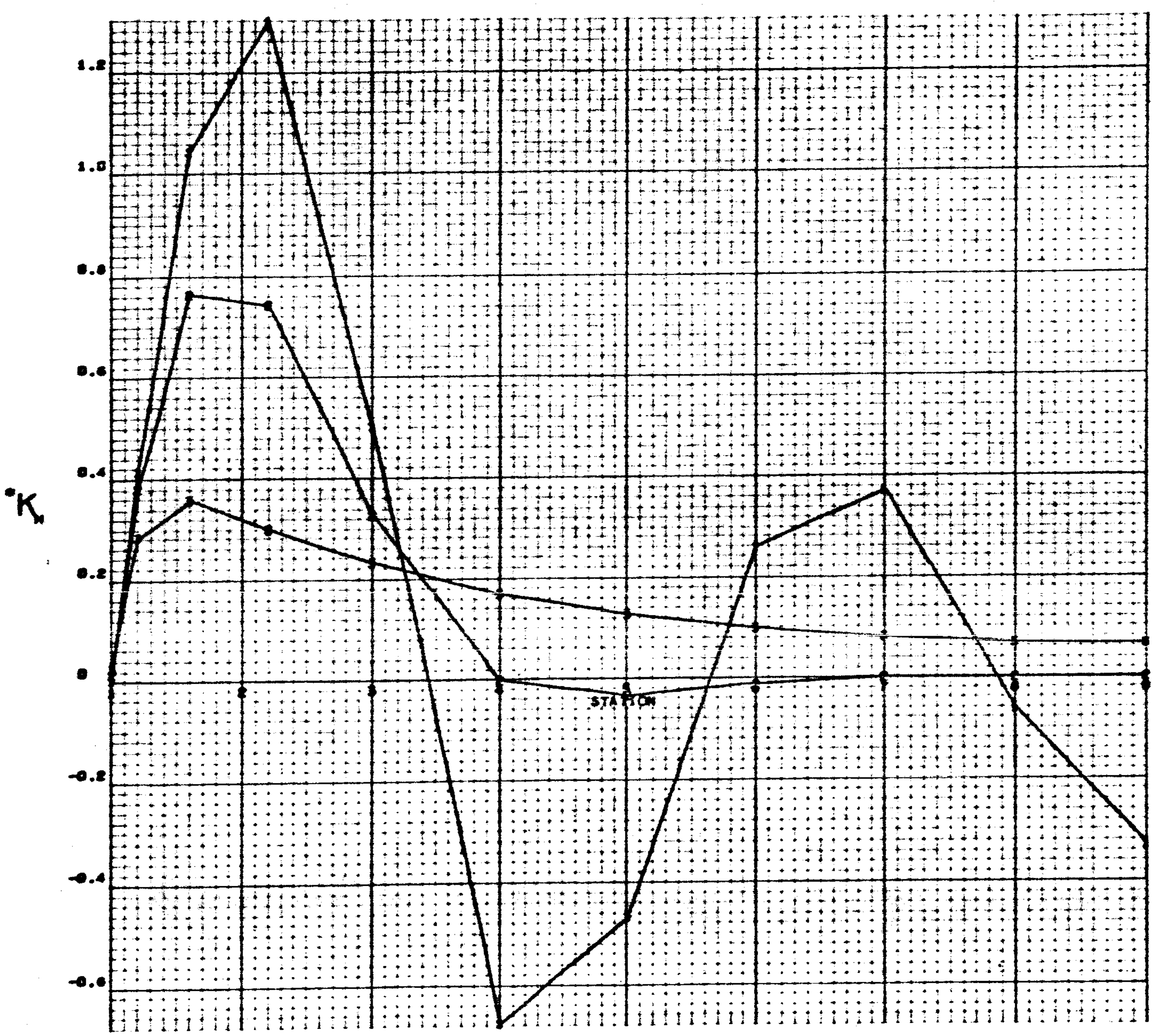
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

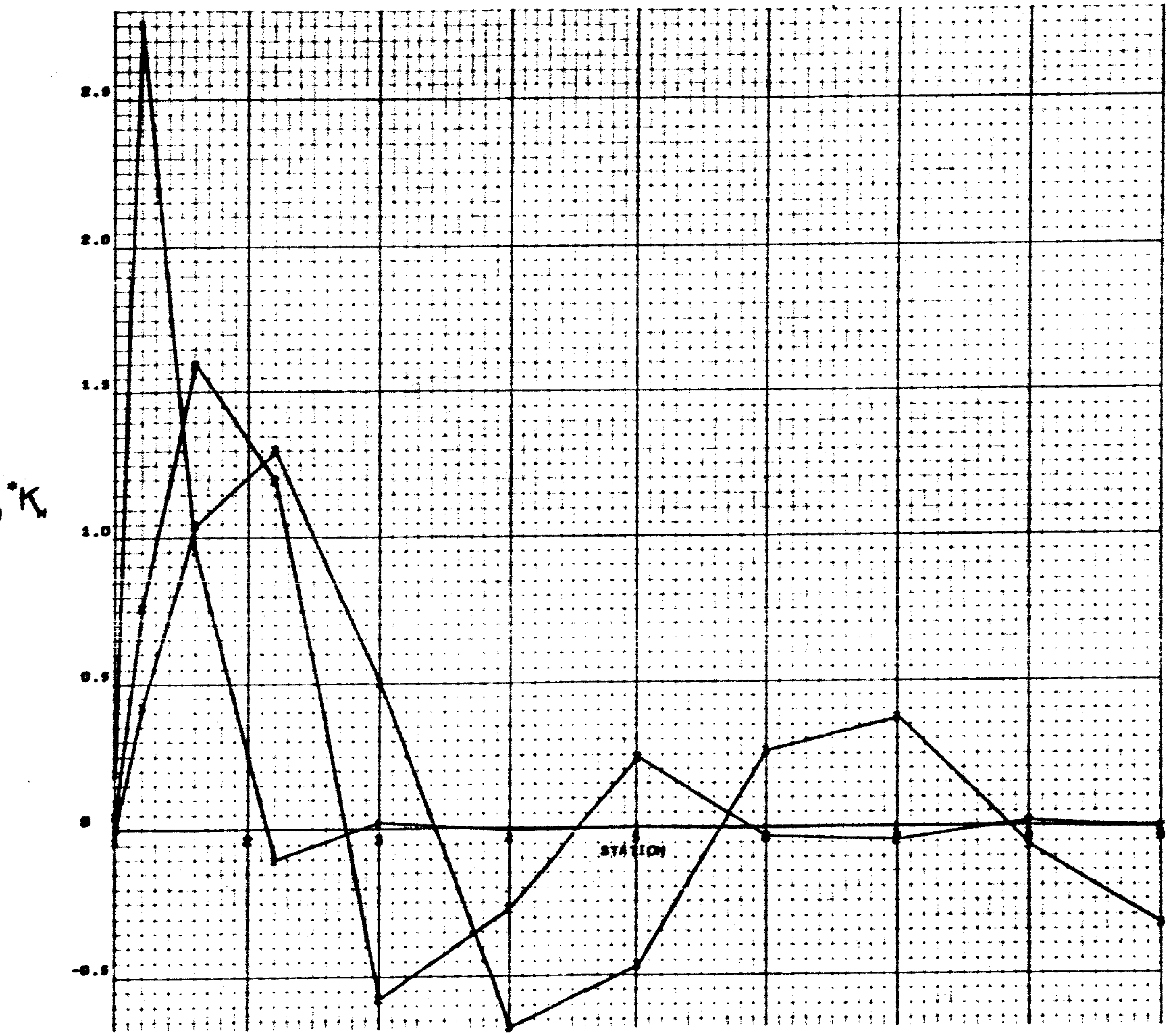
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

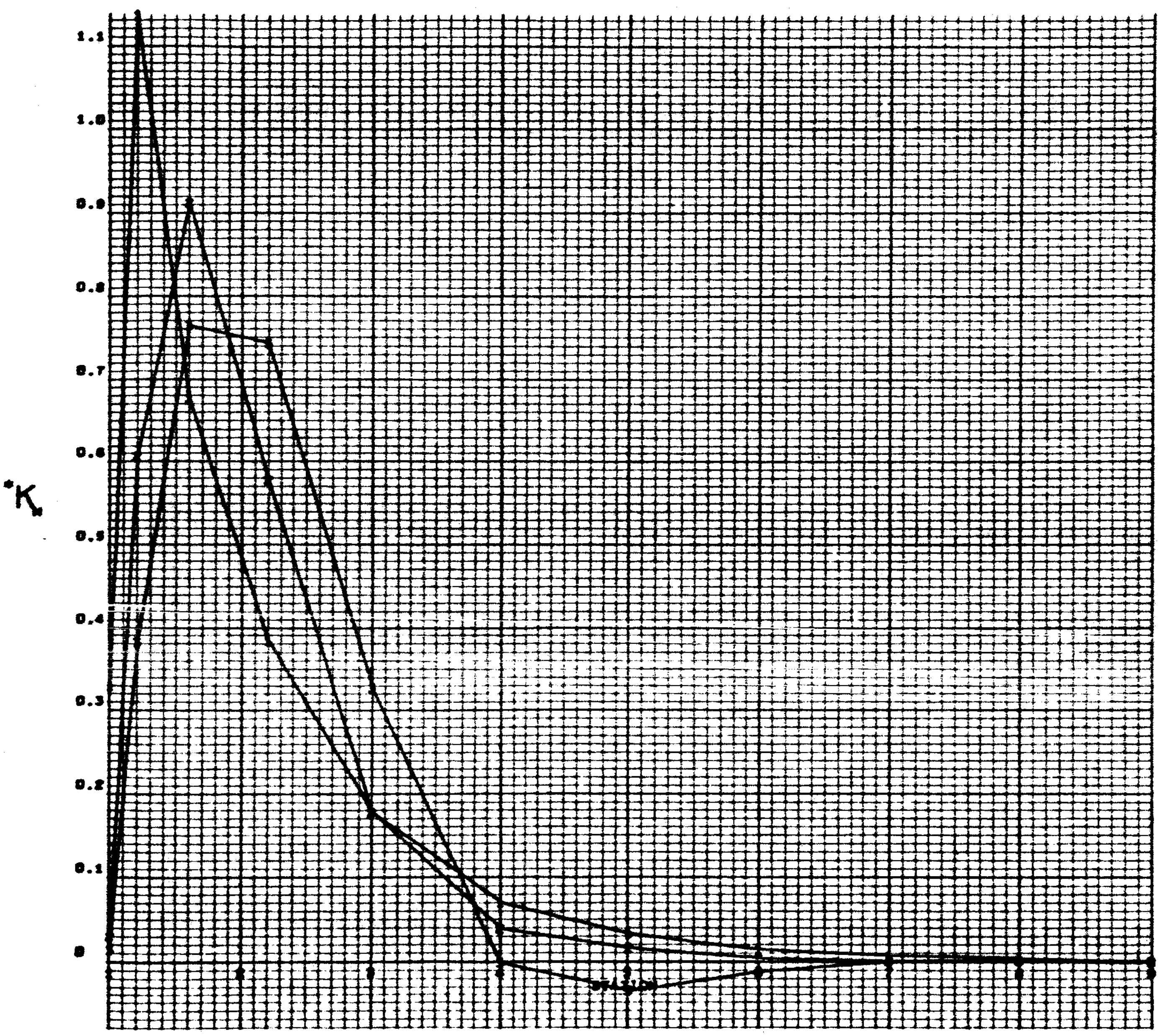
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

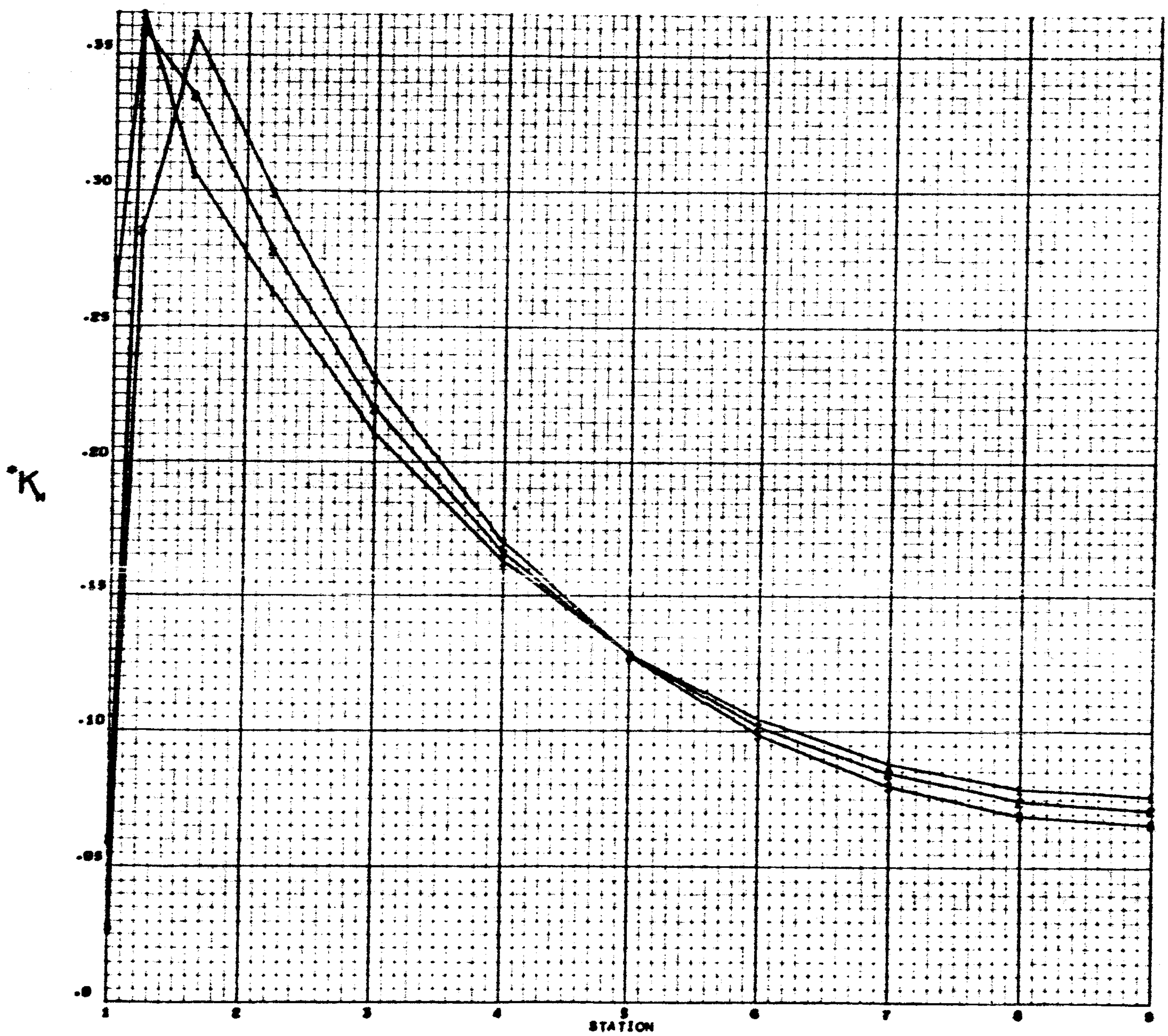
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, M = K_M

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

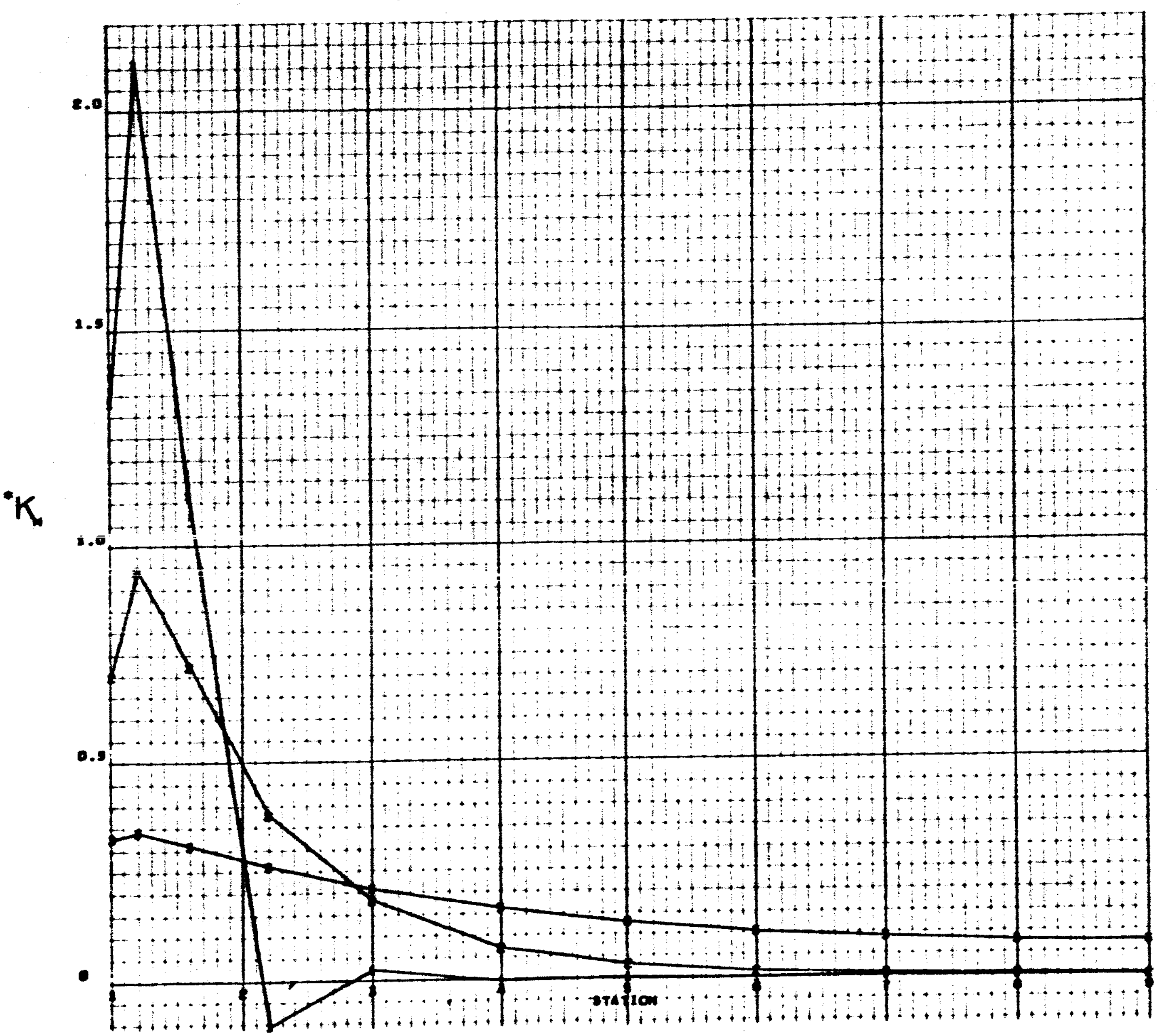


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

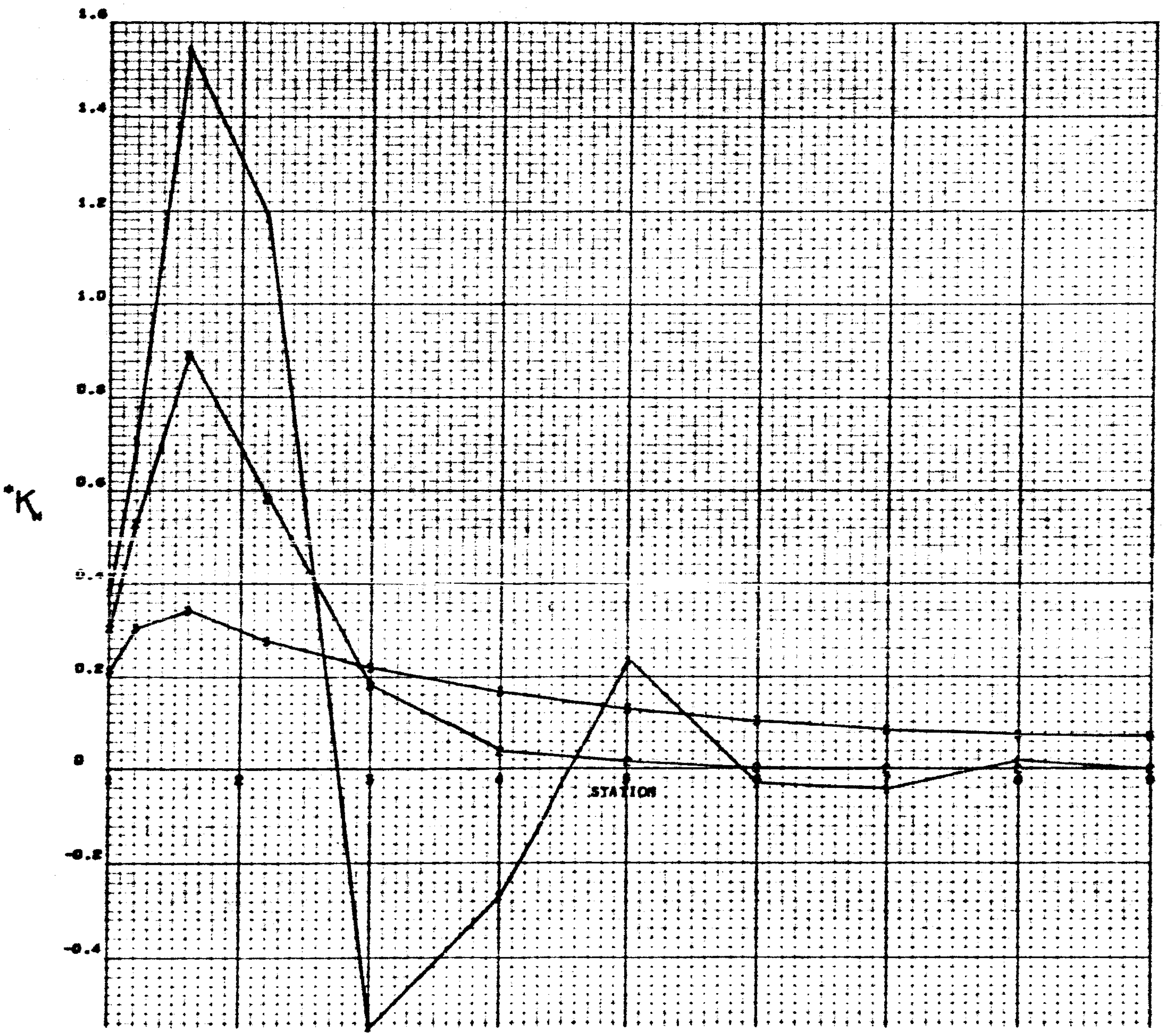
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

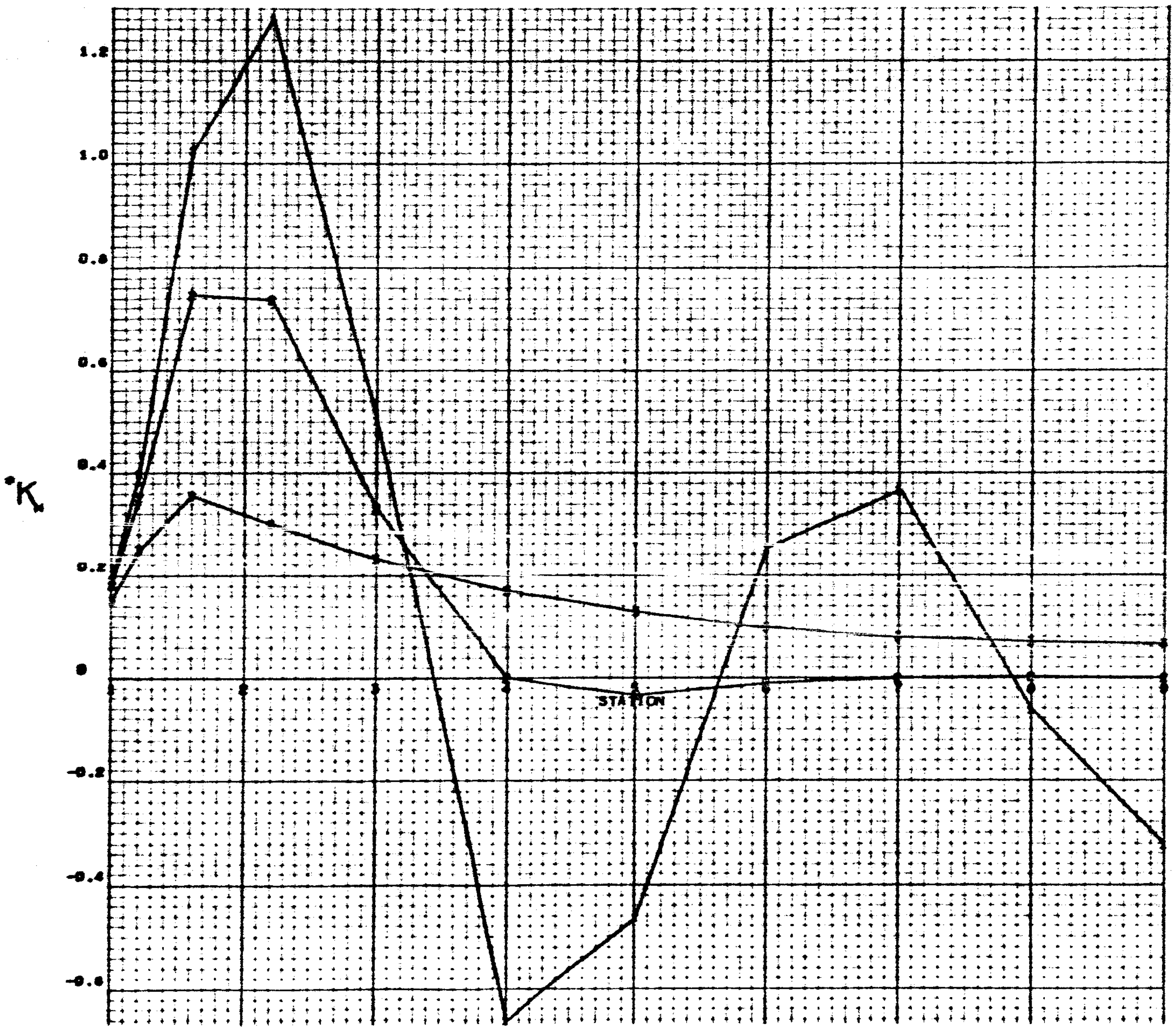
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT / M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

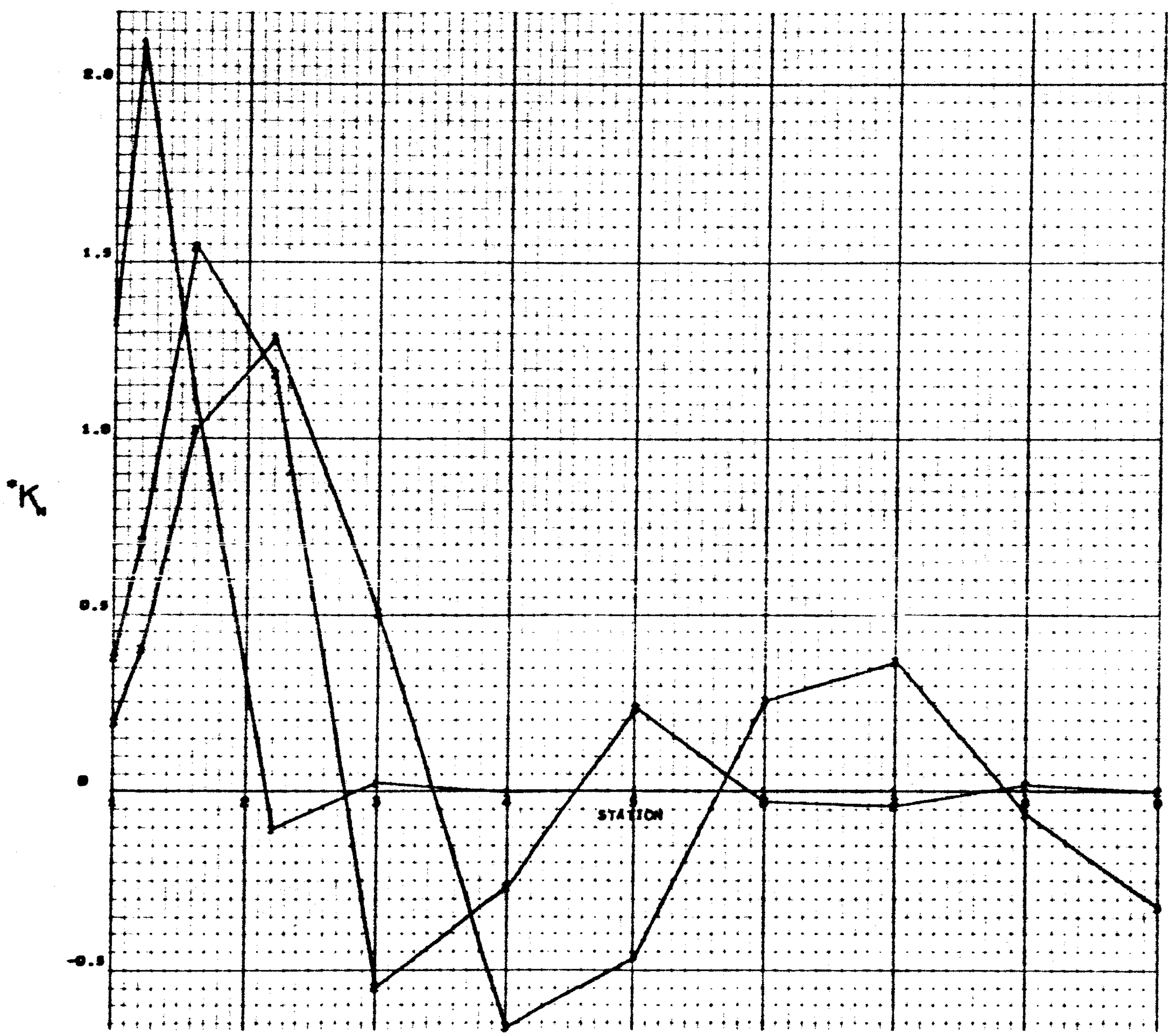
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

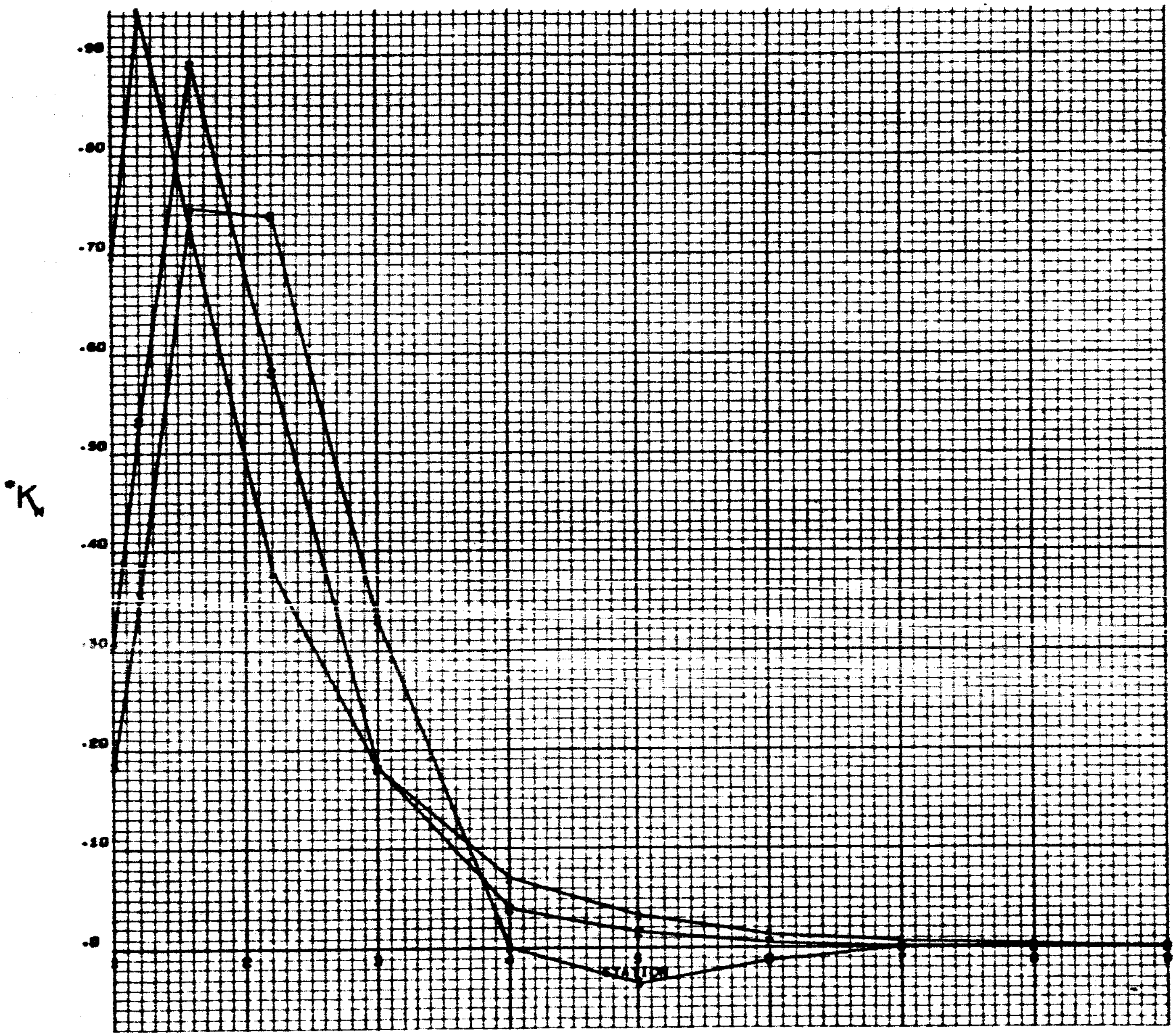
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT /
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

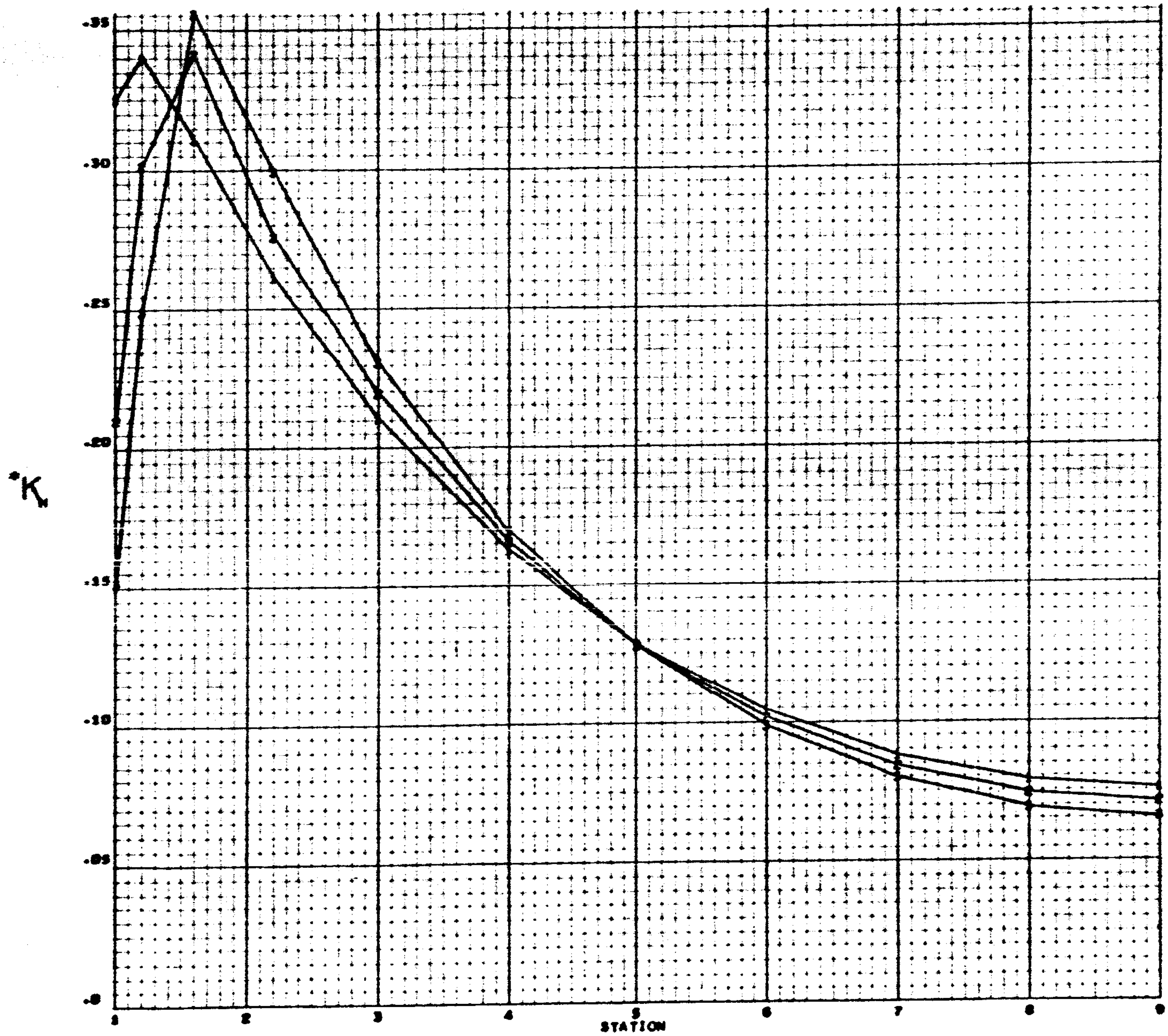
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

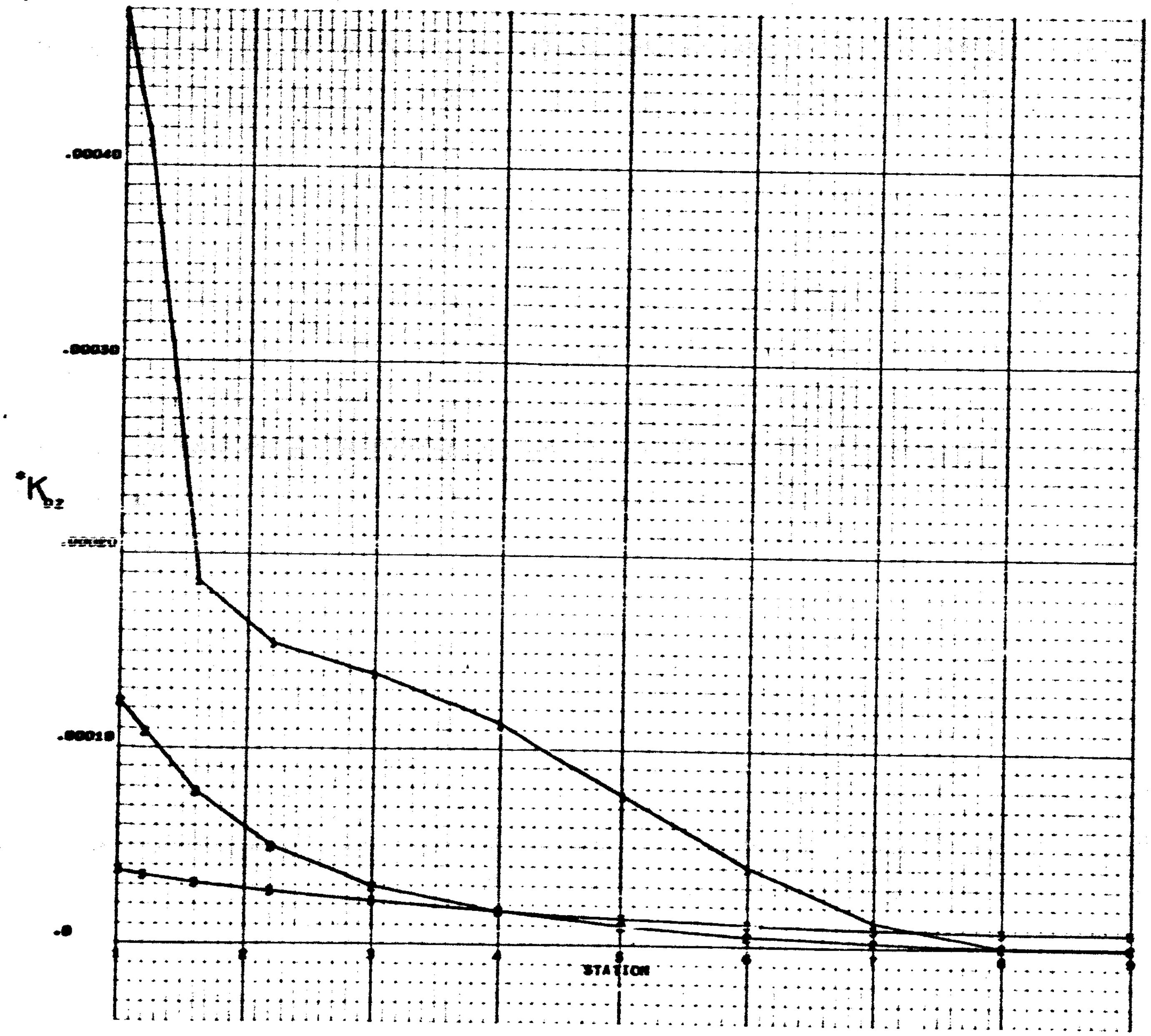
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
M, INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC AXIS, $M = K_M$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

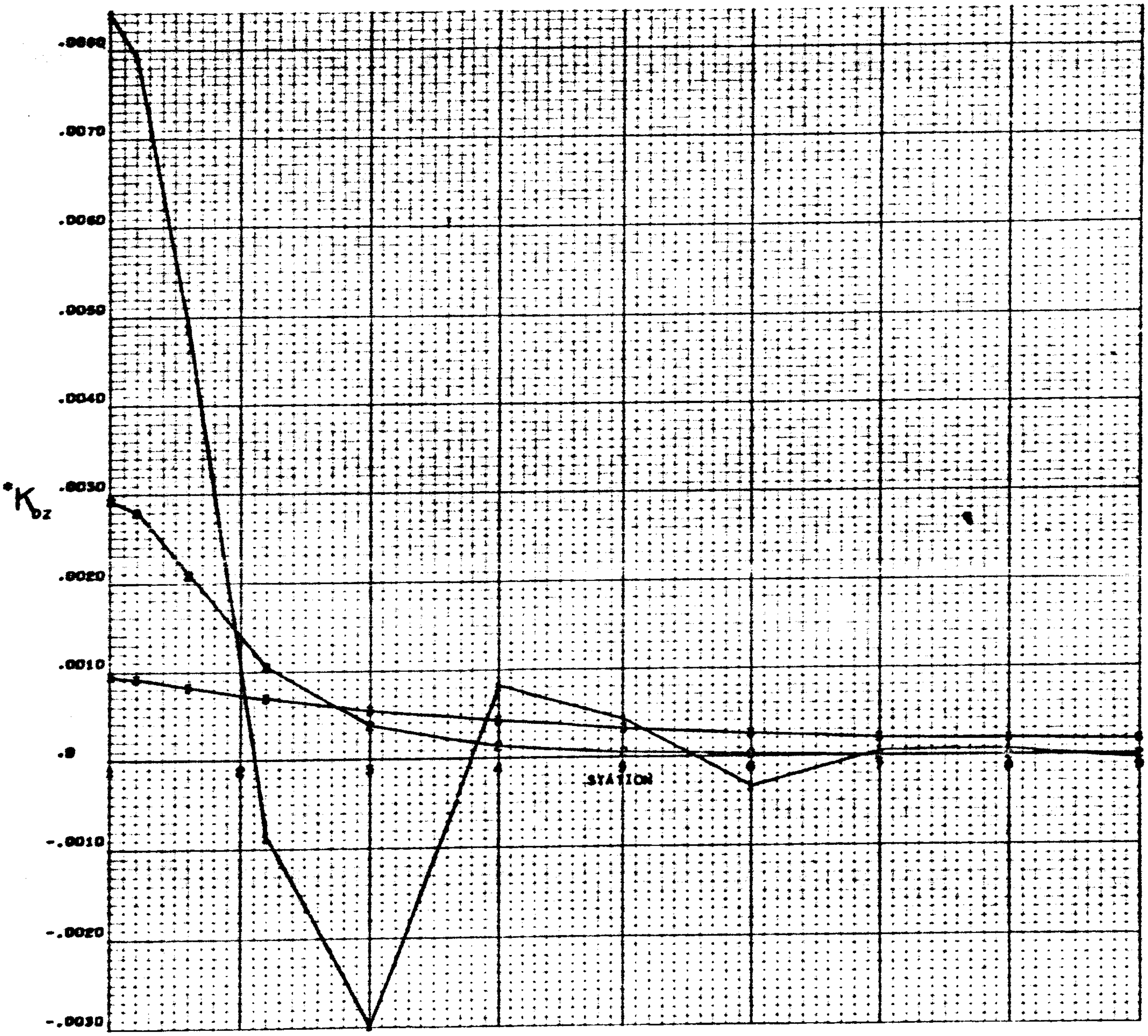


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

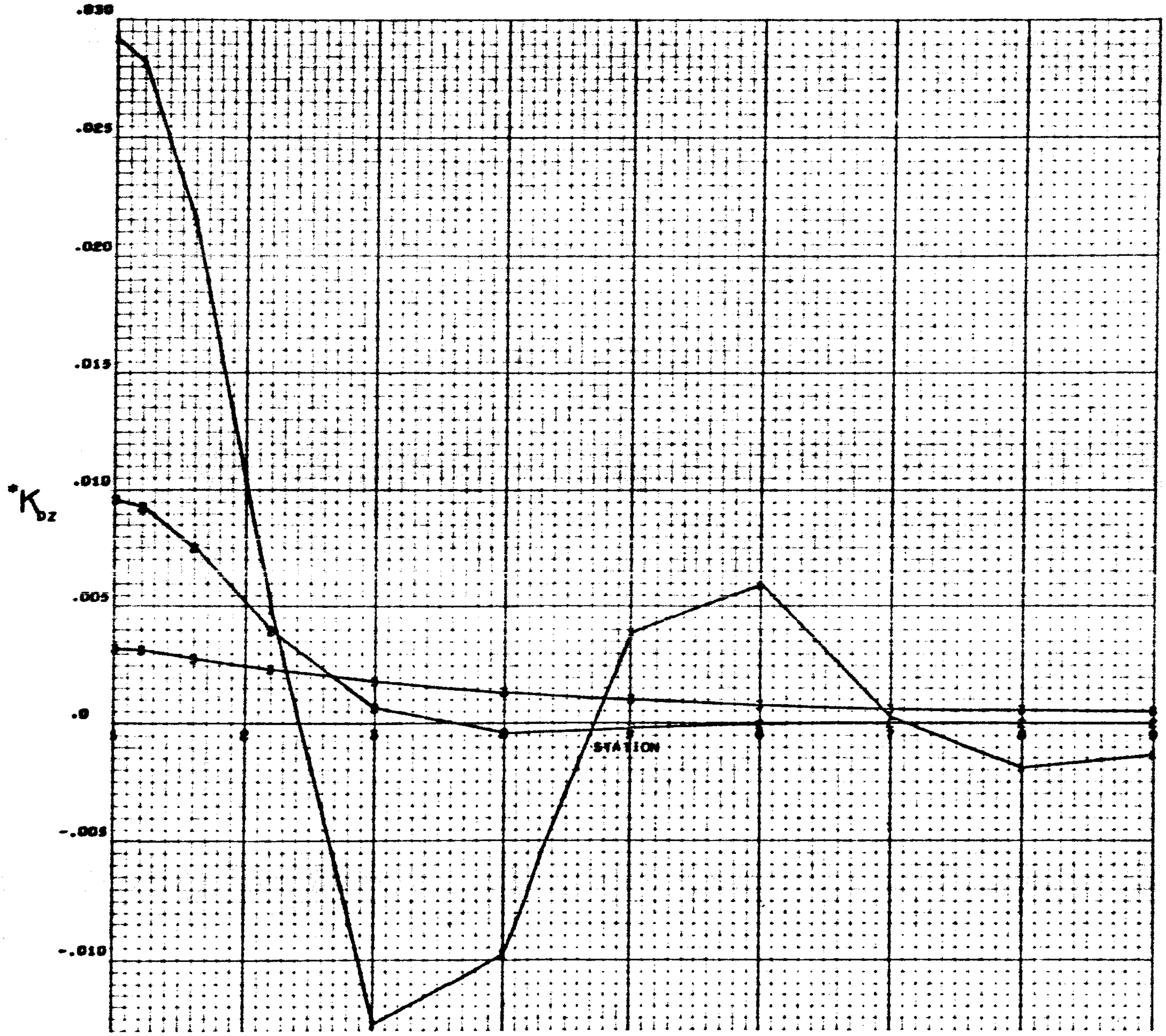
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^3/EI)$

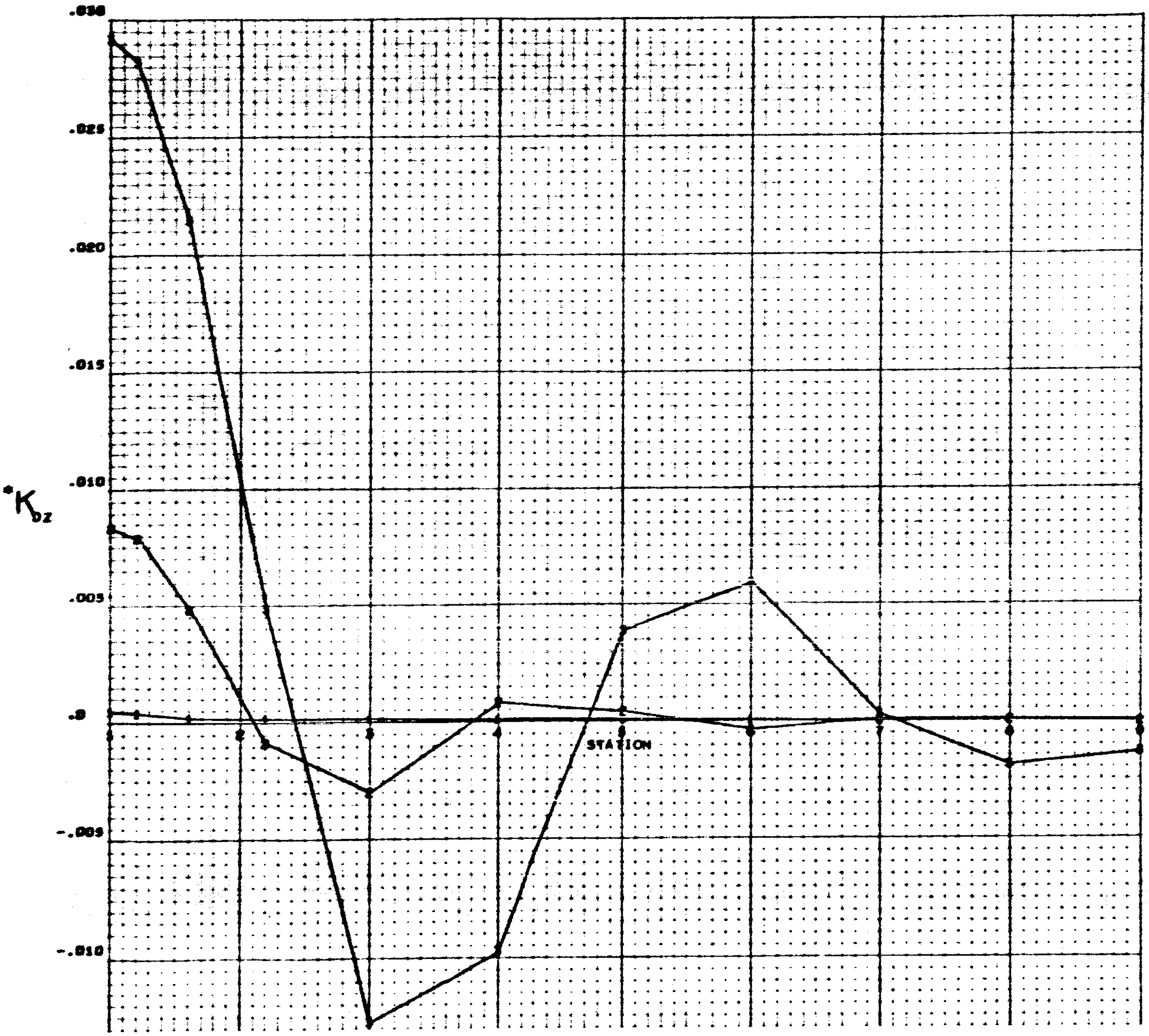
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

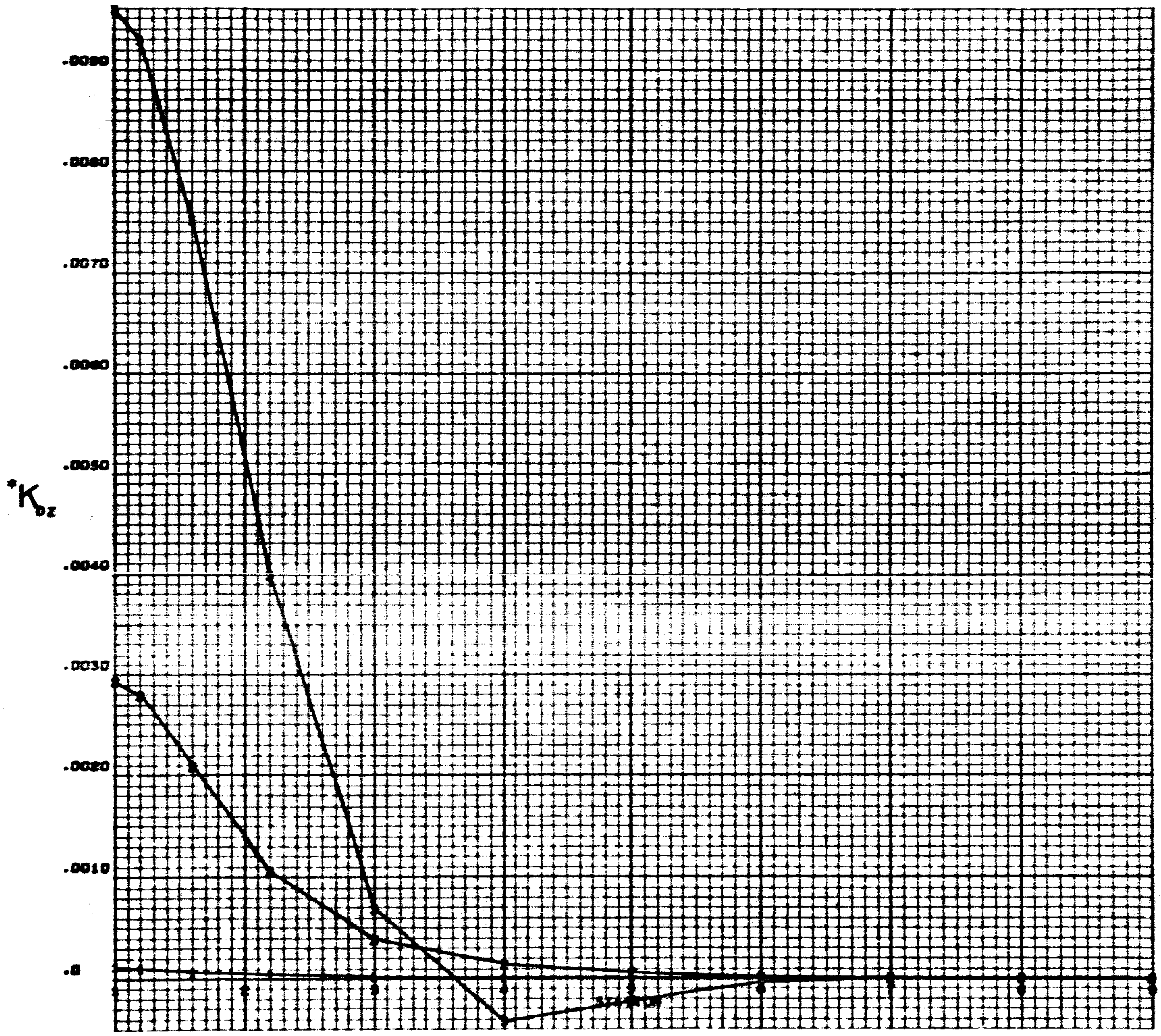
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

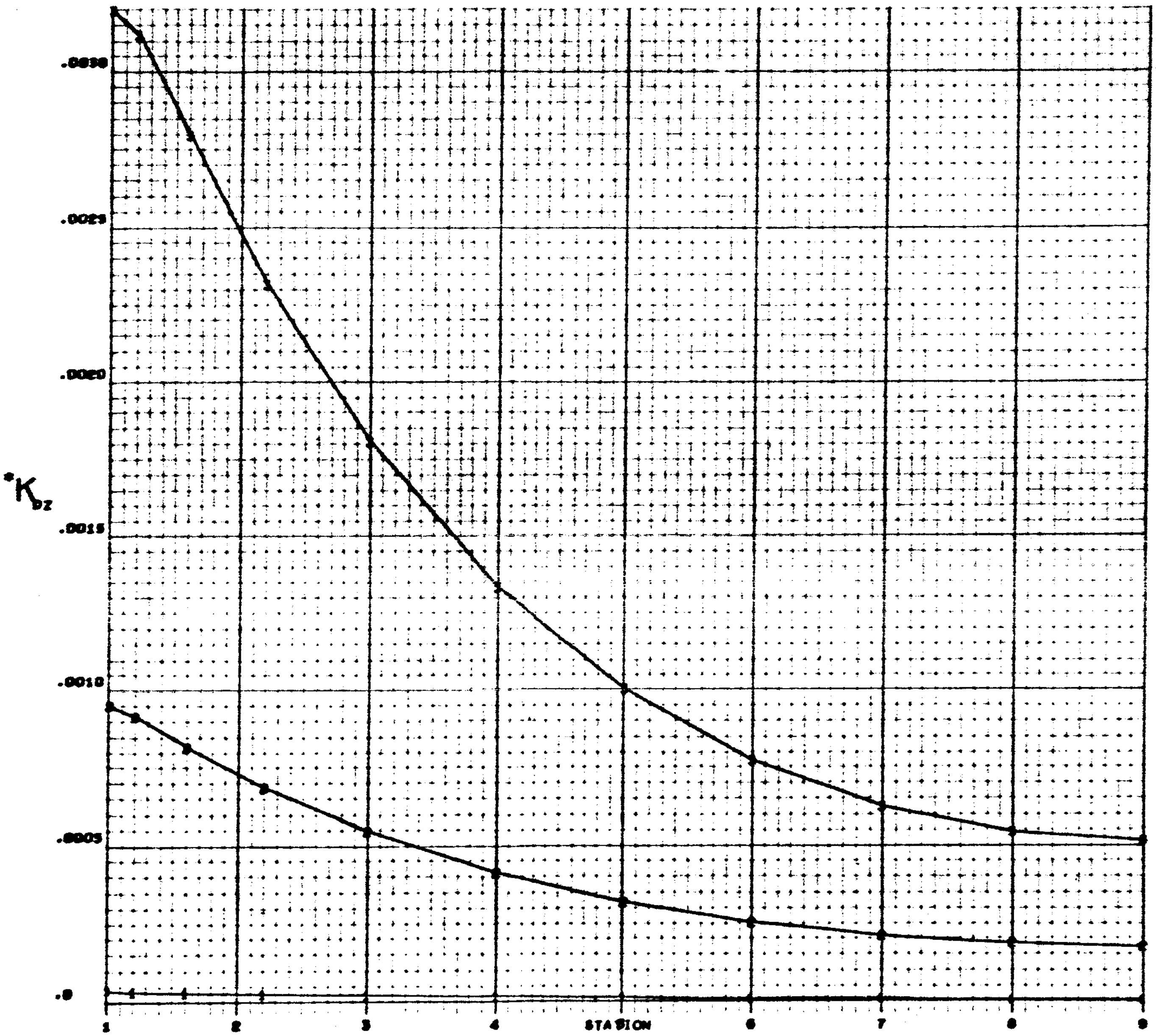
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

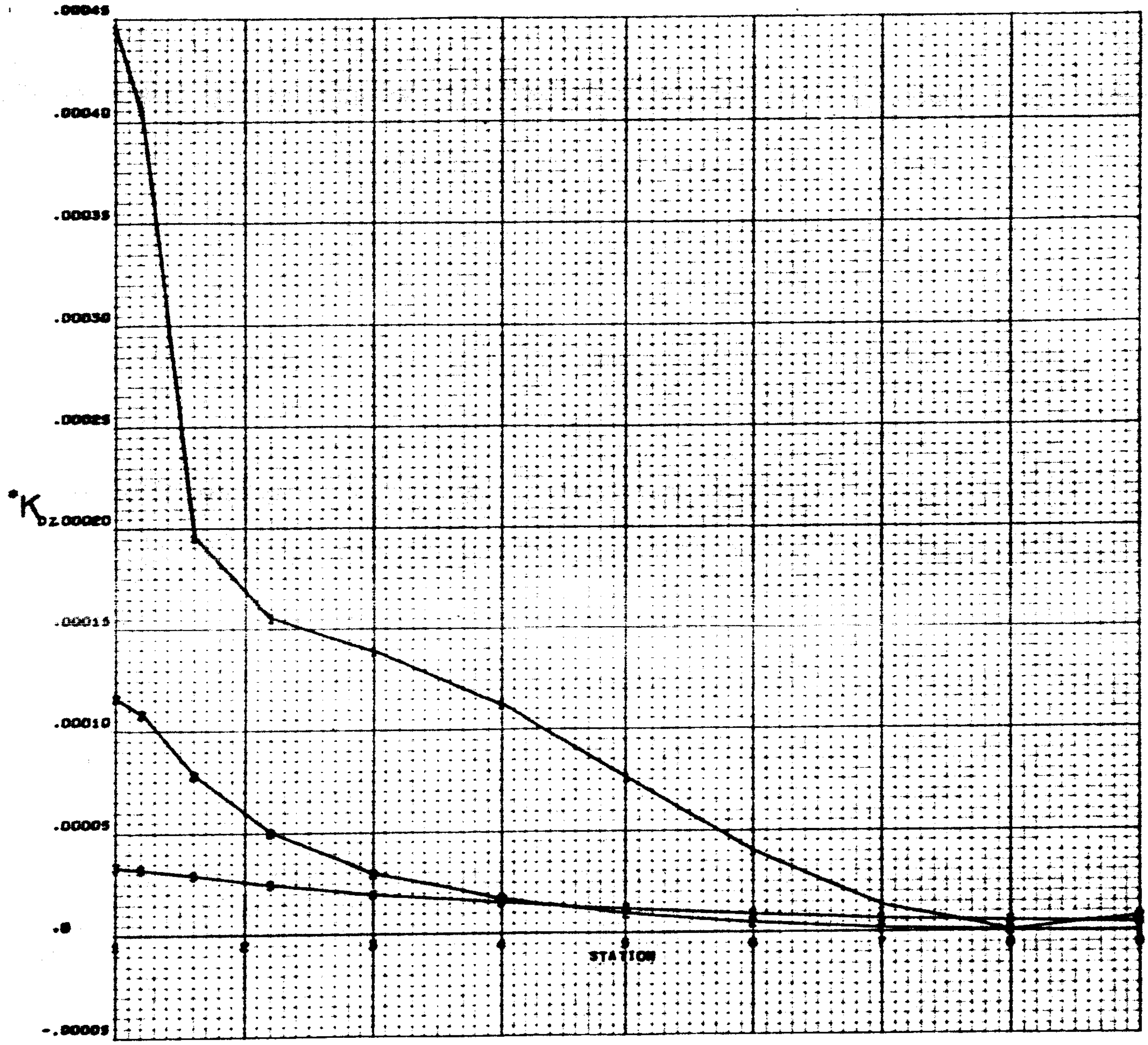
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^3/EI)$

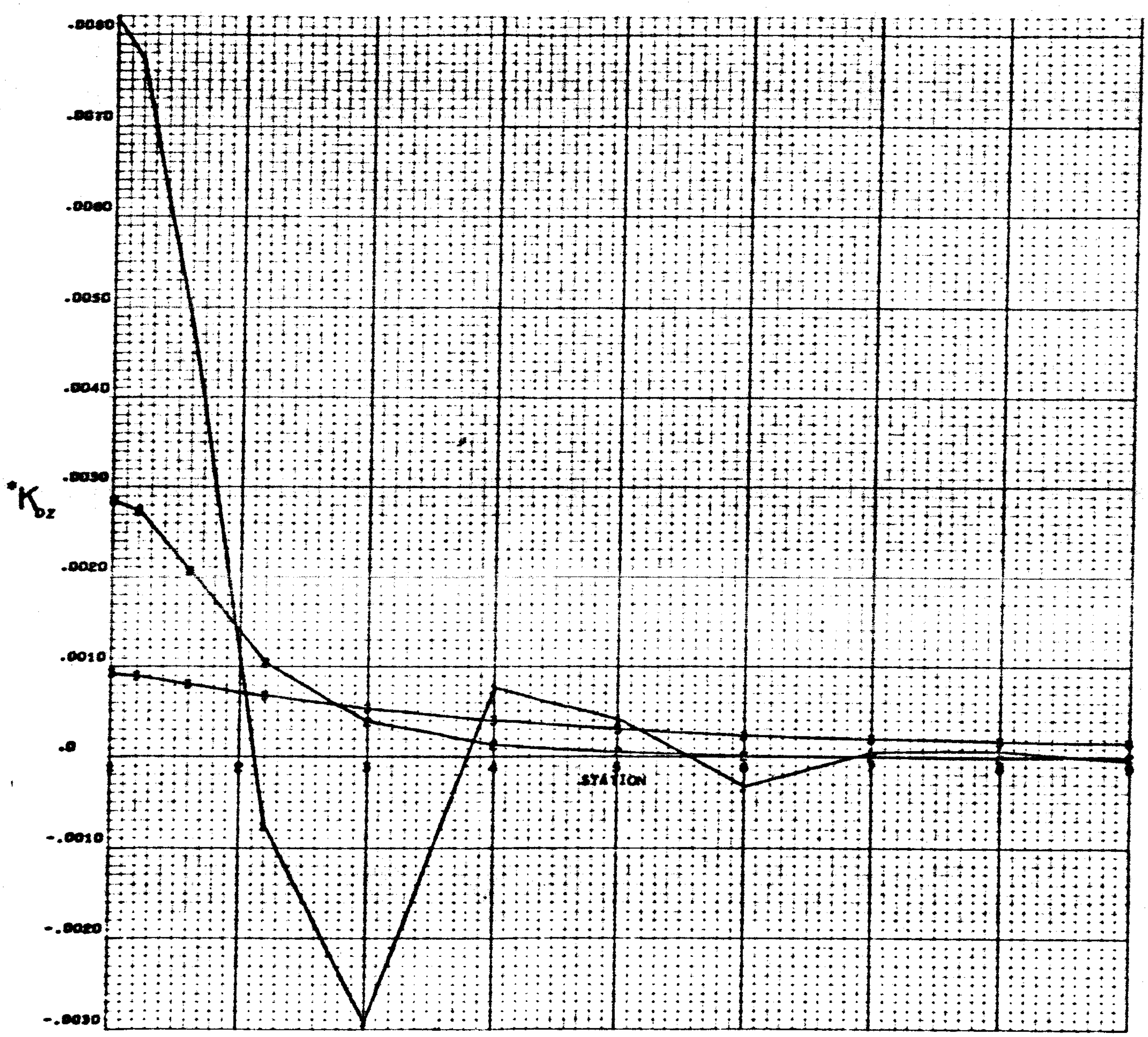
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE

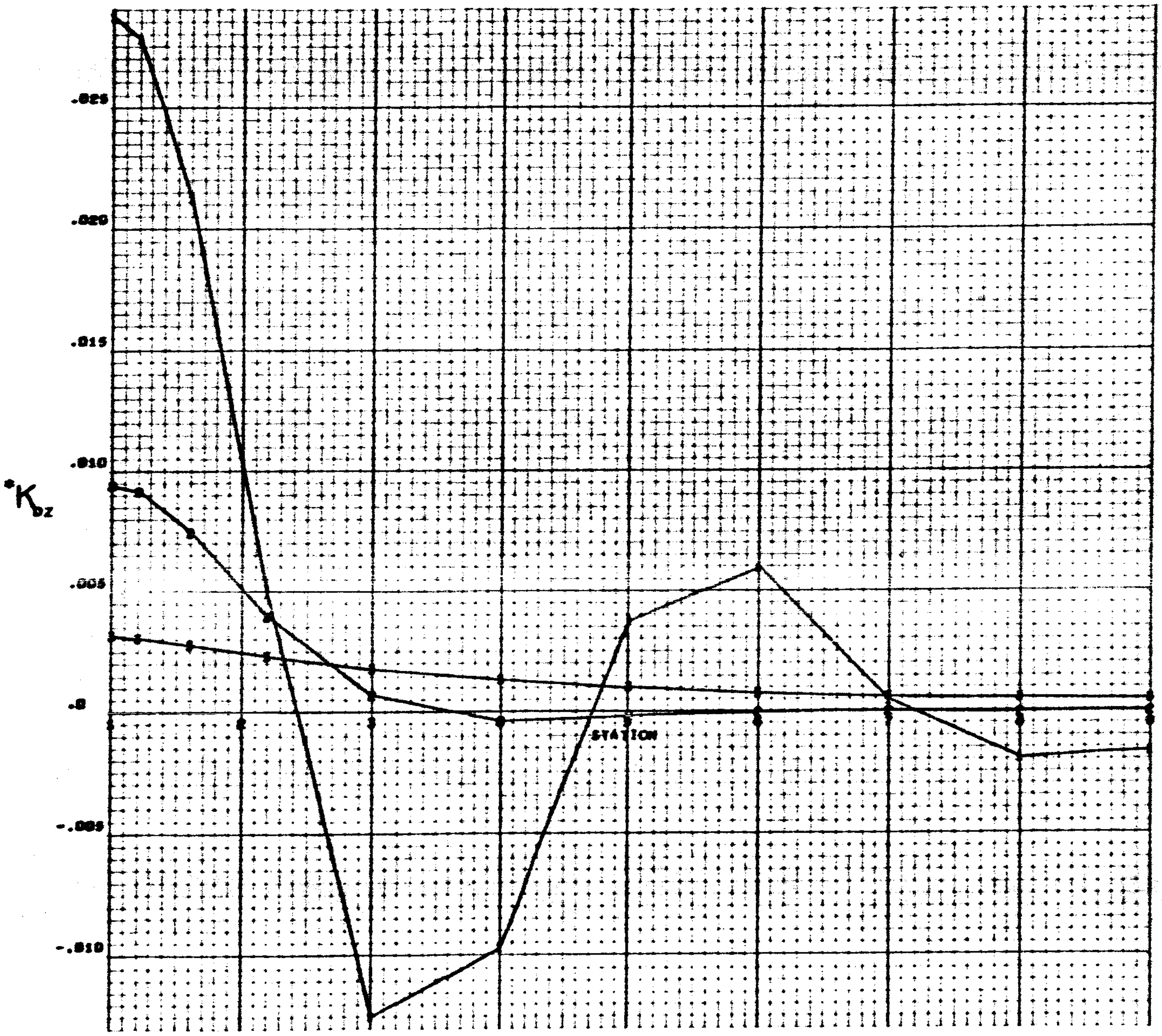


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_z = K_{Dz}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE

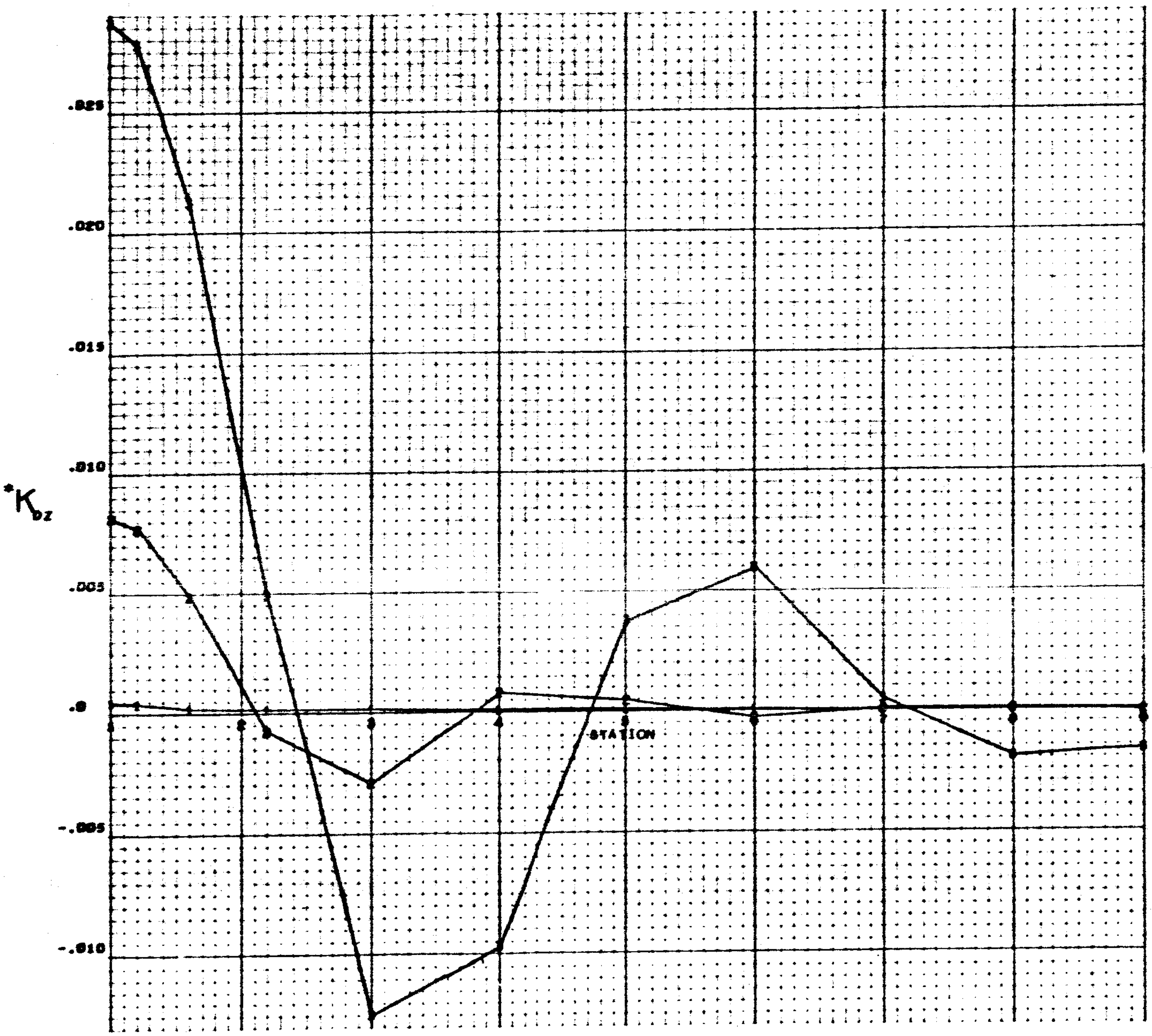


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE

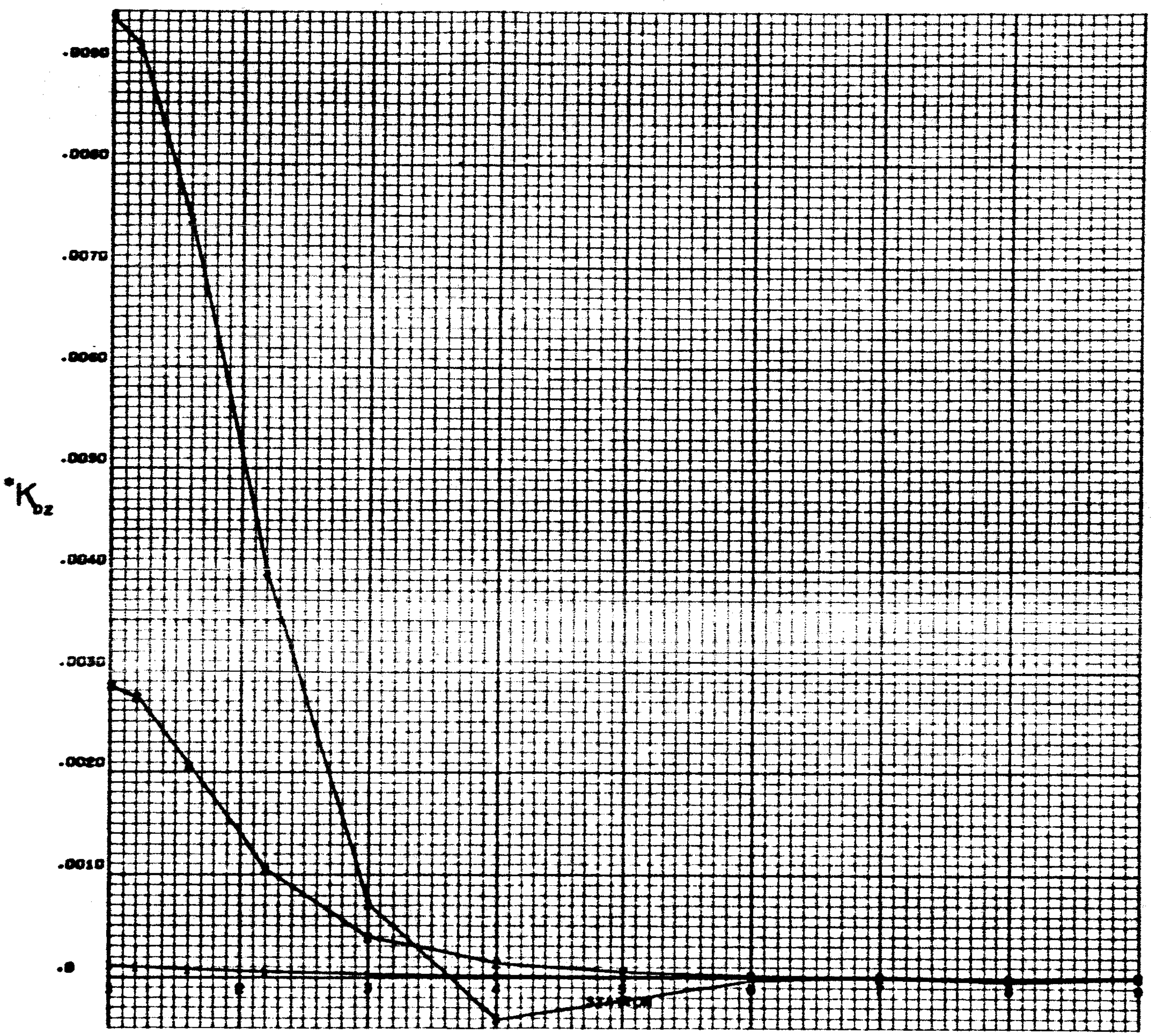


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

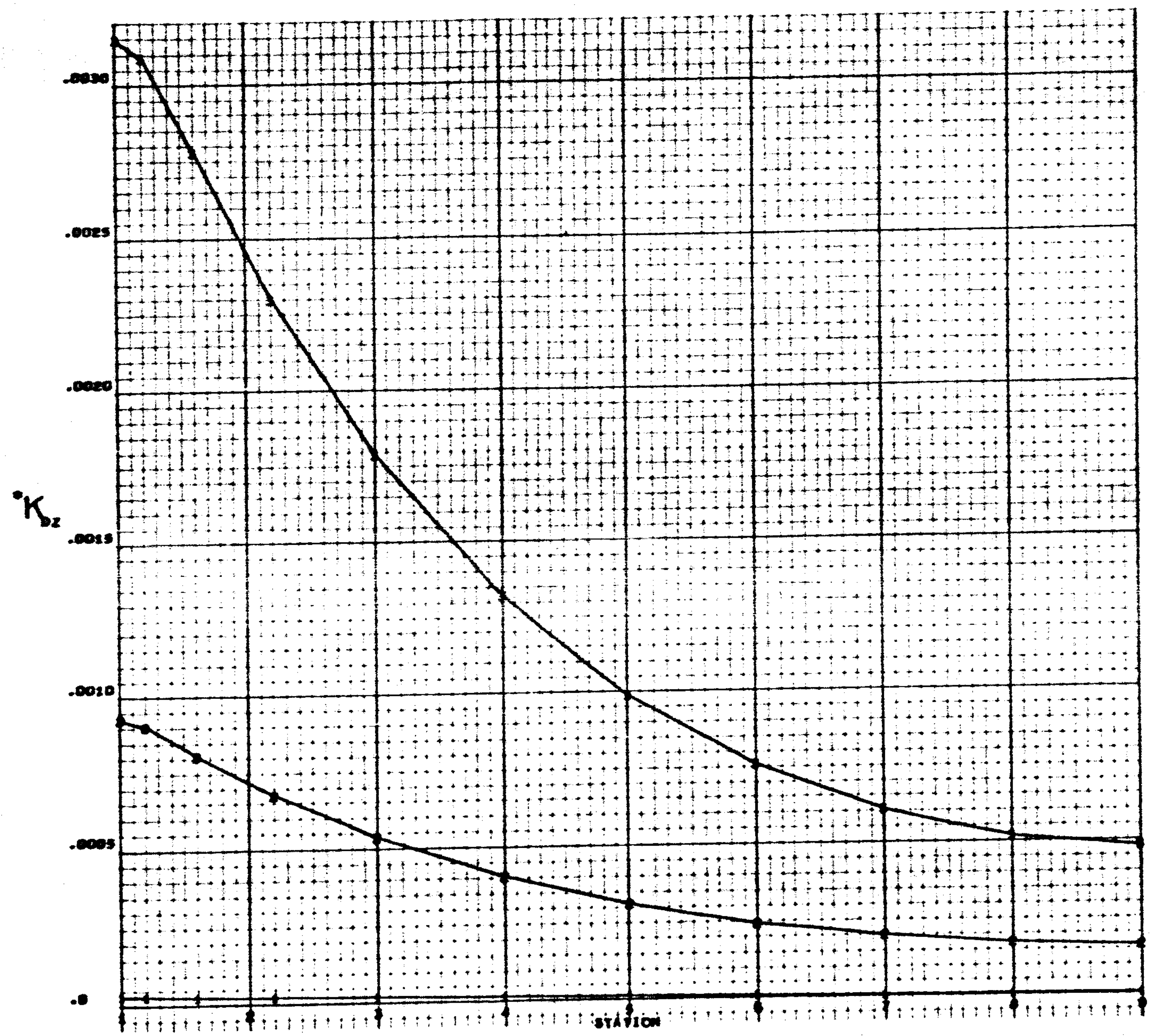
UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.ED, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^3/EI)$

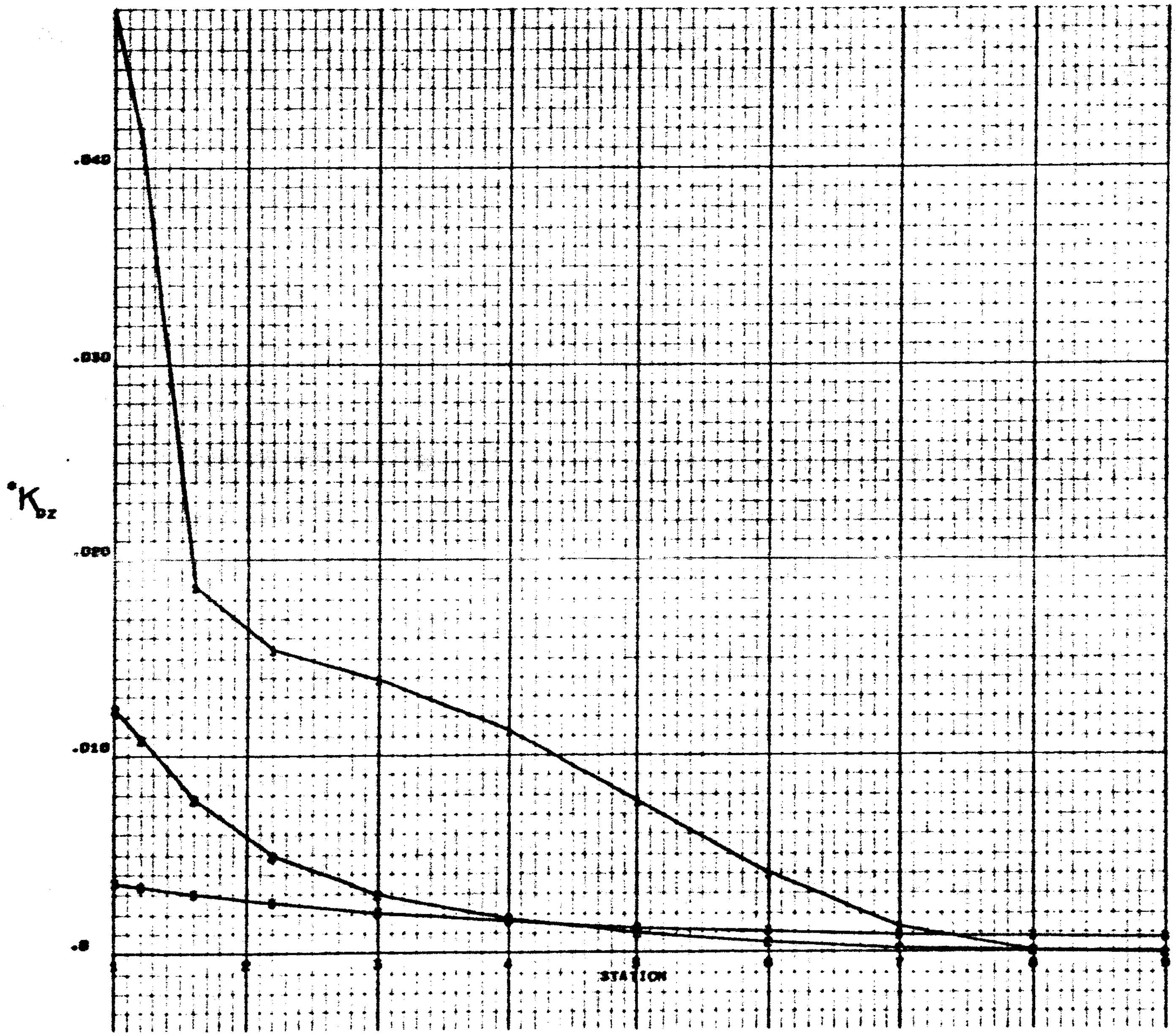
UNIT FORCE DISTRIBUTED OVER ELEMENT | ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^3/EI)$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

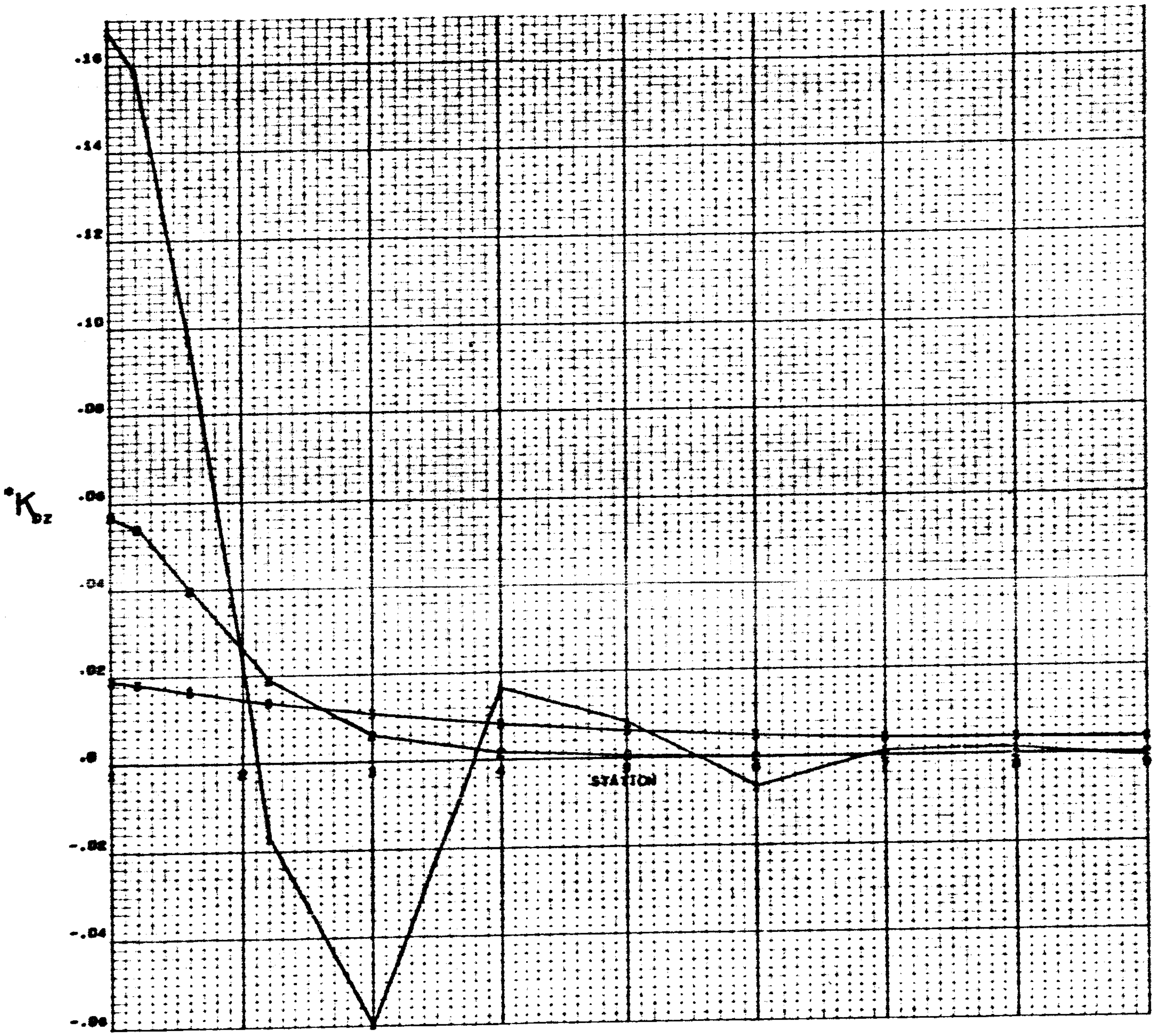


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

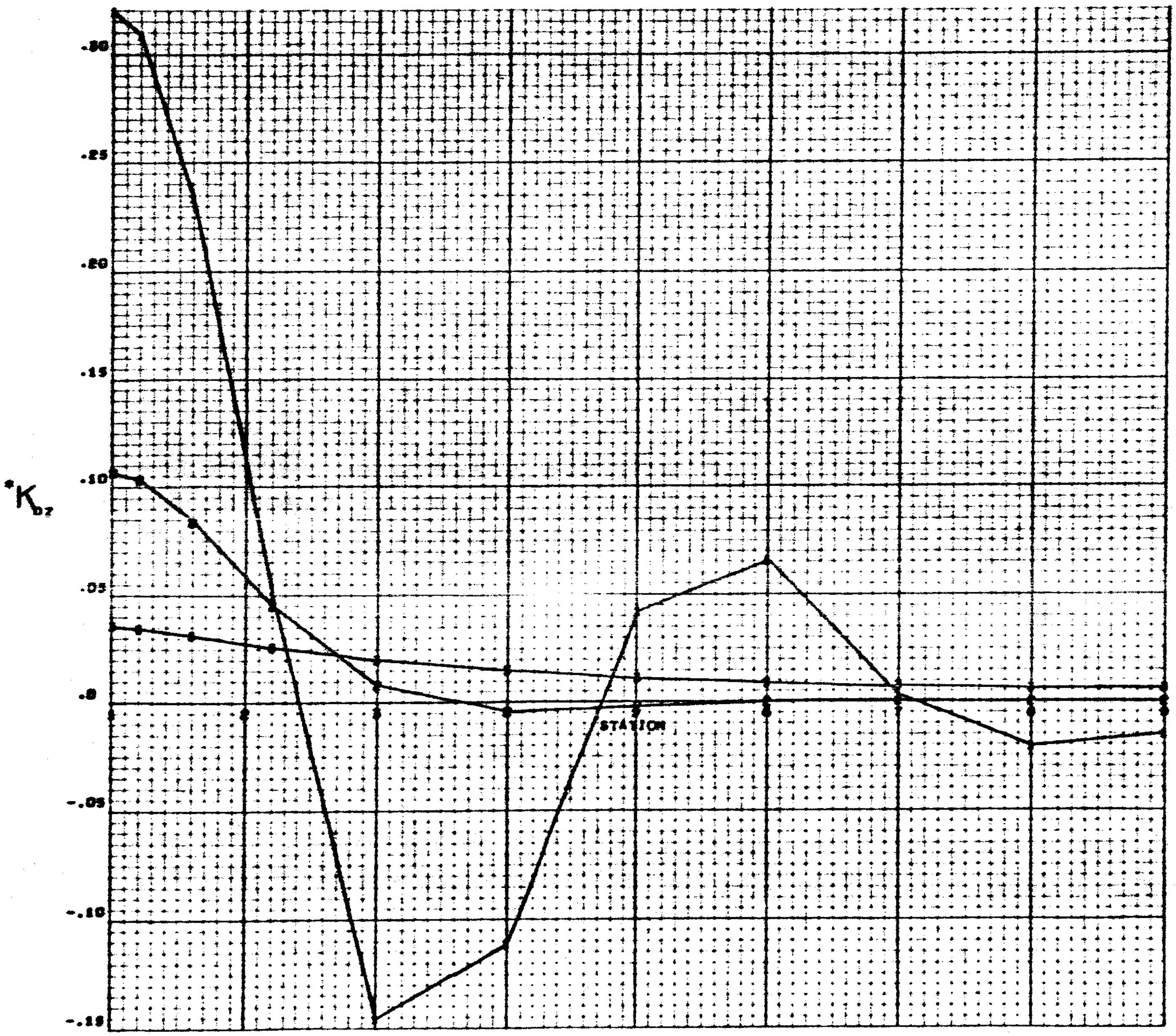
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

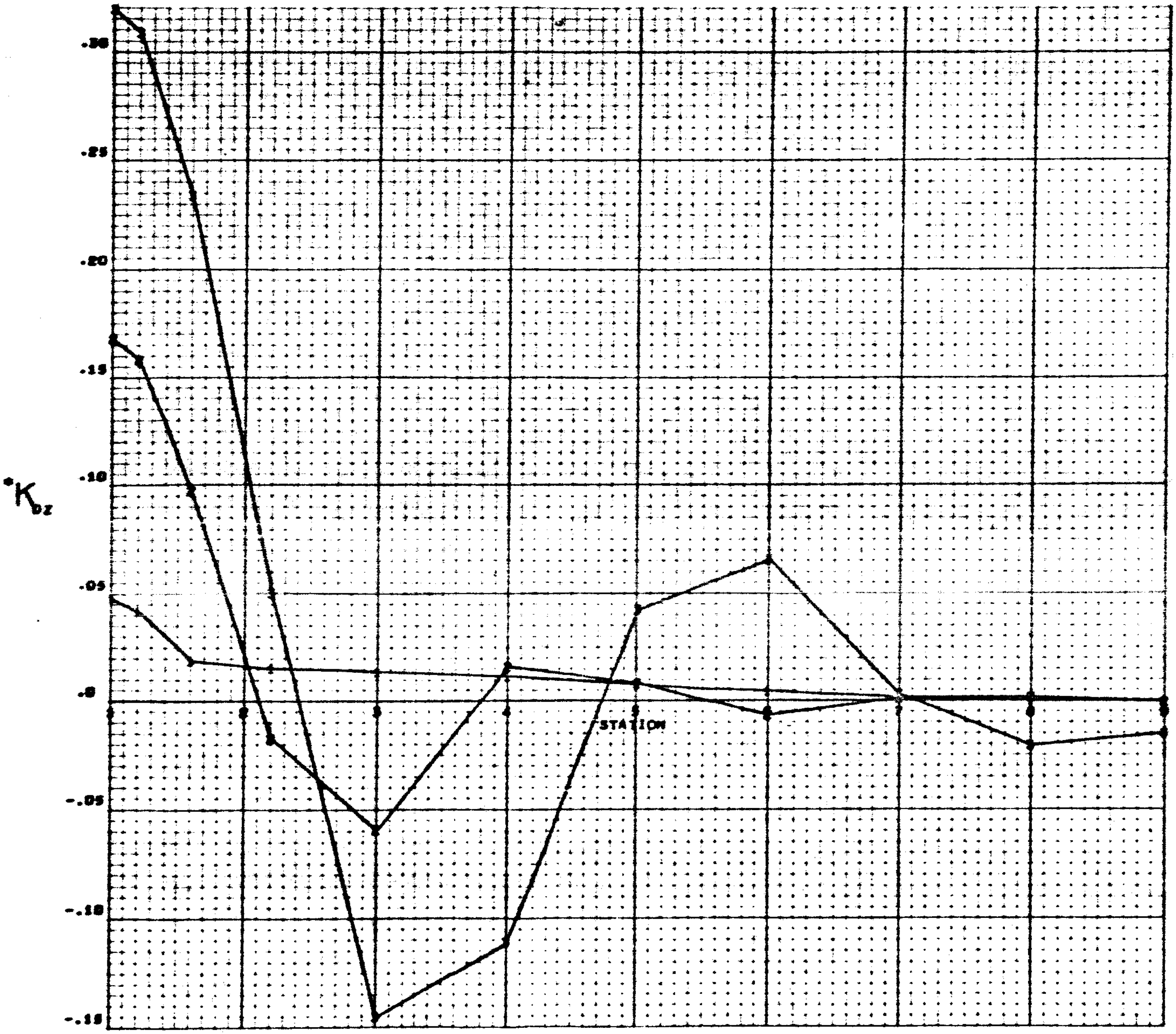
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

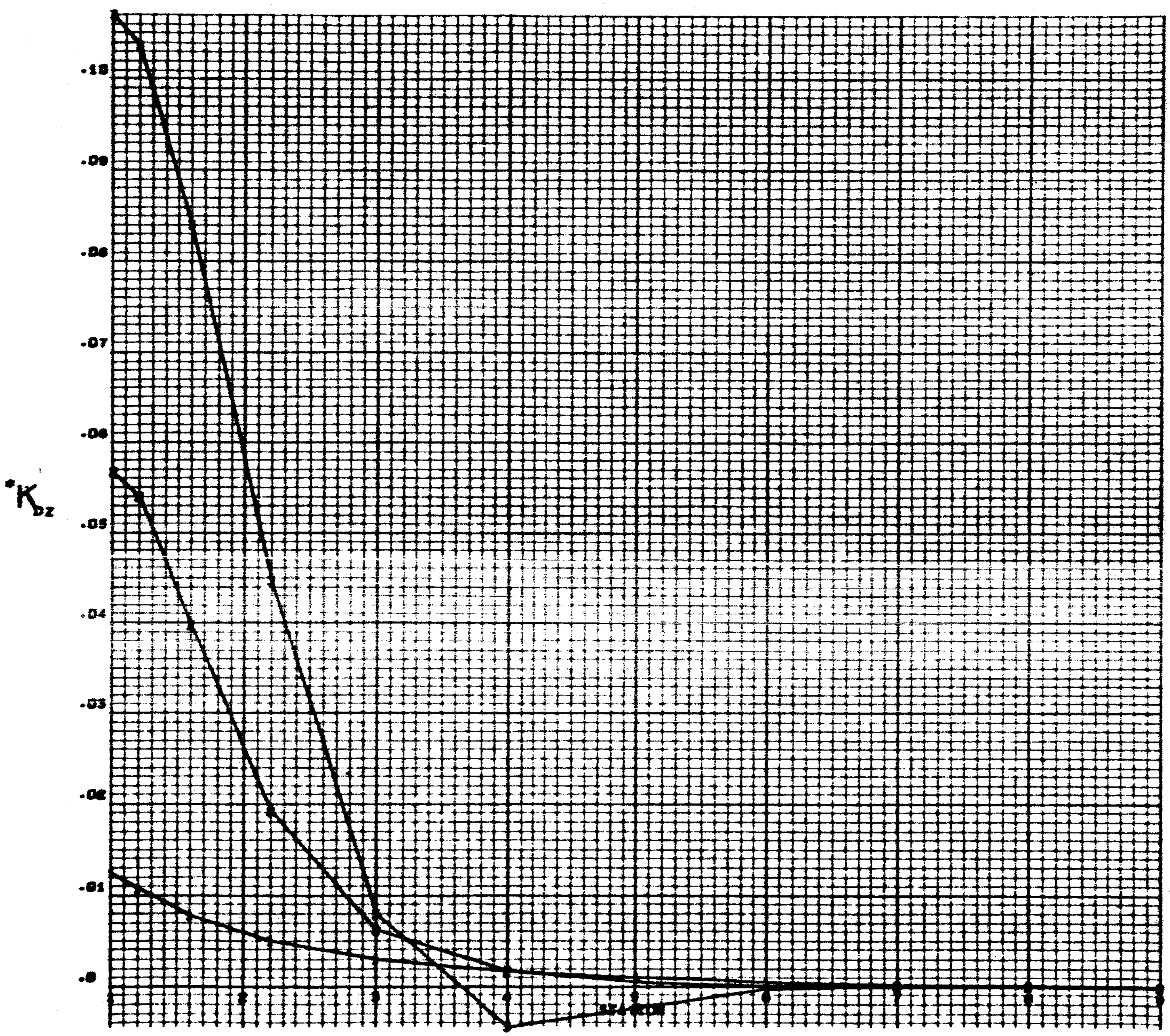
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

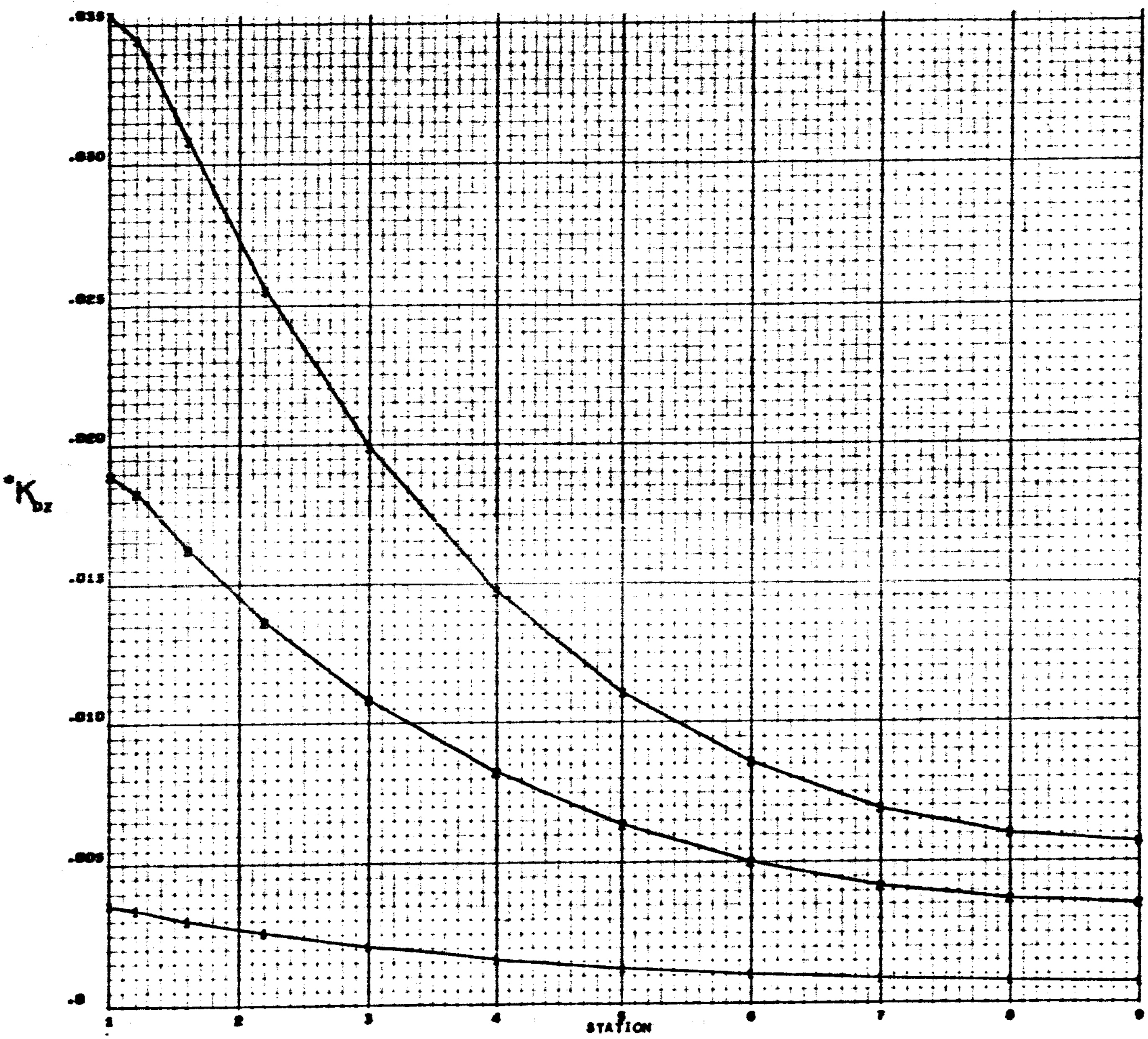
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE

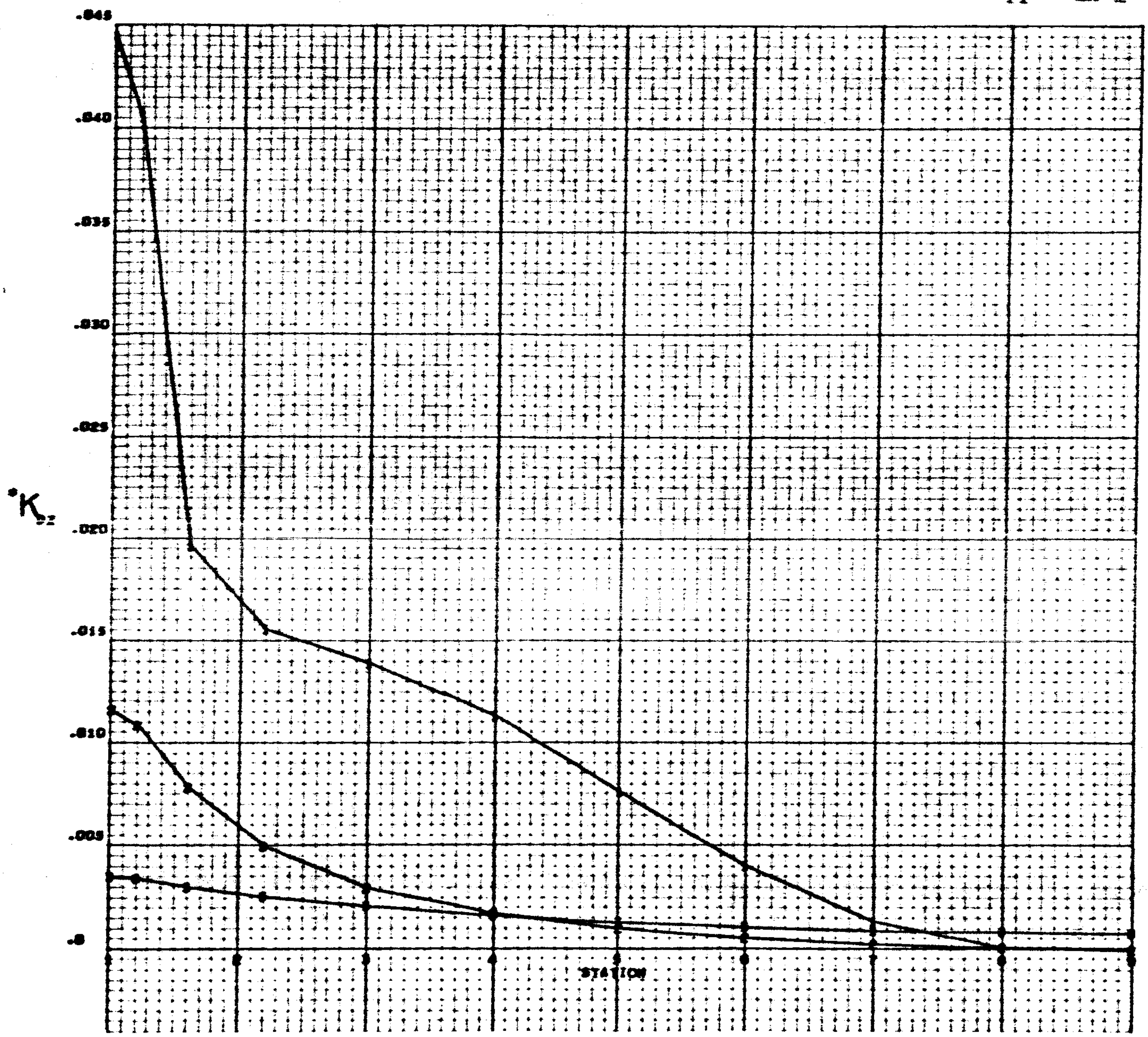


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
δ_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.01, GJ/EI VARIABLE

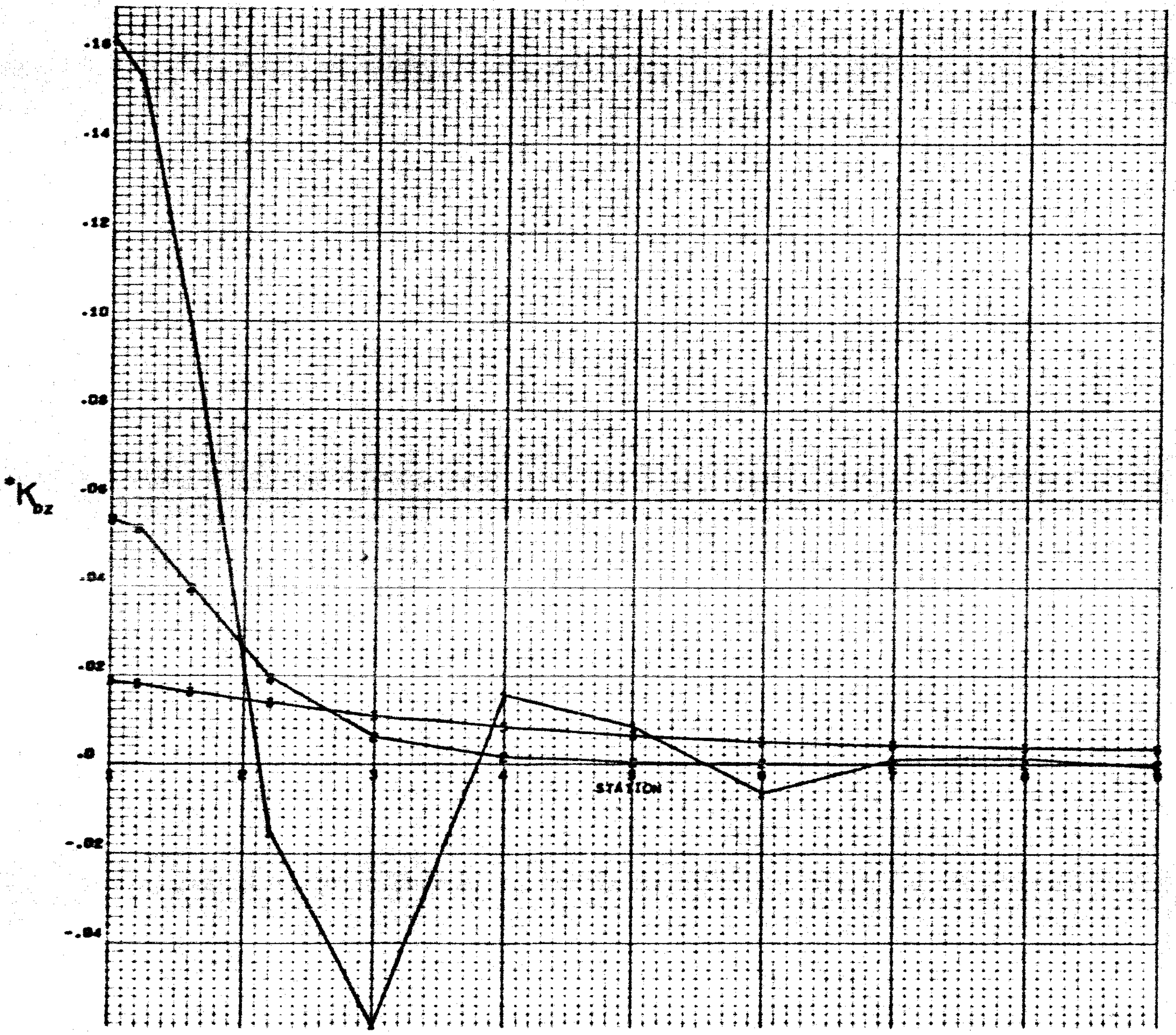


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, δ_Z = $K_{\delta Z}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.05, GJ/EI VARIABLE

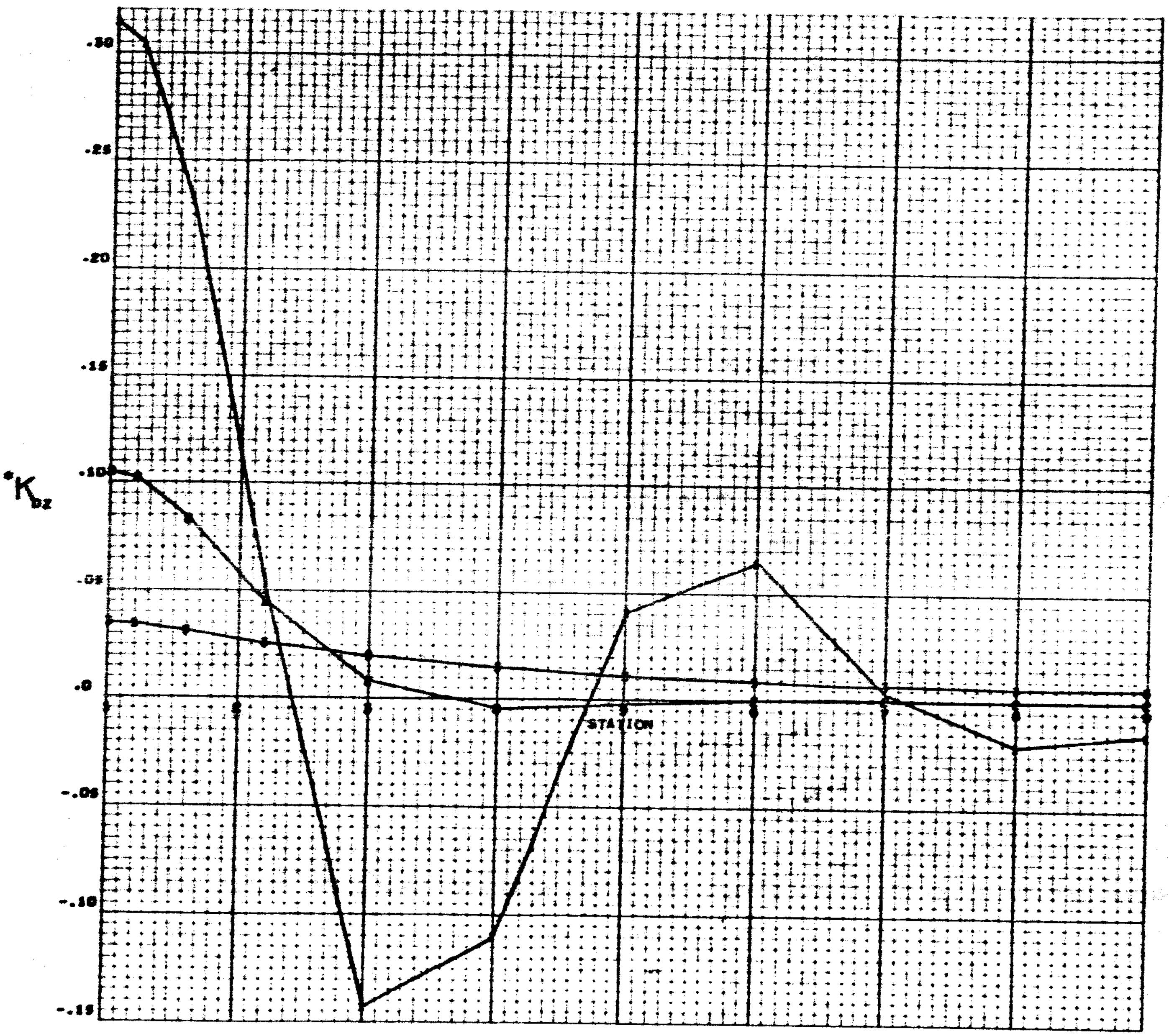


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

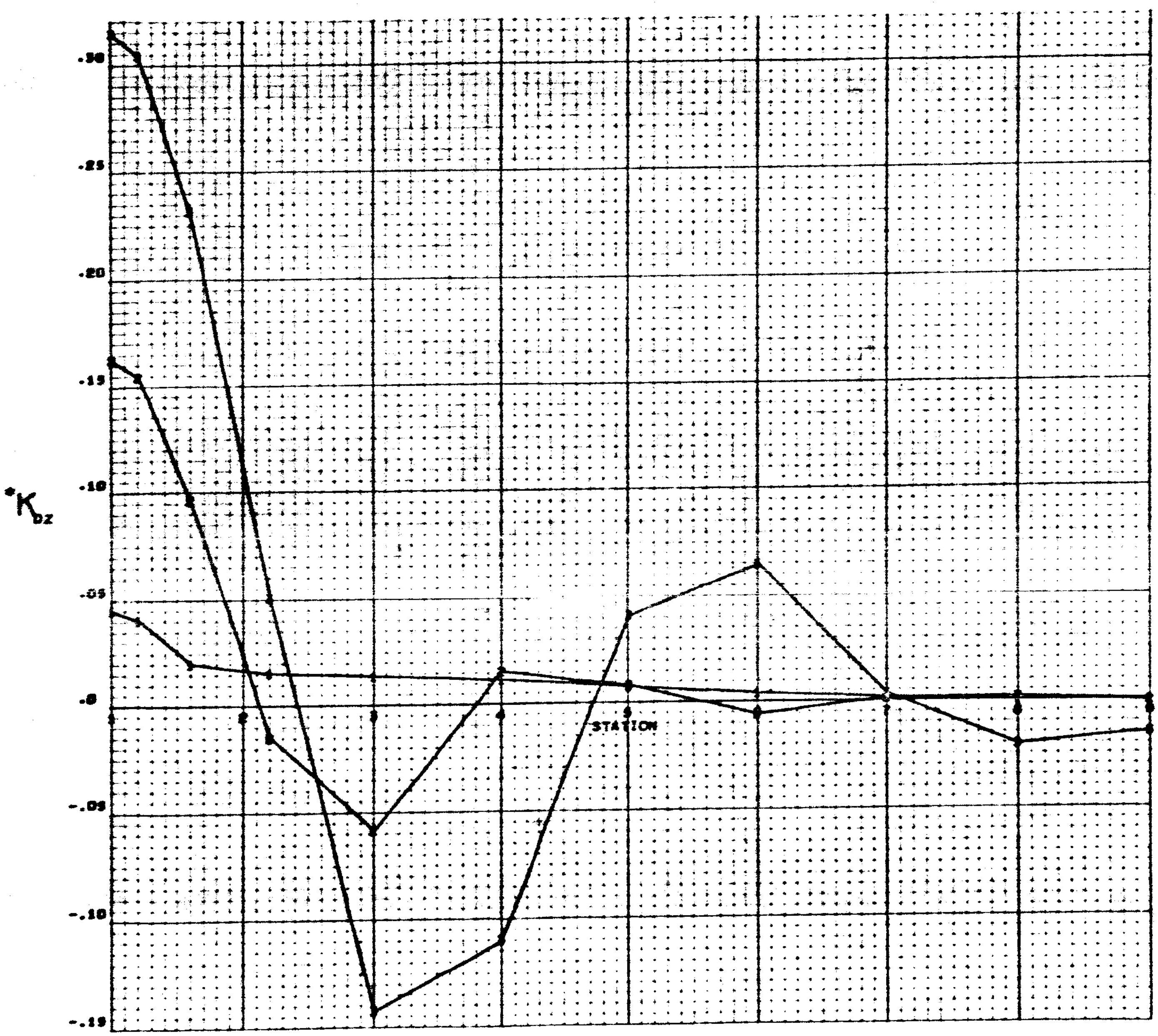
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_z NORMAL DEFLECTION AT ELASTIC CENTER
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . NORMAL DEFLECTION, D_z = $K_{Dz}(R^2/EI)$

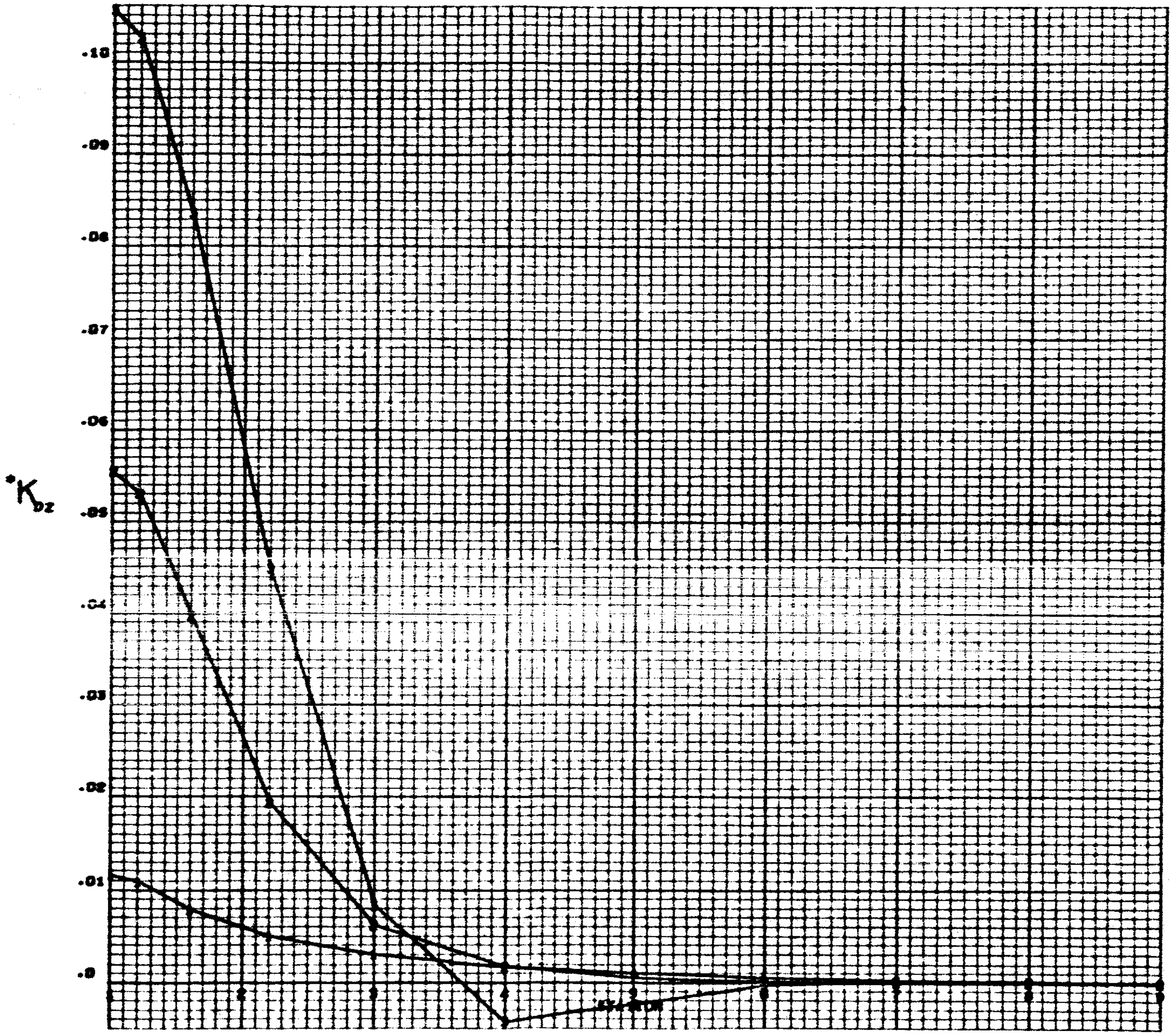
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D_Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, D_Z = $K_{DZ}(R^2/EI)$

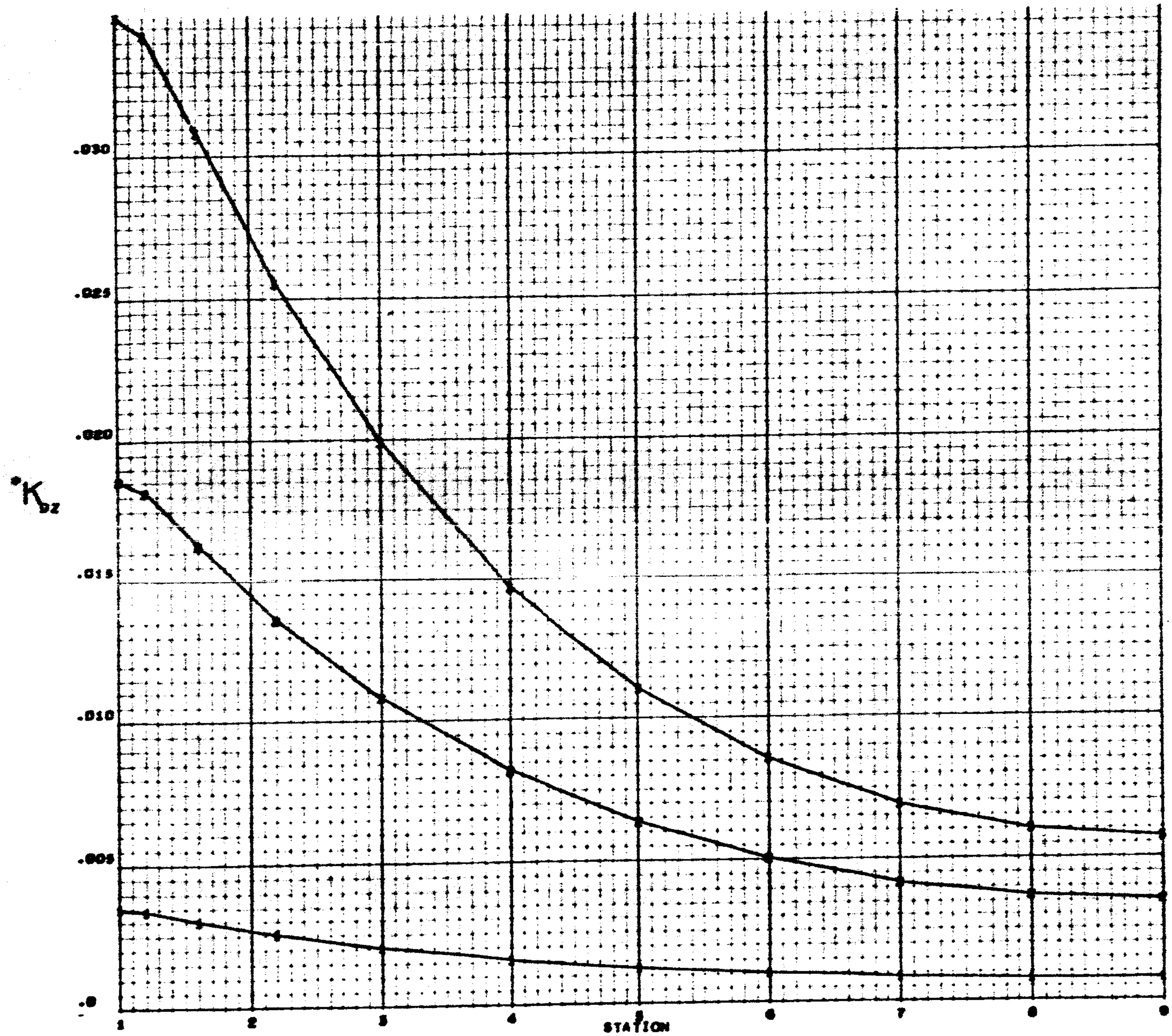
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

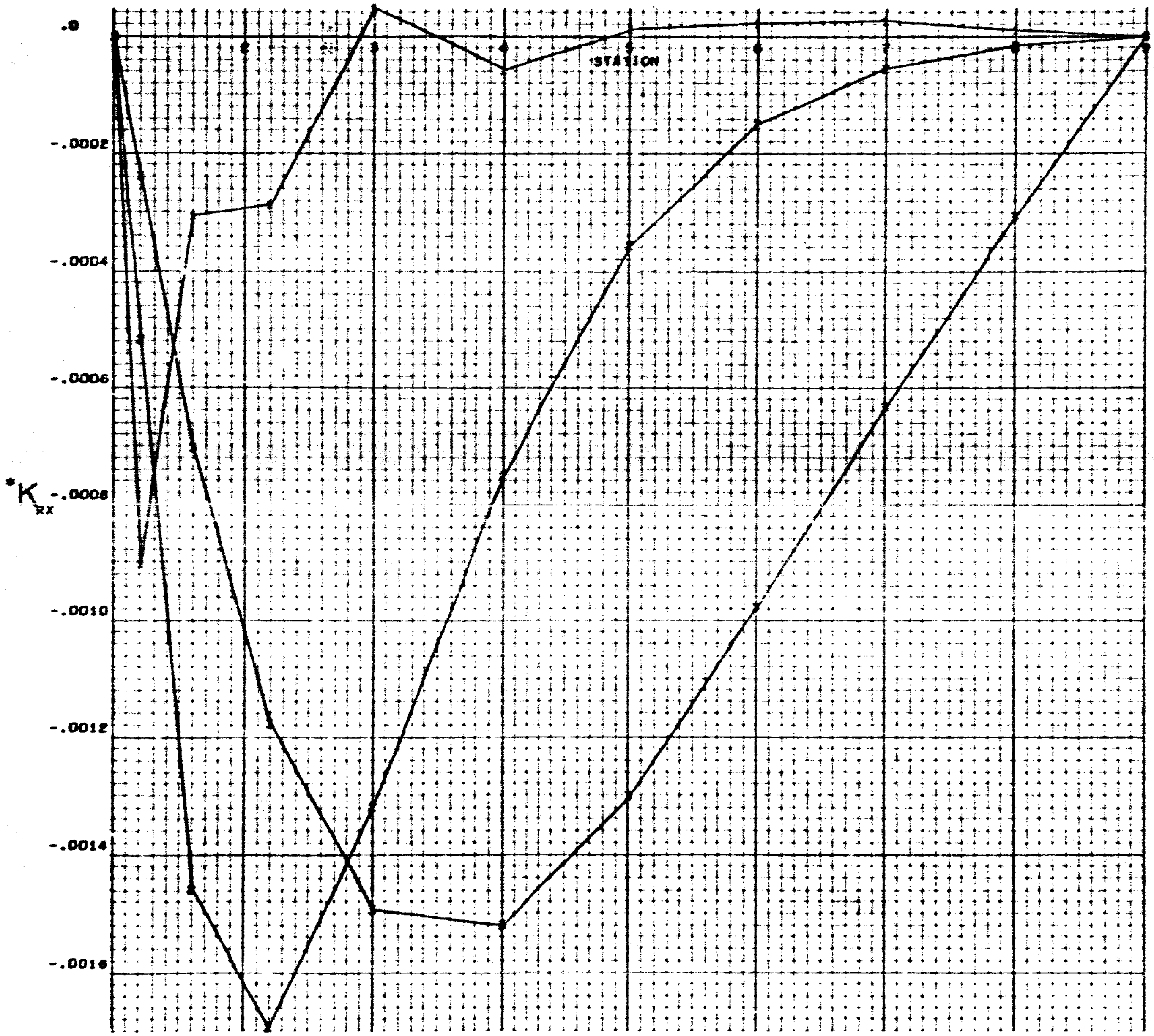
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
D Z NORMAL DEFLECTION AT ELASTIC CENTER
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . NORMAL DEFLECTION, $D_Z = K_{DZ}(R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_x, ROTATION ABOUT THE X AXIS
C/R = -0.01, GJ/EI VARIABLE

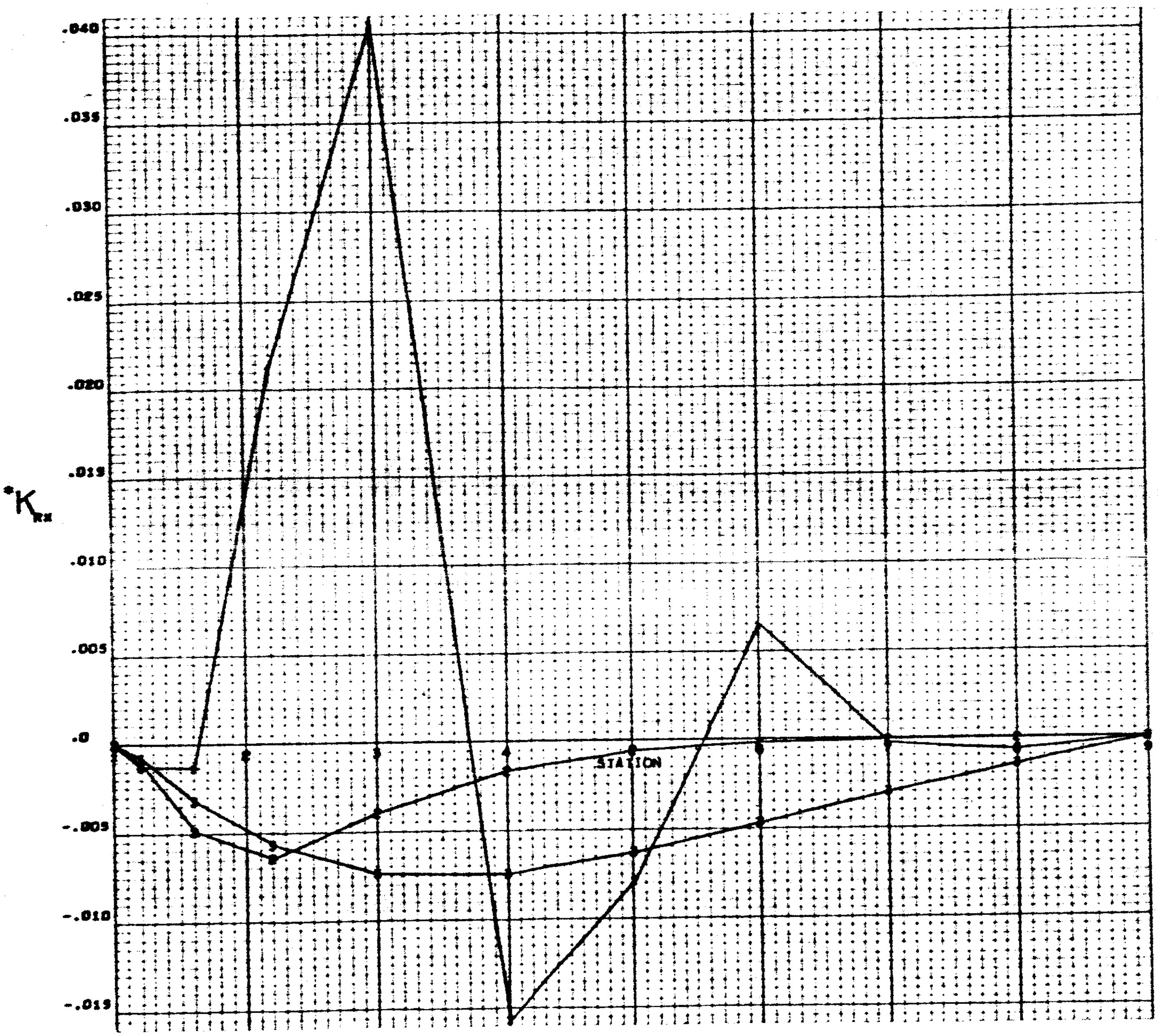


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_x = K_{RX}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.05, GJ/EI VARIABLE

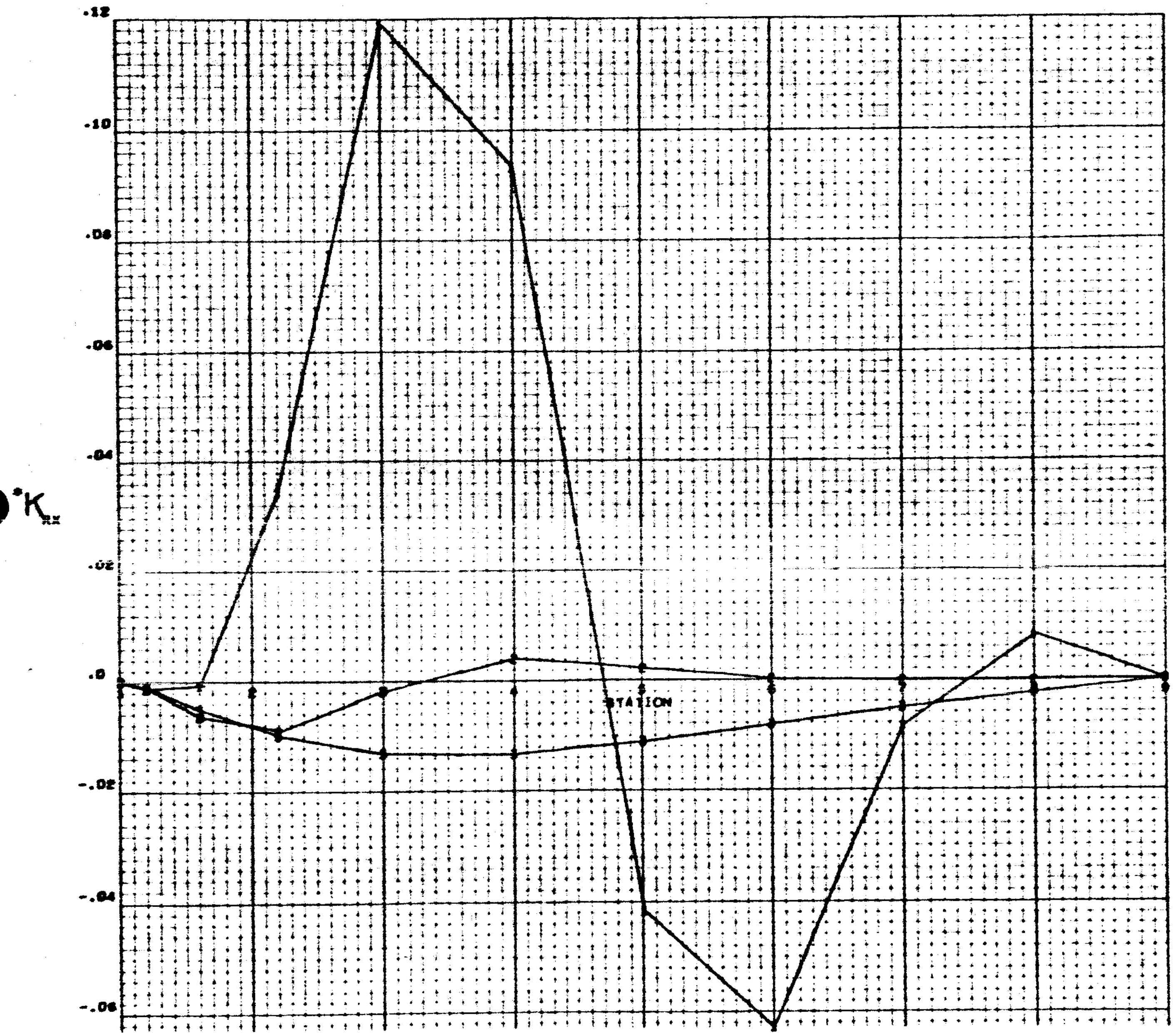


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.09, GJ/EI VARIABLE

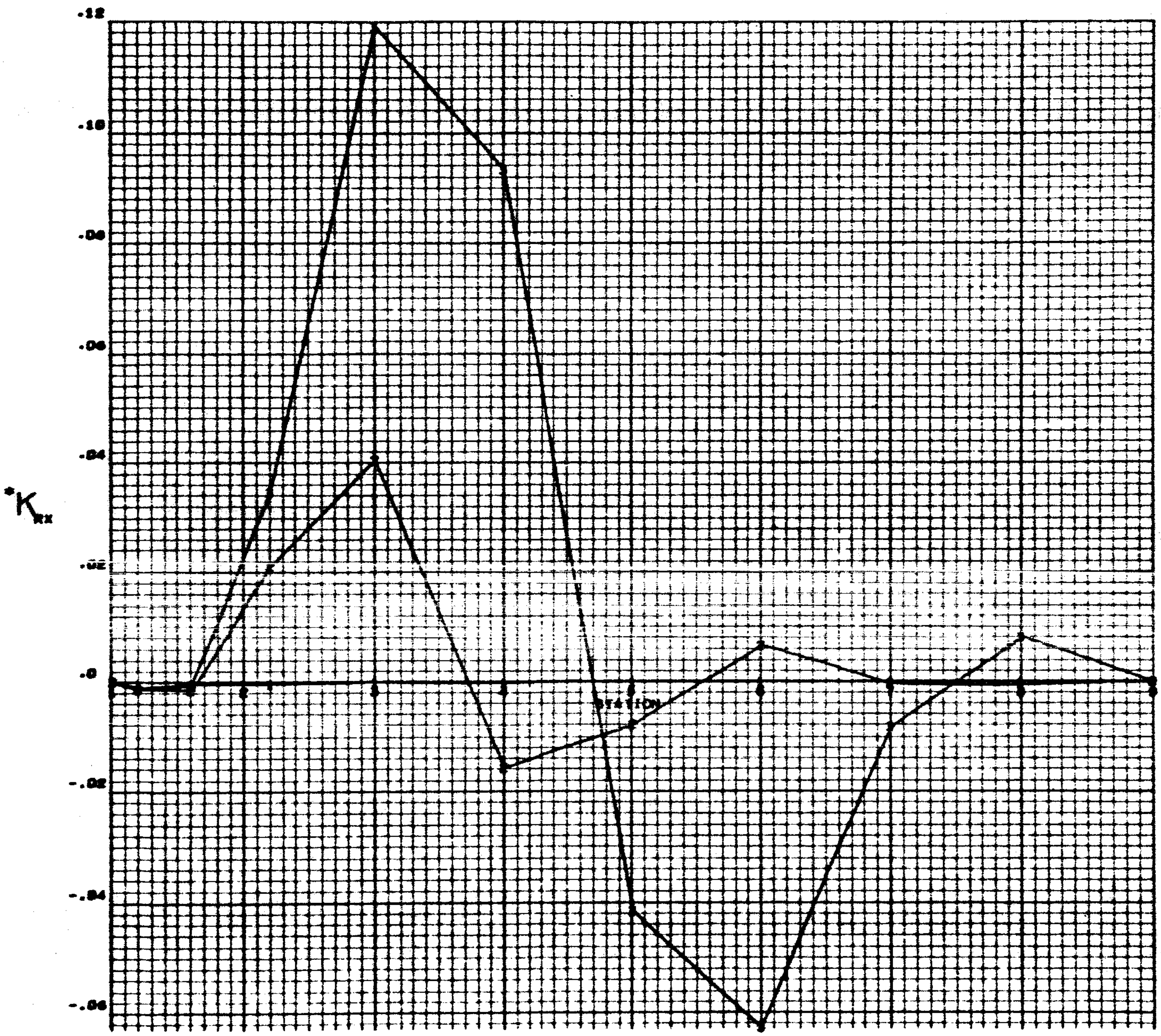


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

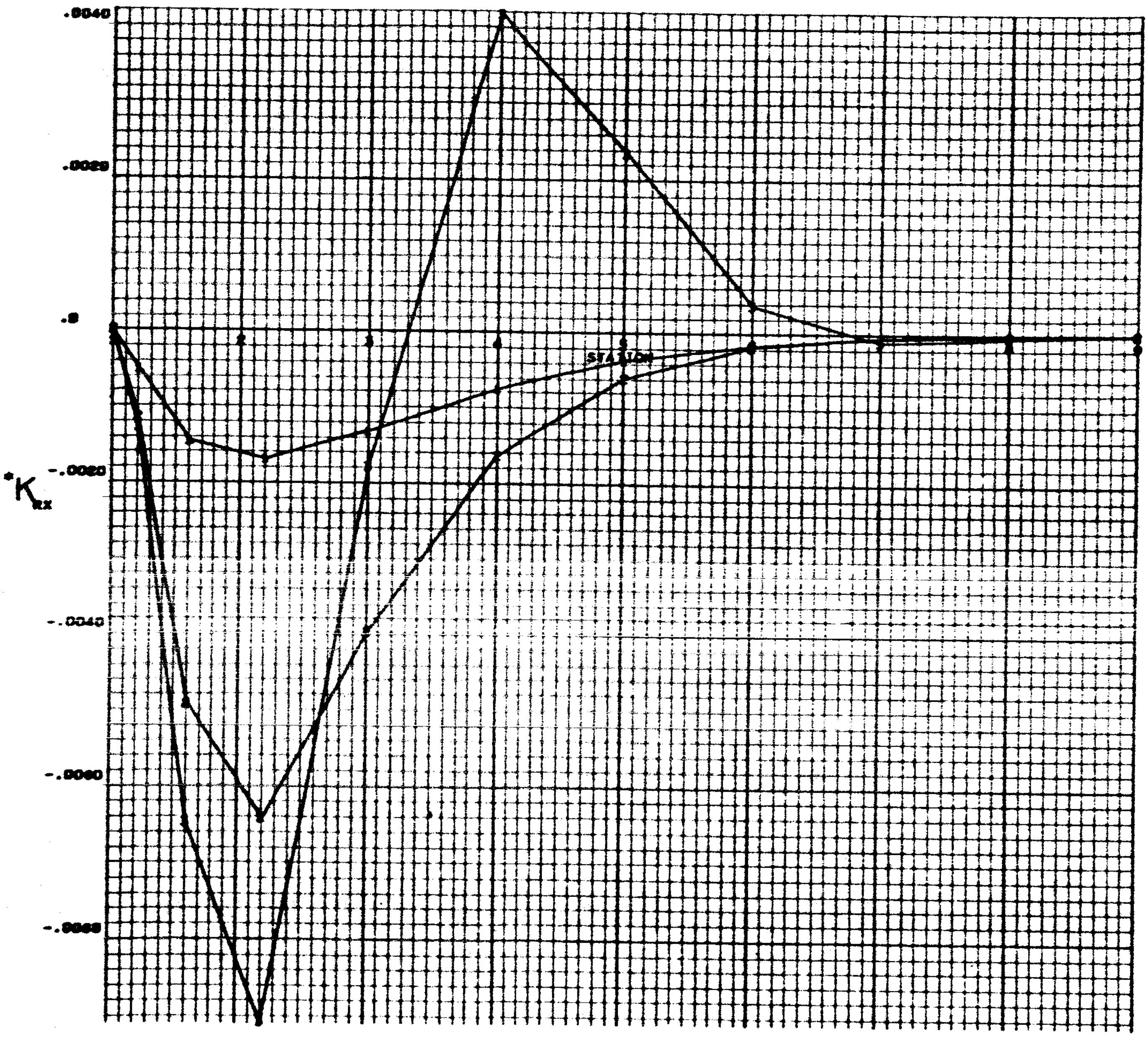
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

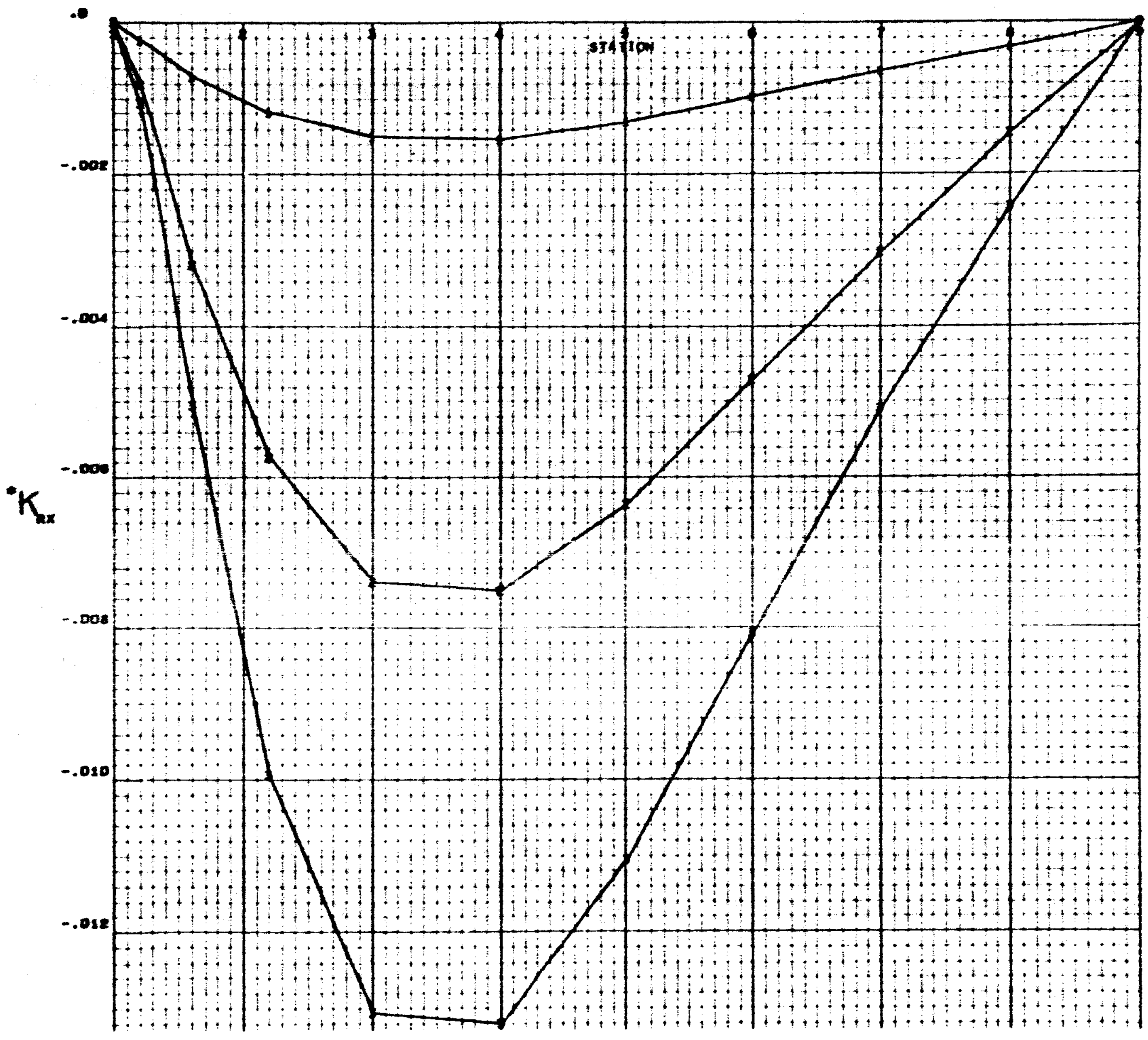
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

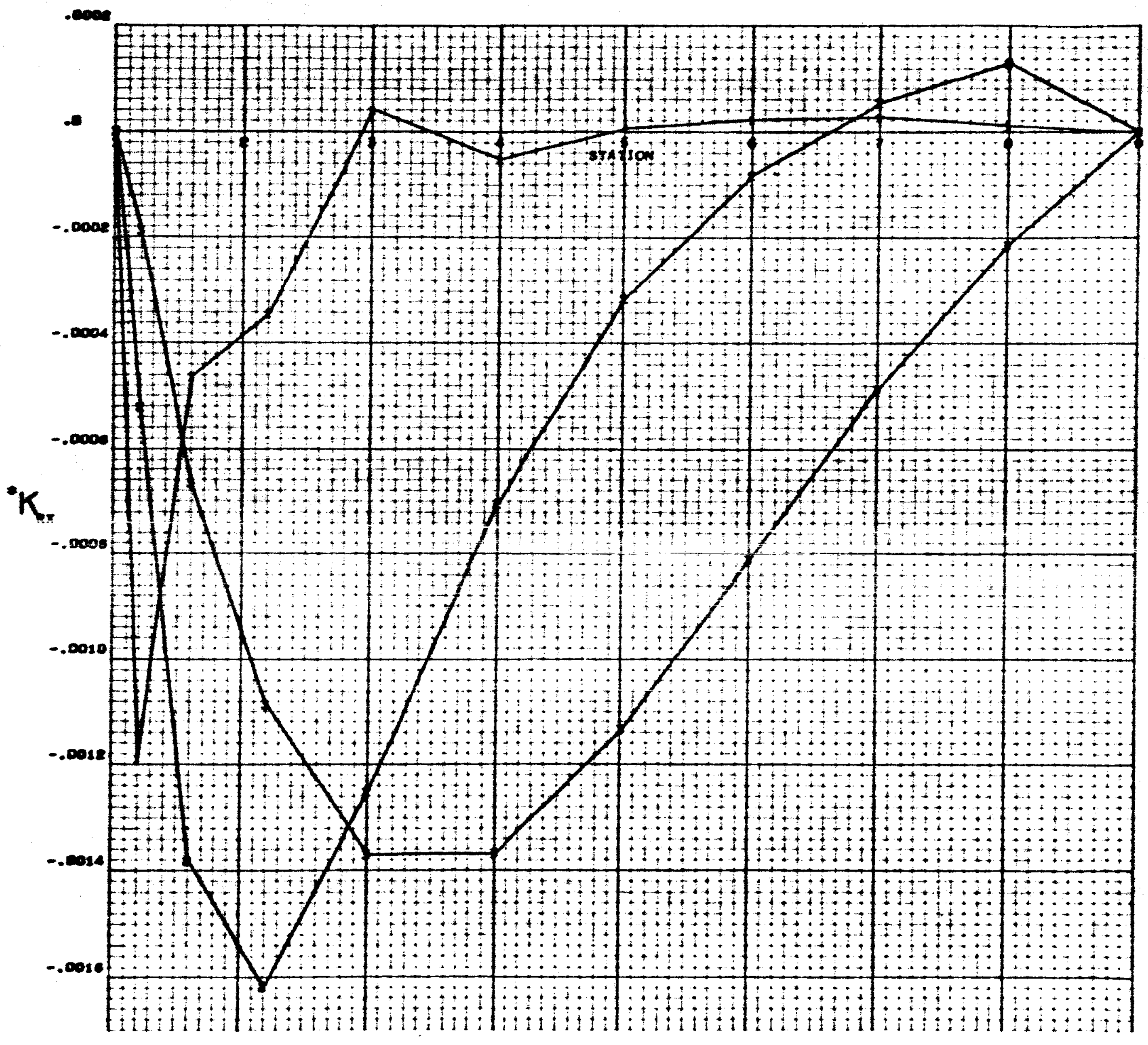
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS. $R_X = K_{RX}(R^2/EI)$

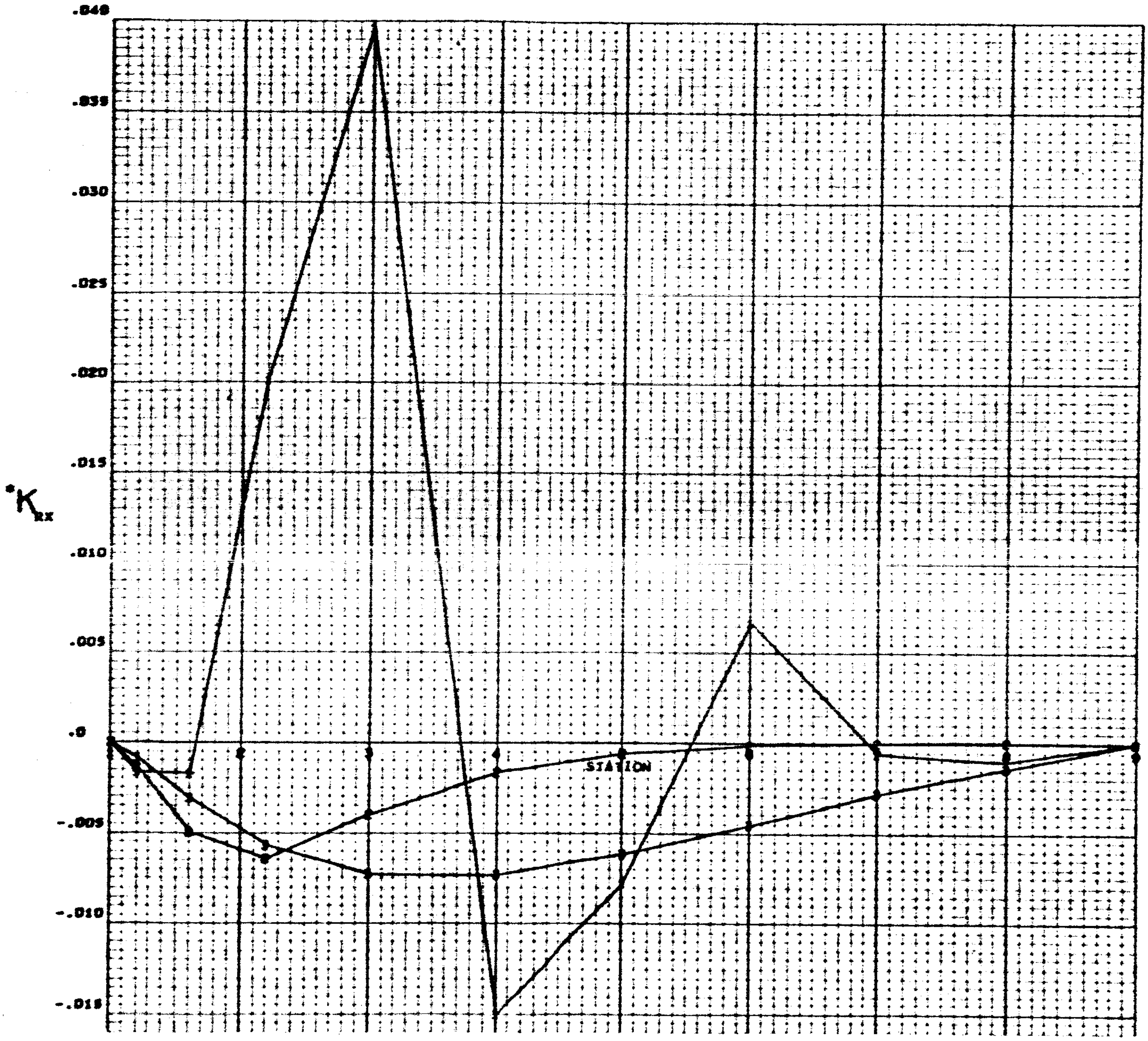
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_x, ROTATION ABOUT THE X AXIS
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_x = K_{RX}(R^2/EI)$

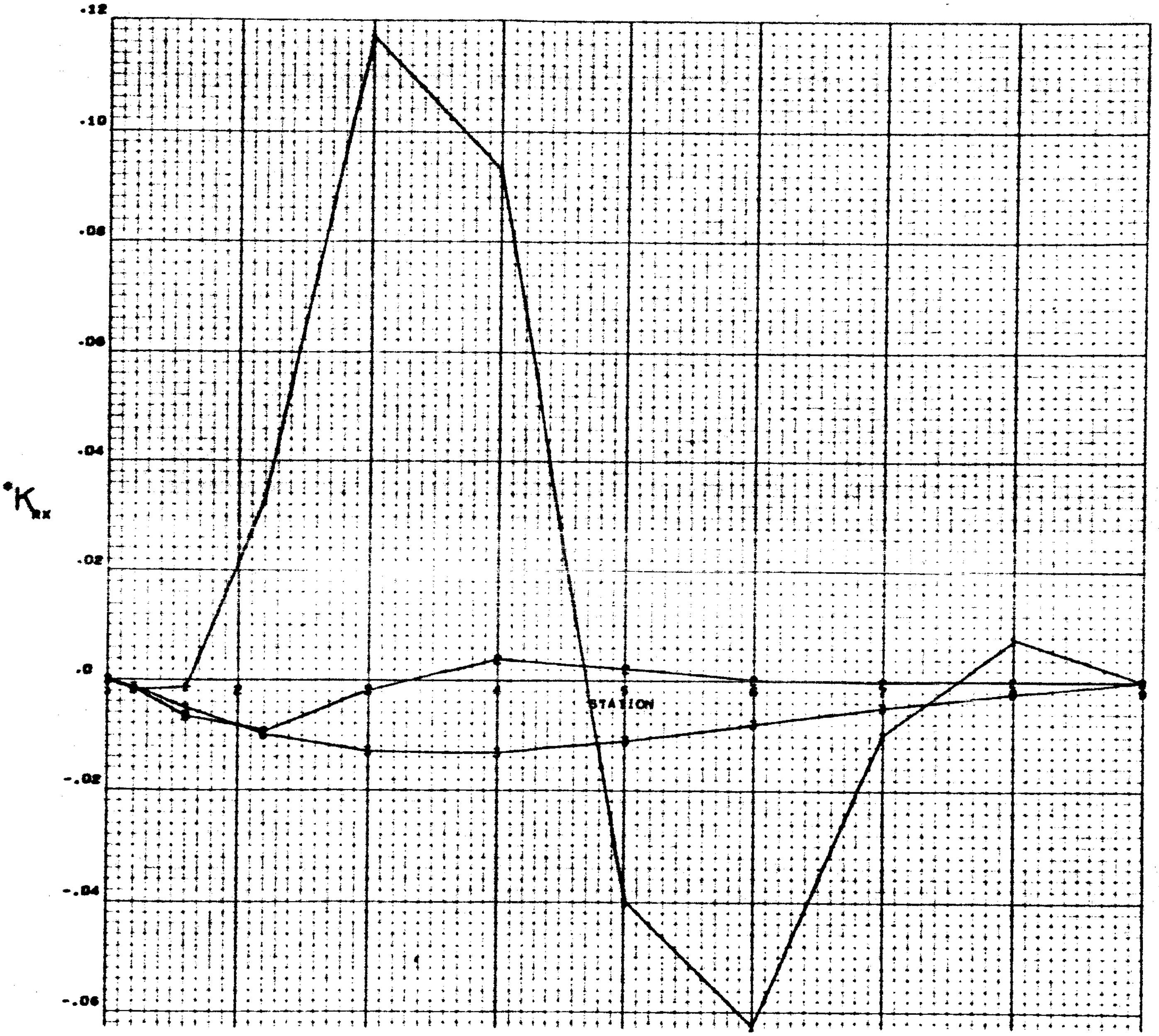
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

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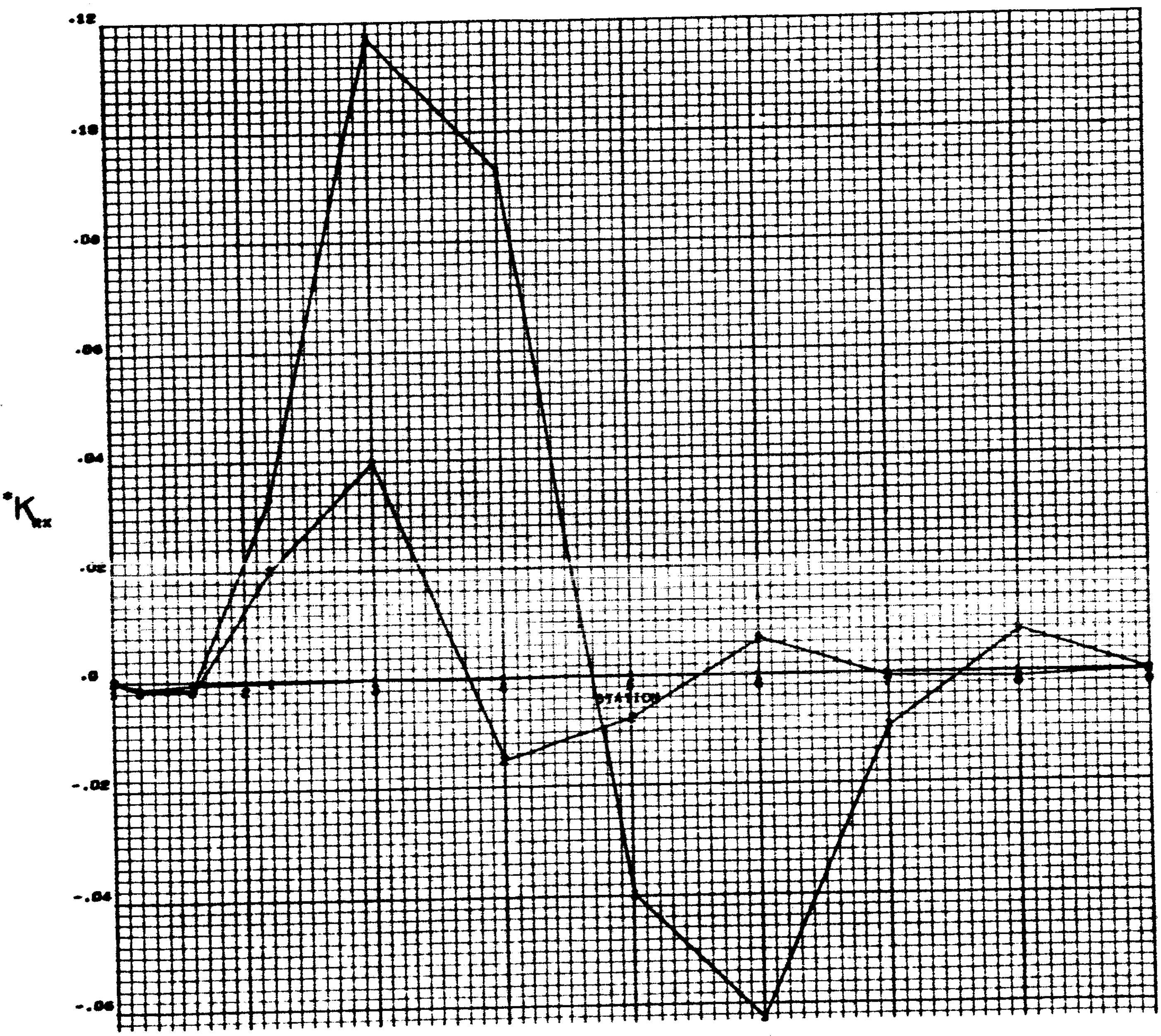
UNIT FORCE DISTRIBUTED OVER ELEMENT (ELASTIC CENTER

R_X, ROTATION ABOUT THE X AXIS

GJ/EI = 0.02, C/R VARIABLE

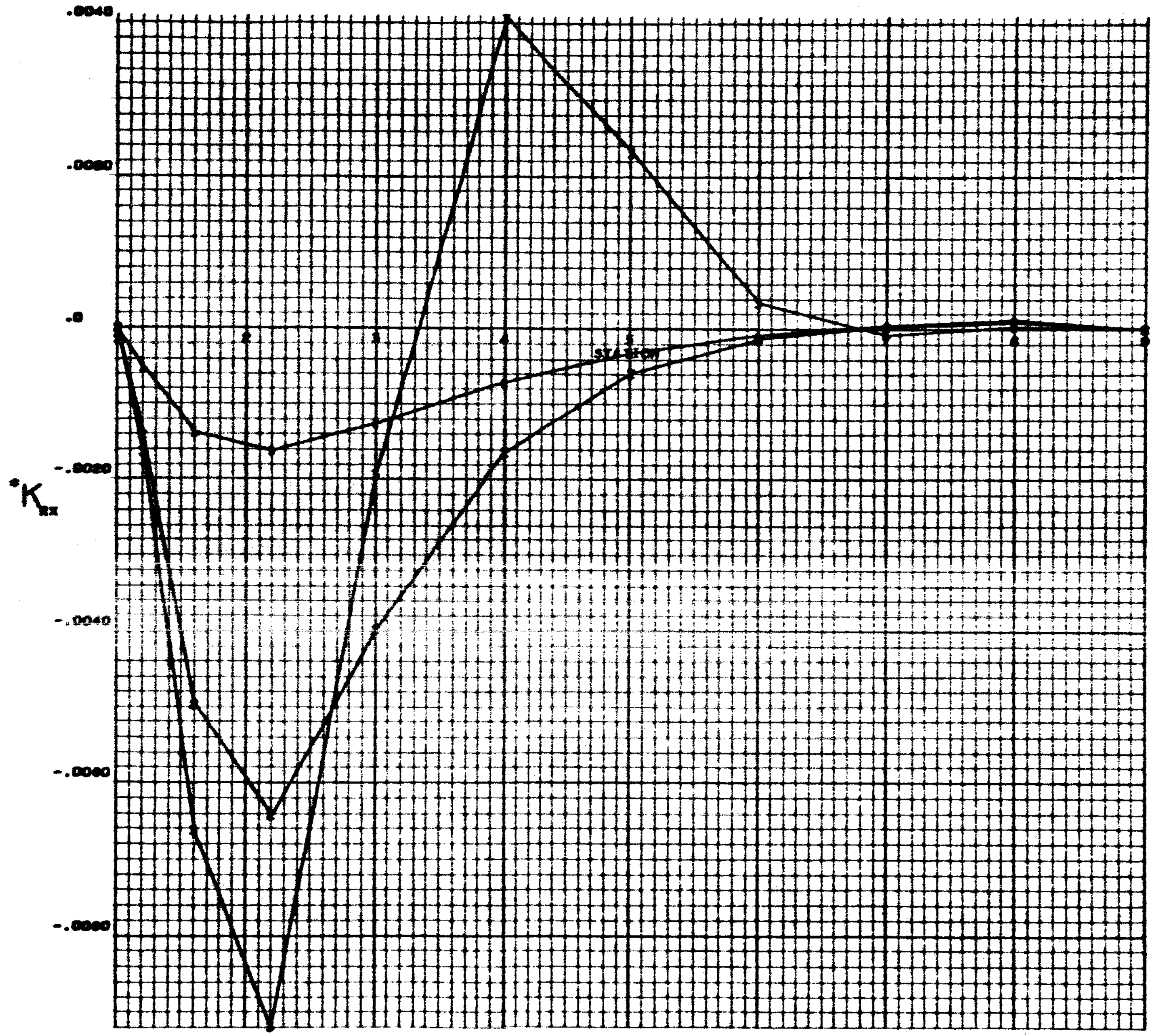


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

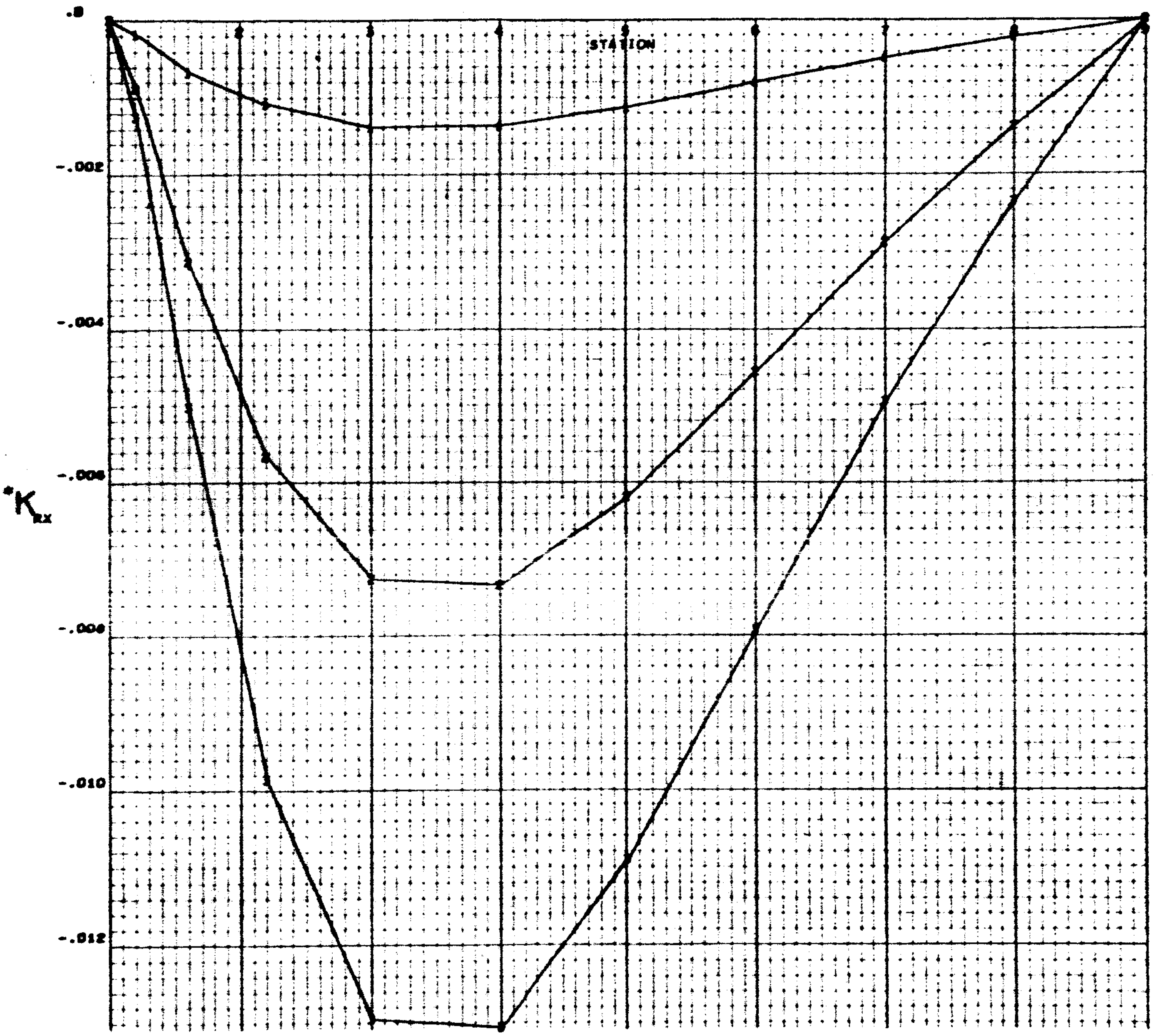
UNIT FORCE DISTRIBUTED OVER ELEMENT / ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

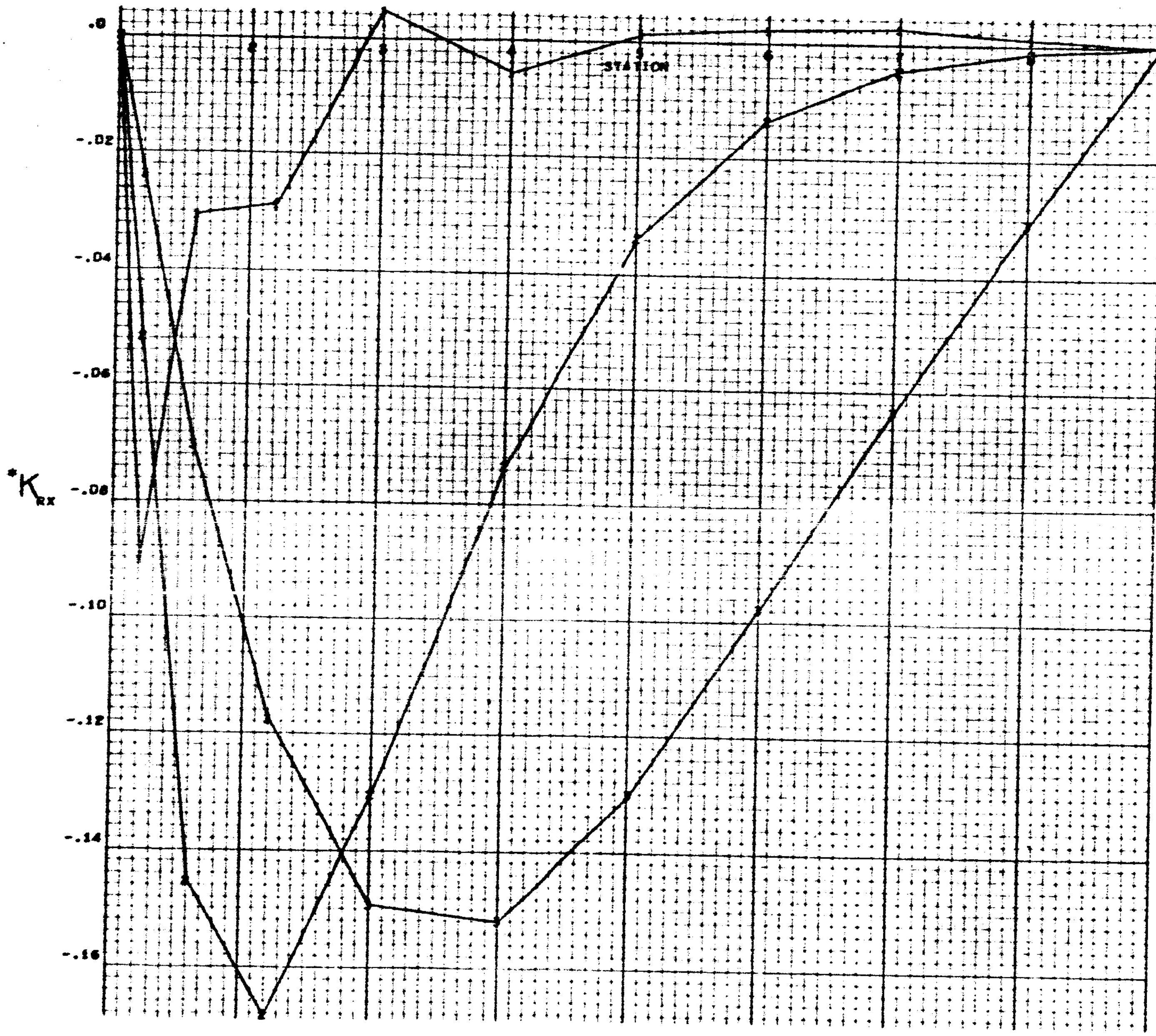
UNIT FORCE DISTRIBUTED OVER ELEMENT ! ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R^2/EI)$

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.01, GJ/EI VARIABLE

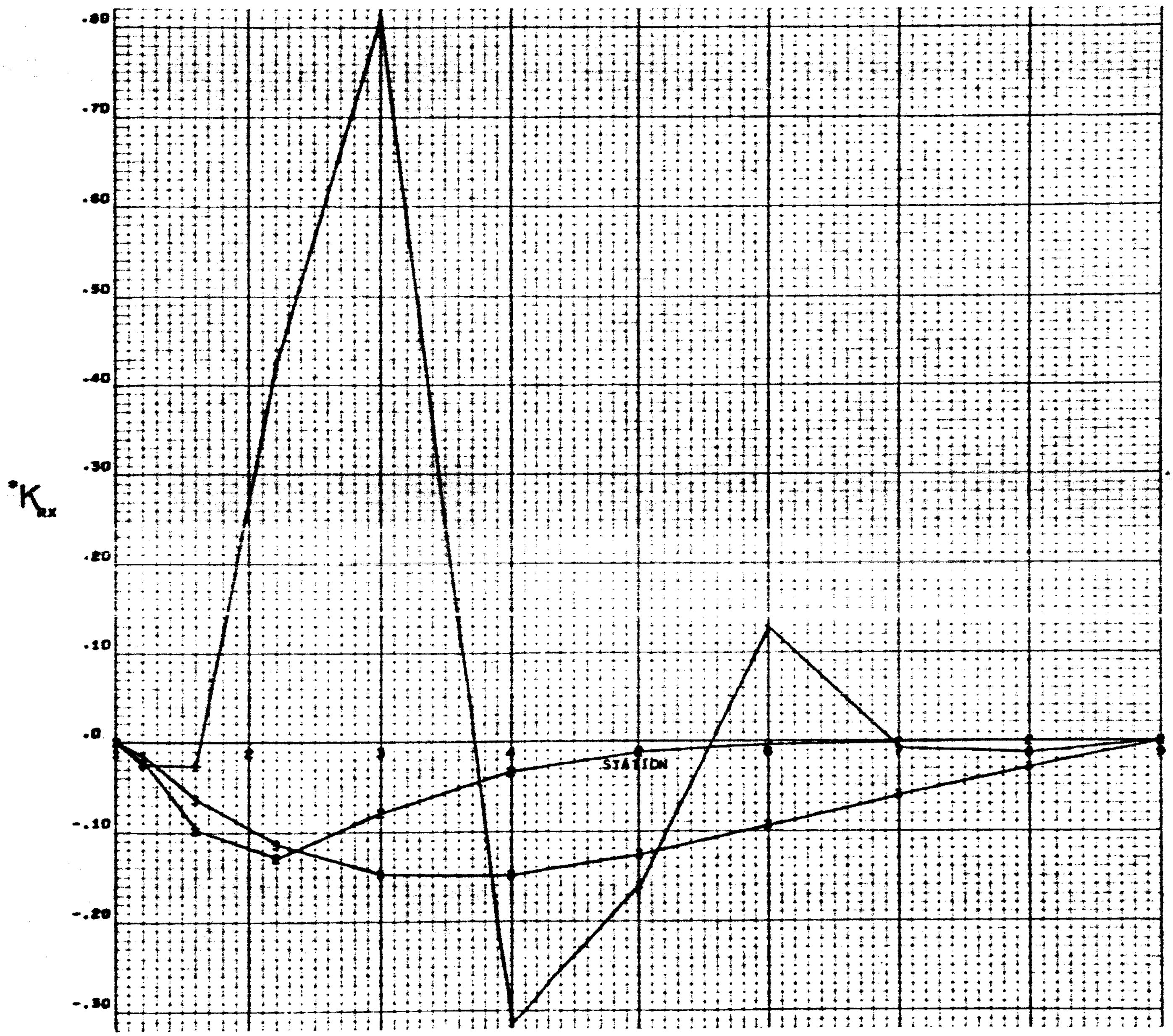


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

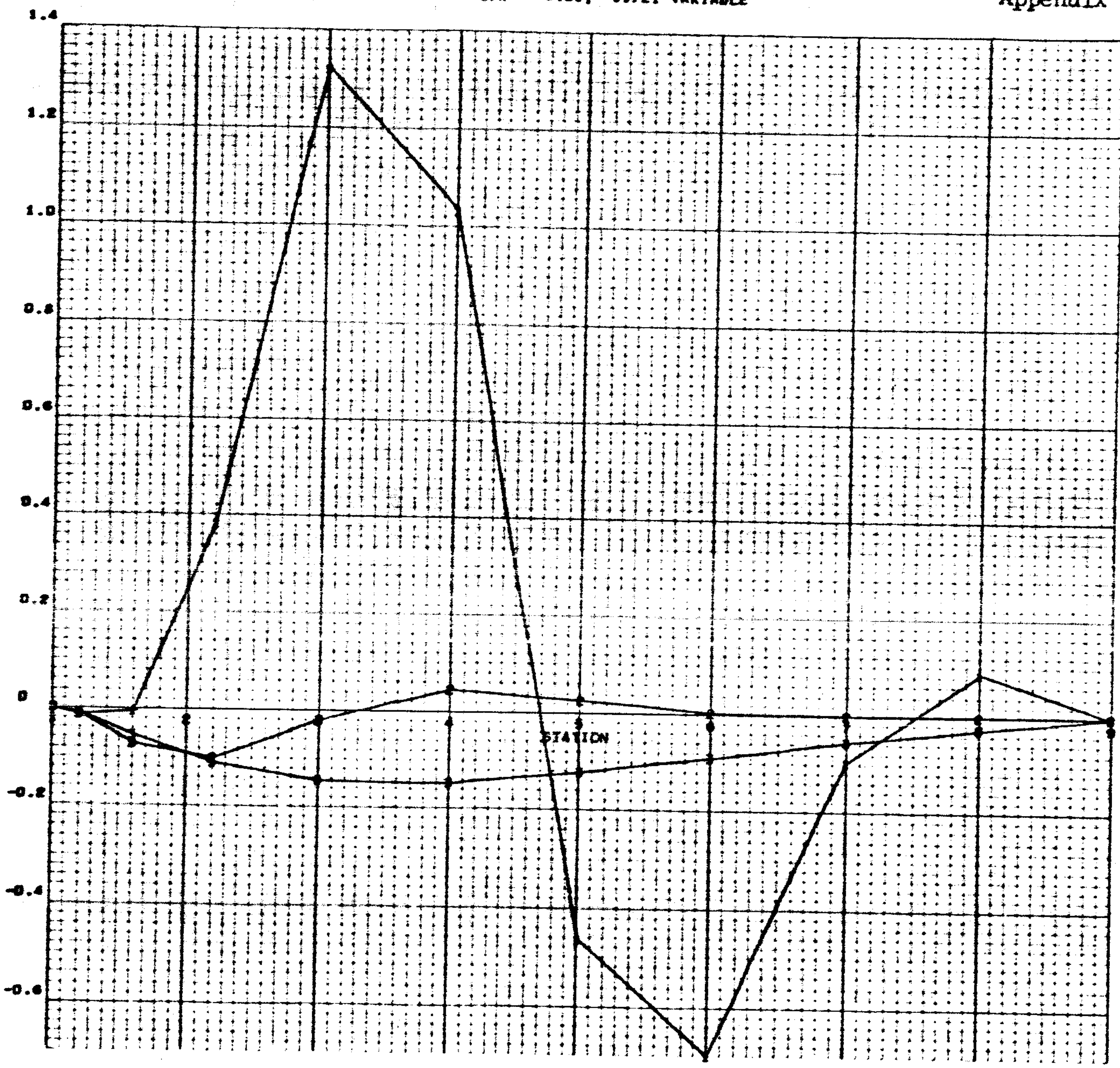
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

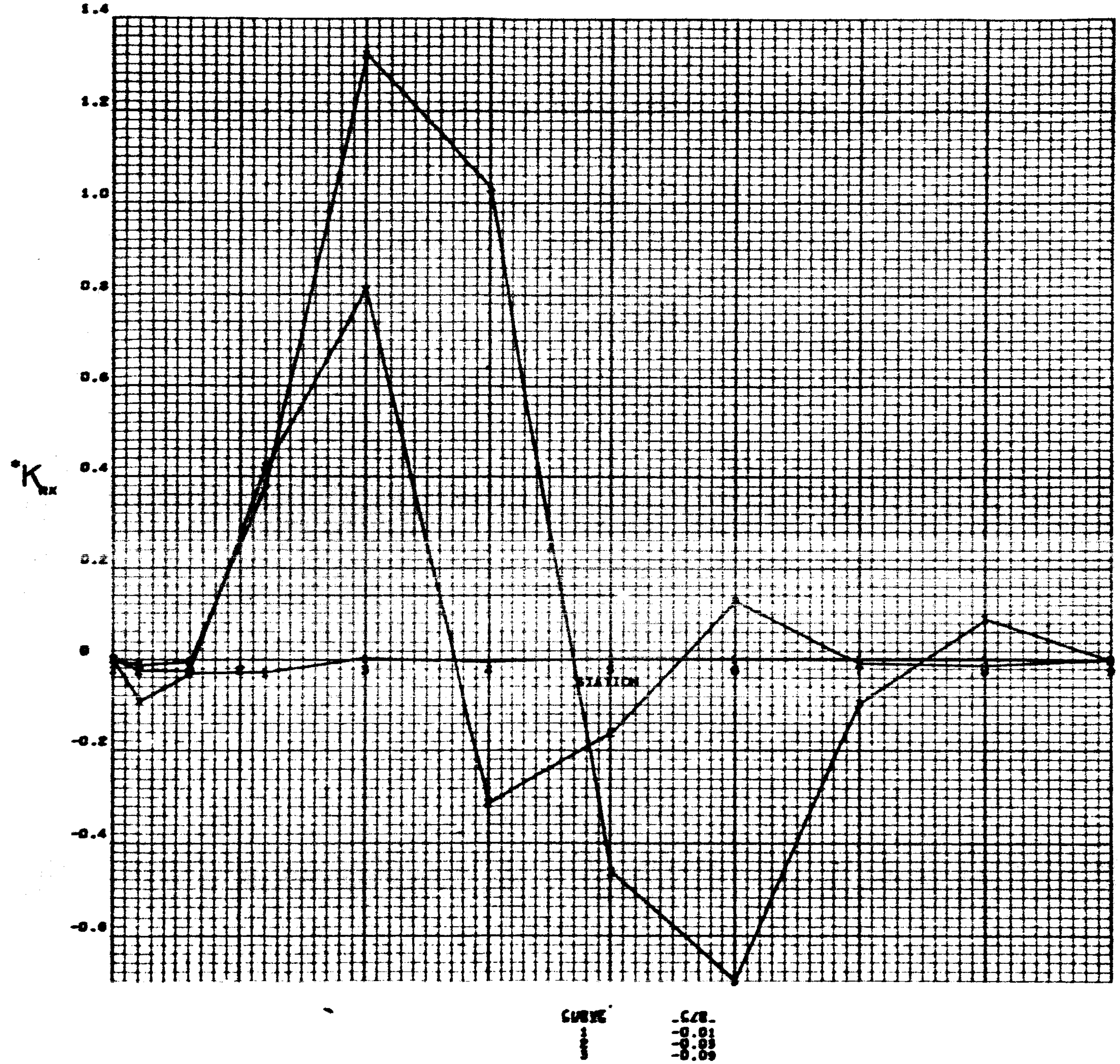
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R \;\; /EI)$

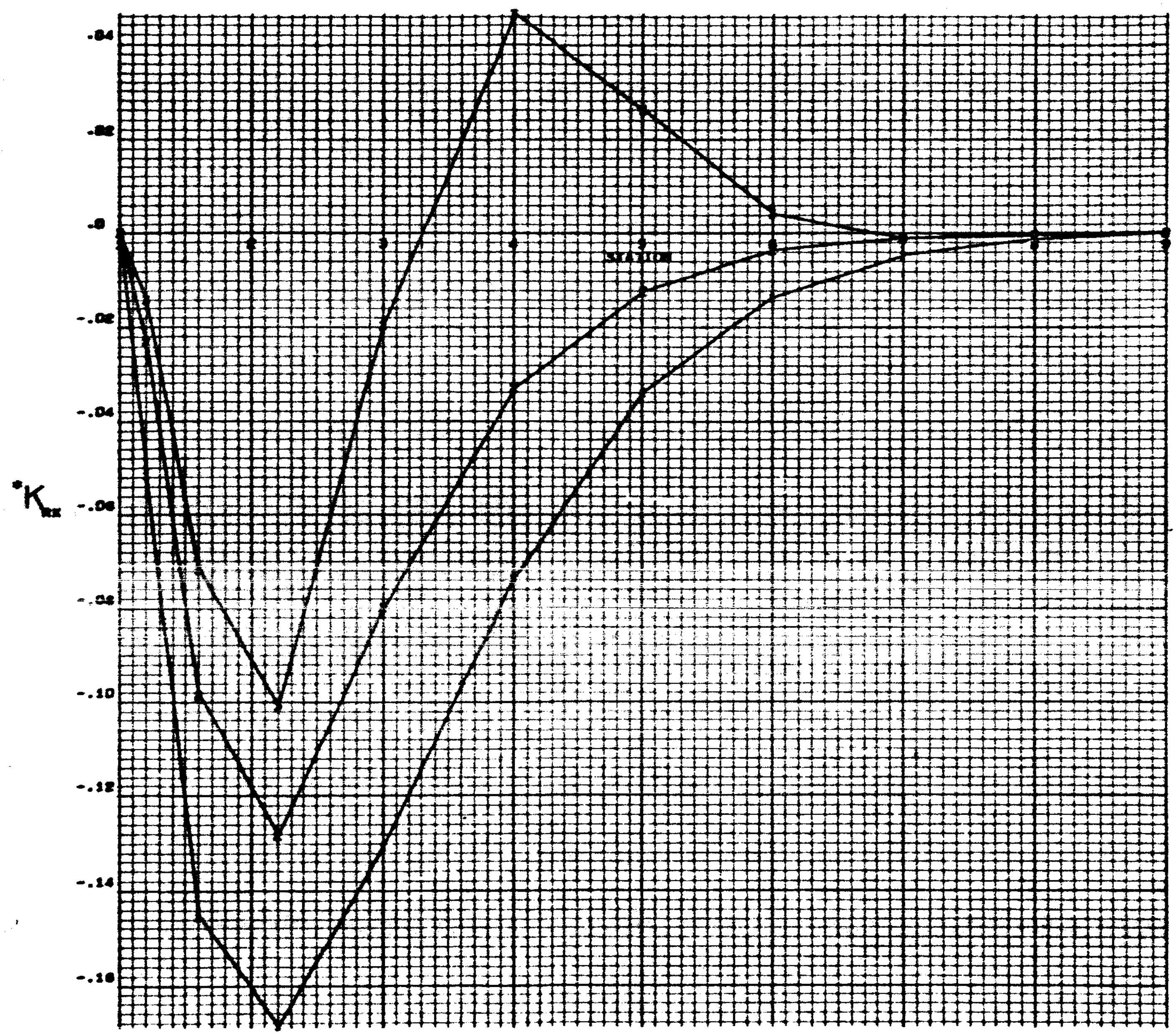
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.03
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}$(R /EI)

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE

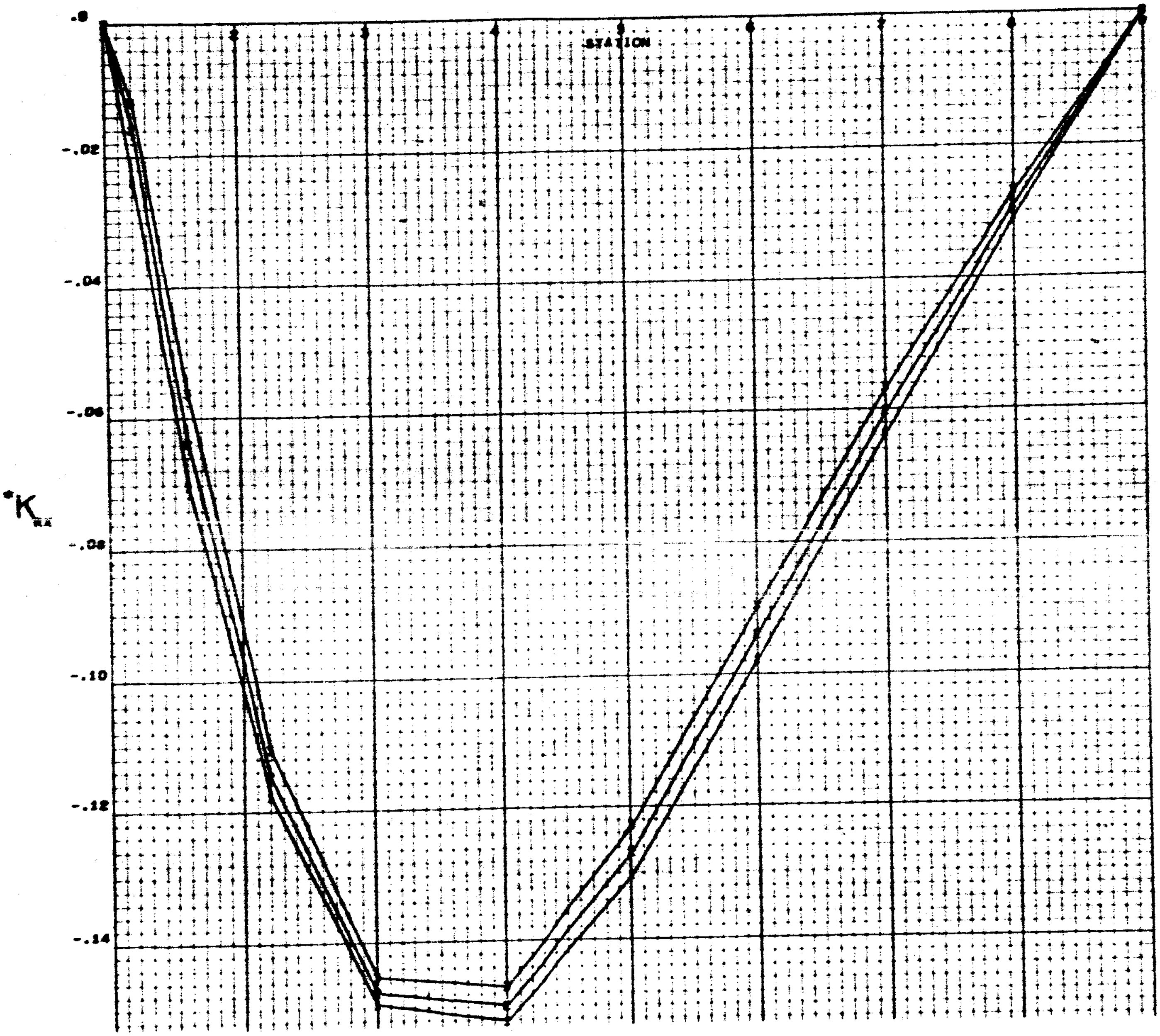


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

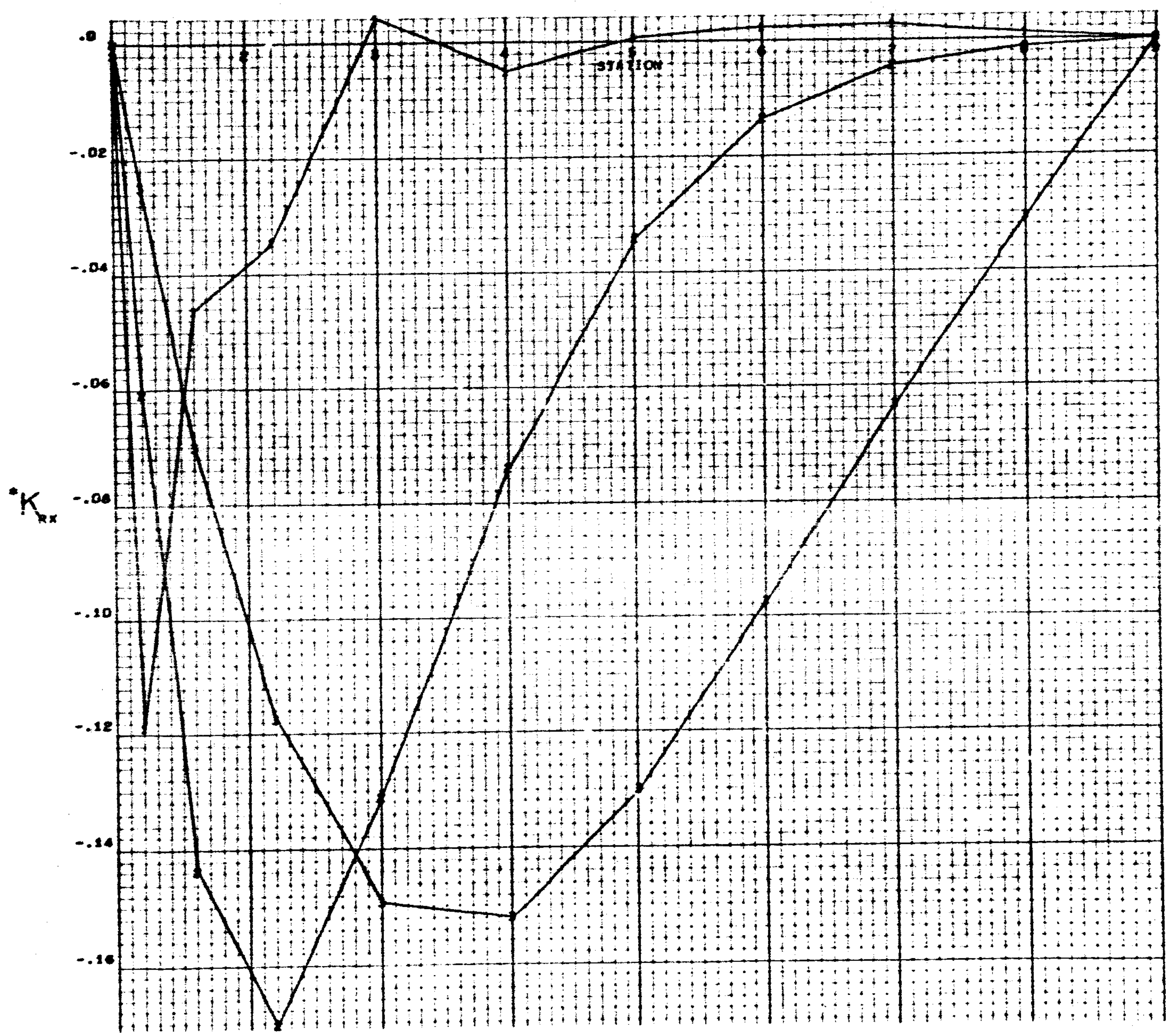
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}$(R /EI)

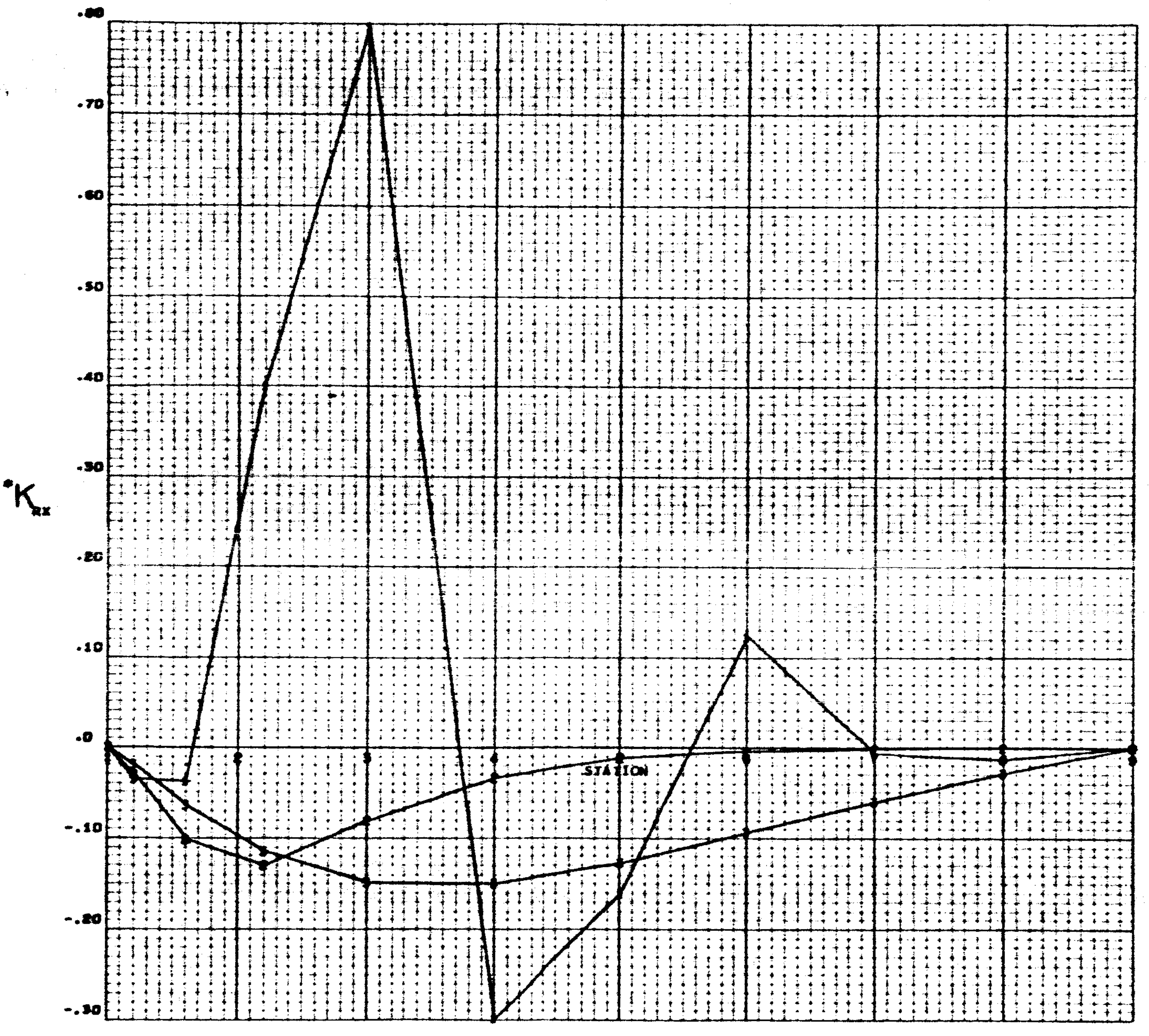
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_x, ROTATION ABOUT THE X AXIS
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_x = K_{RX}(R \quad /EI)$

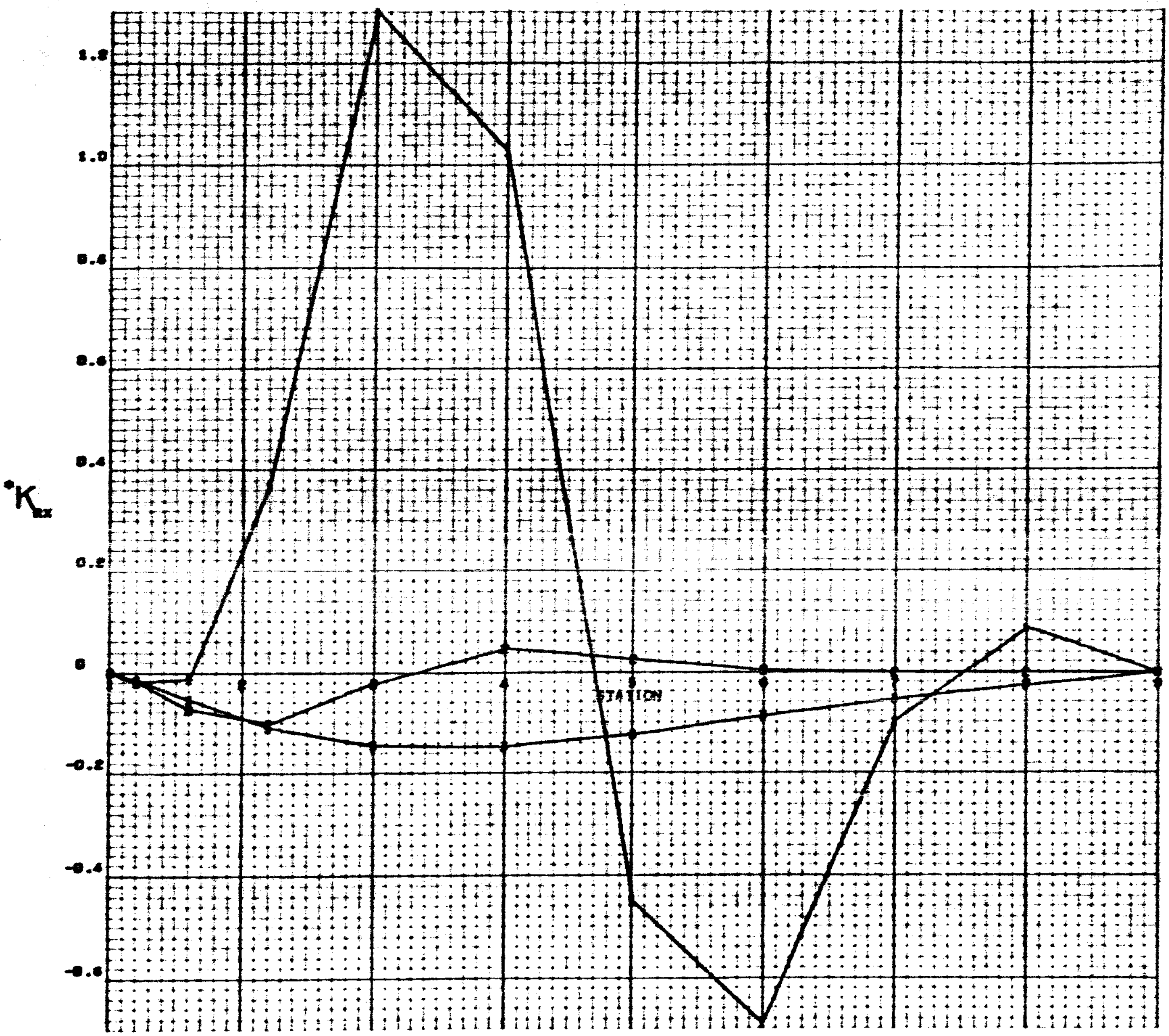
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R \quad /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
C/R = -0.99, GJ/EI VARIABLE

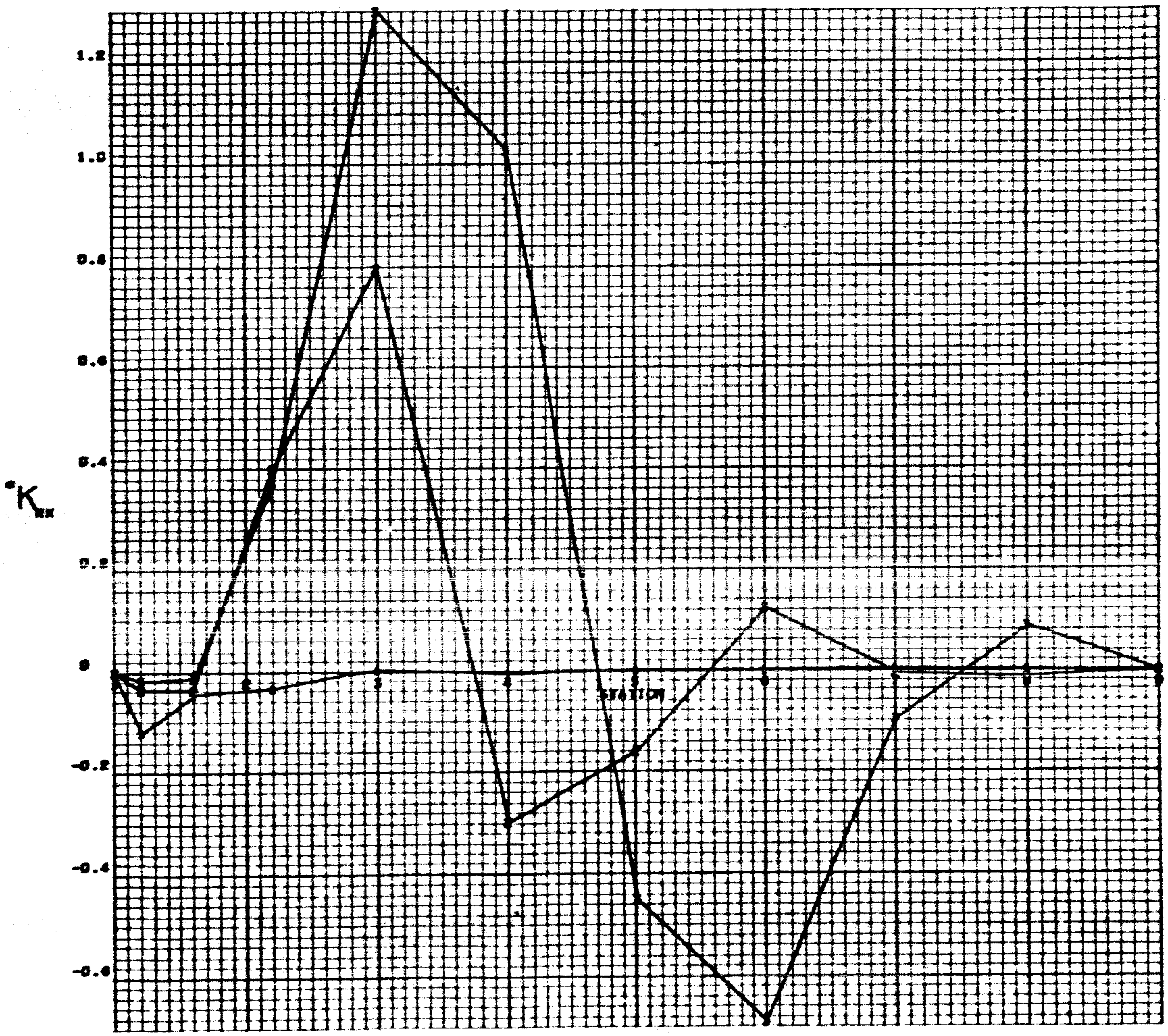


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R \quad /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

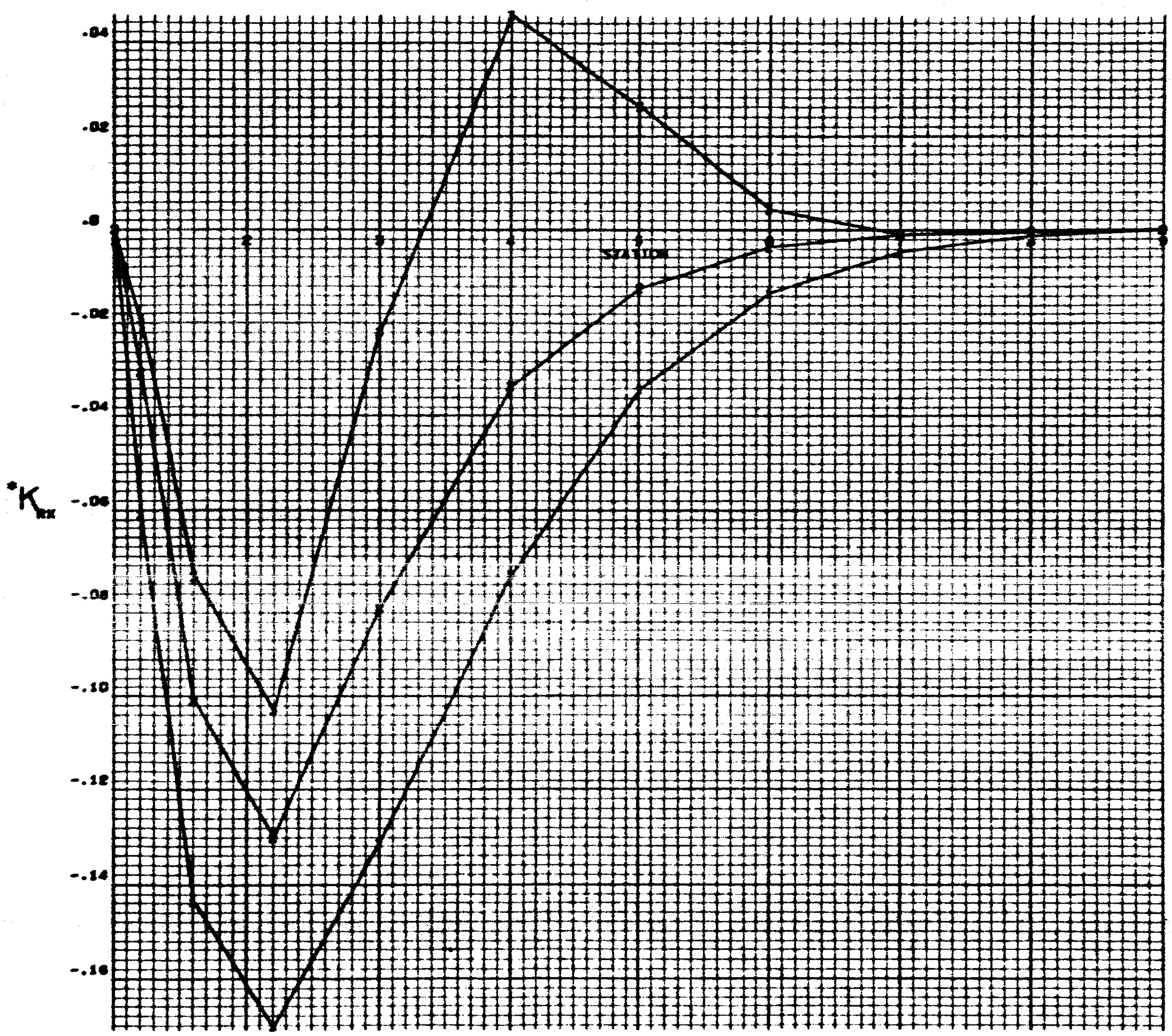
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT :
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R \ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 0.20, C/R VARIABLE

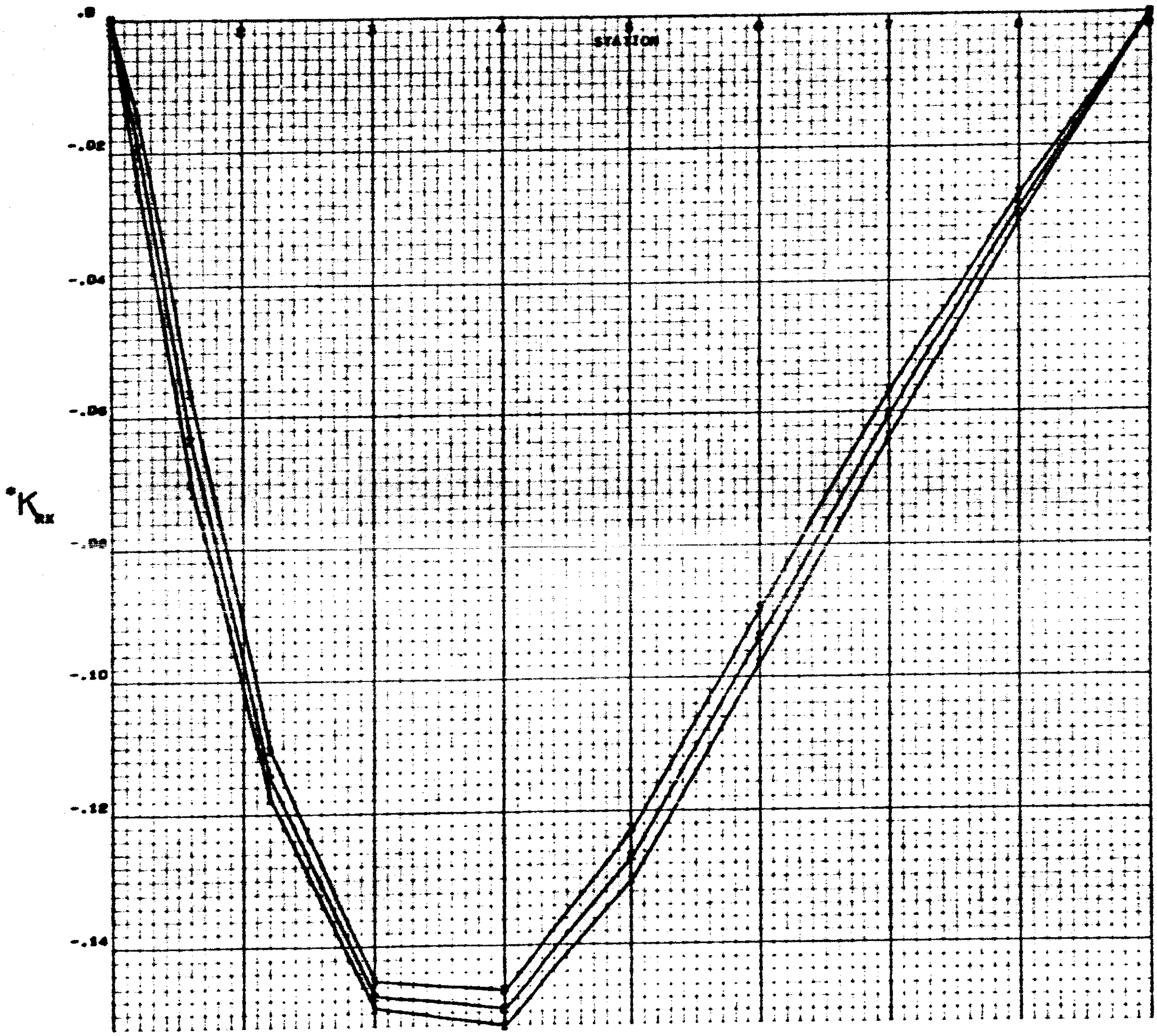


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_X, ROTATION ABOUT THE X AXIS
GJ/EI = 2.00, C/R VARIABLE

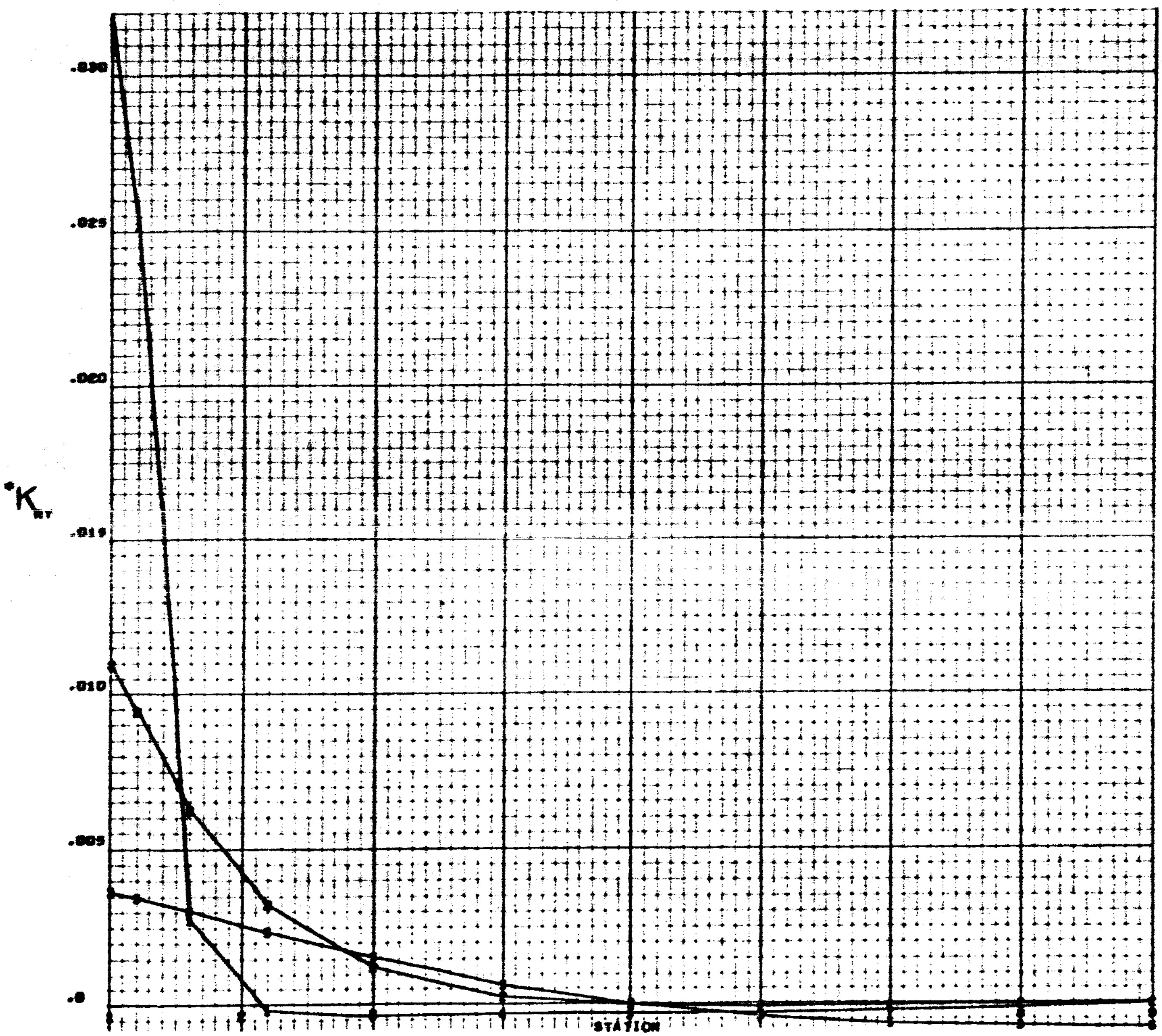


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE X AXIS, $R_X = K_{RX}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

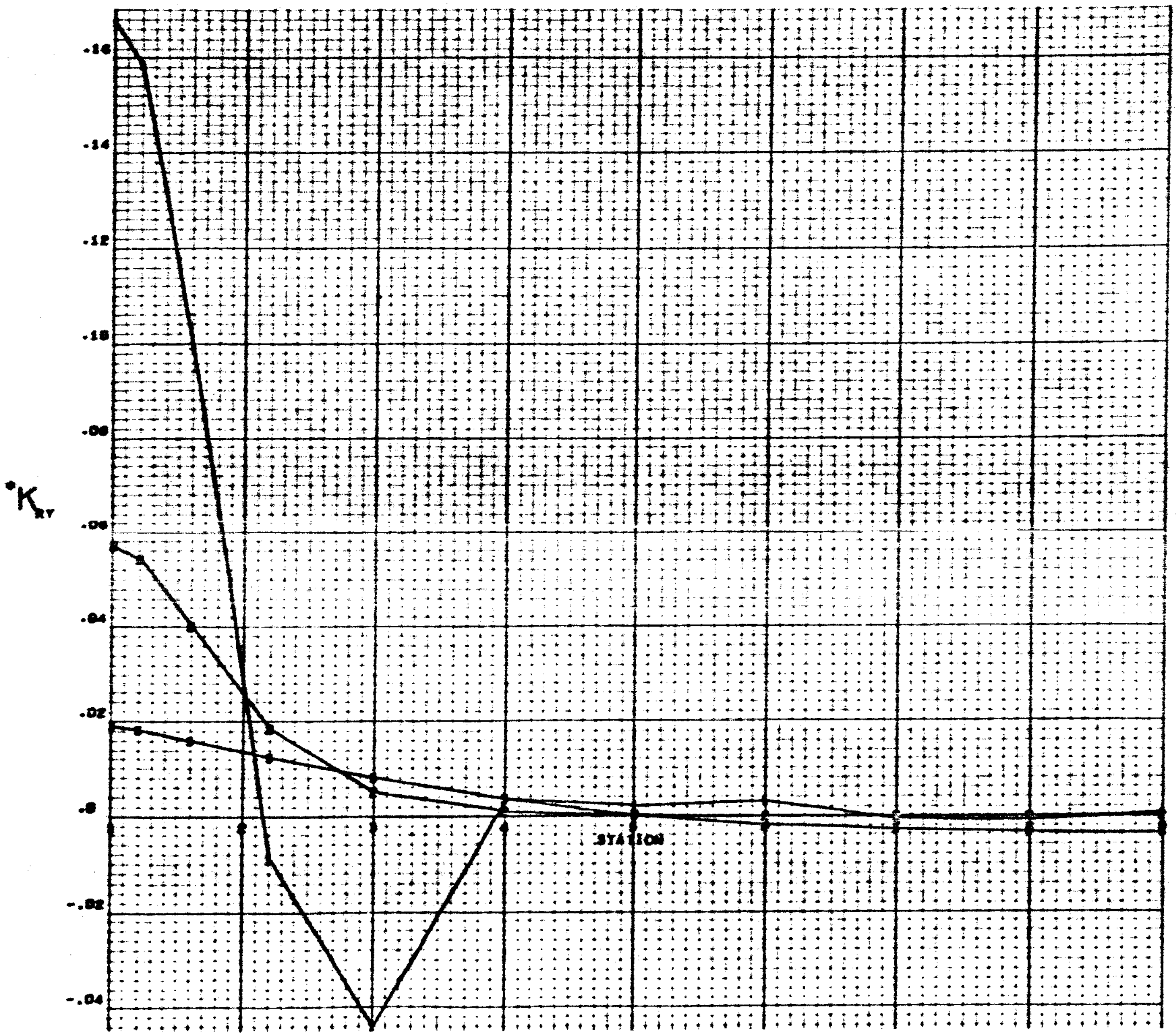
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

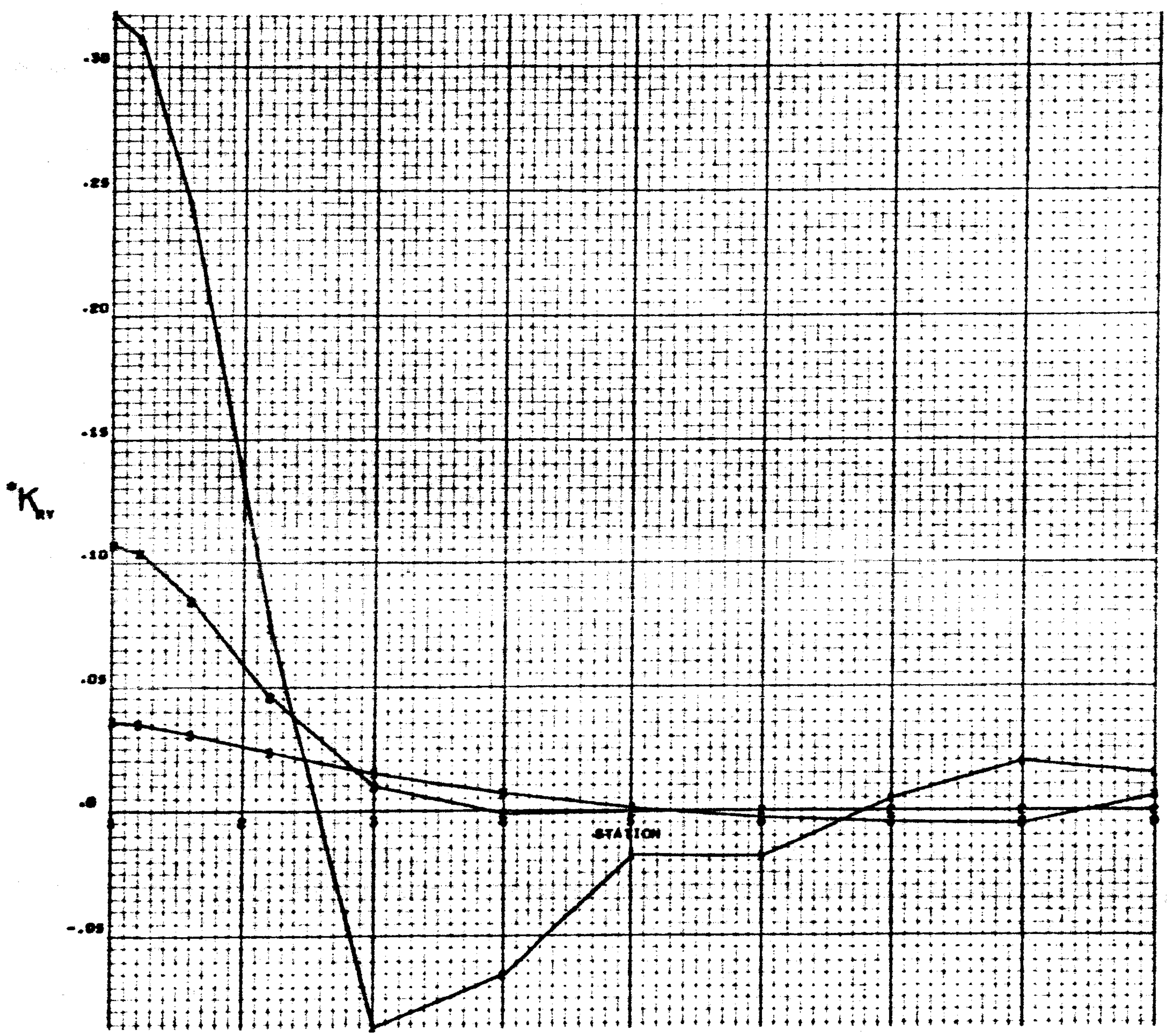
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

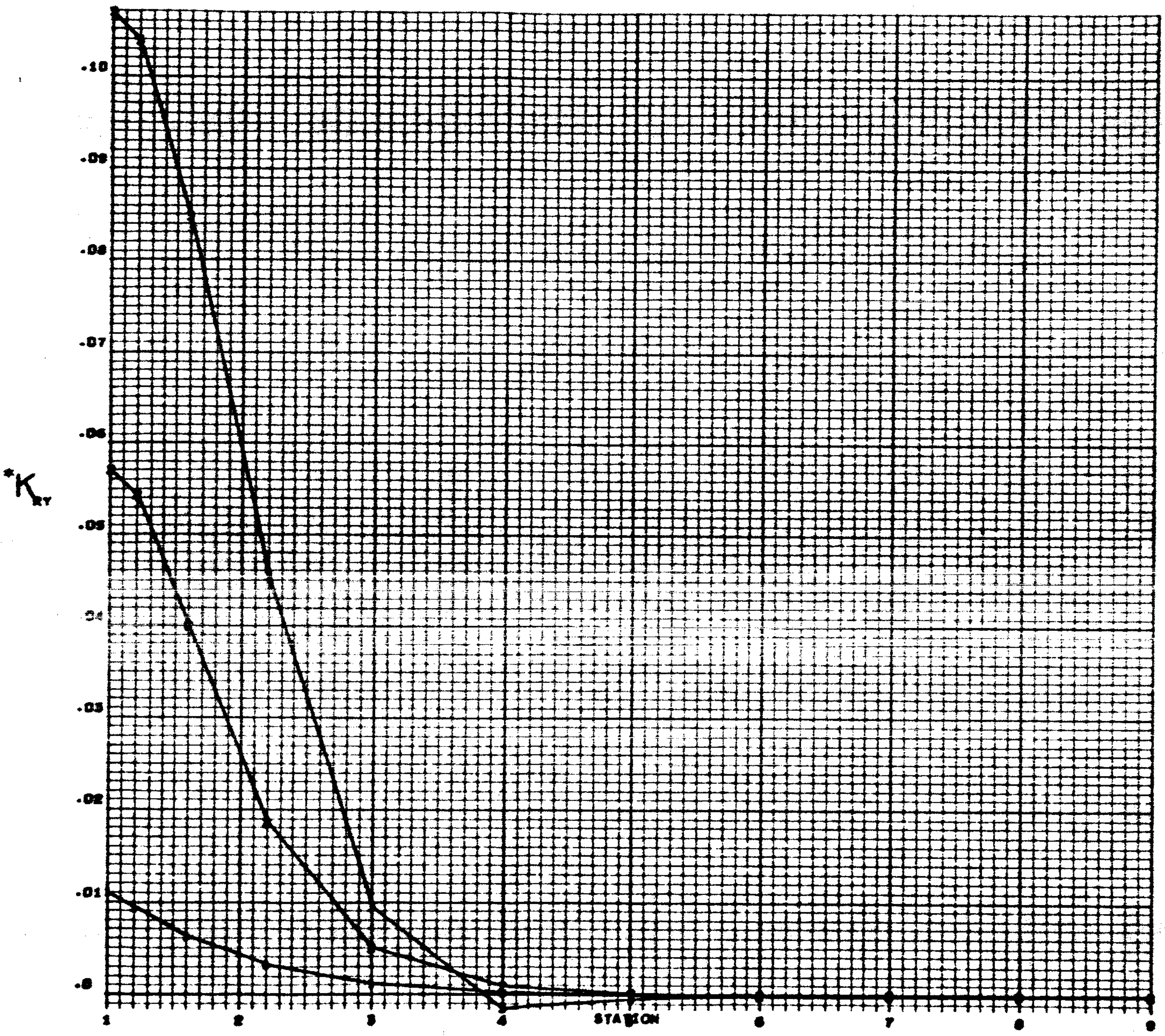
*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE

CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

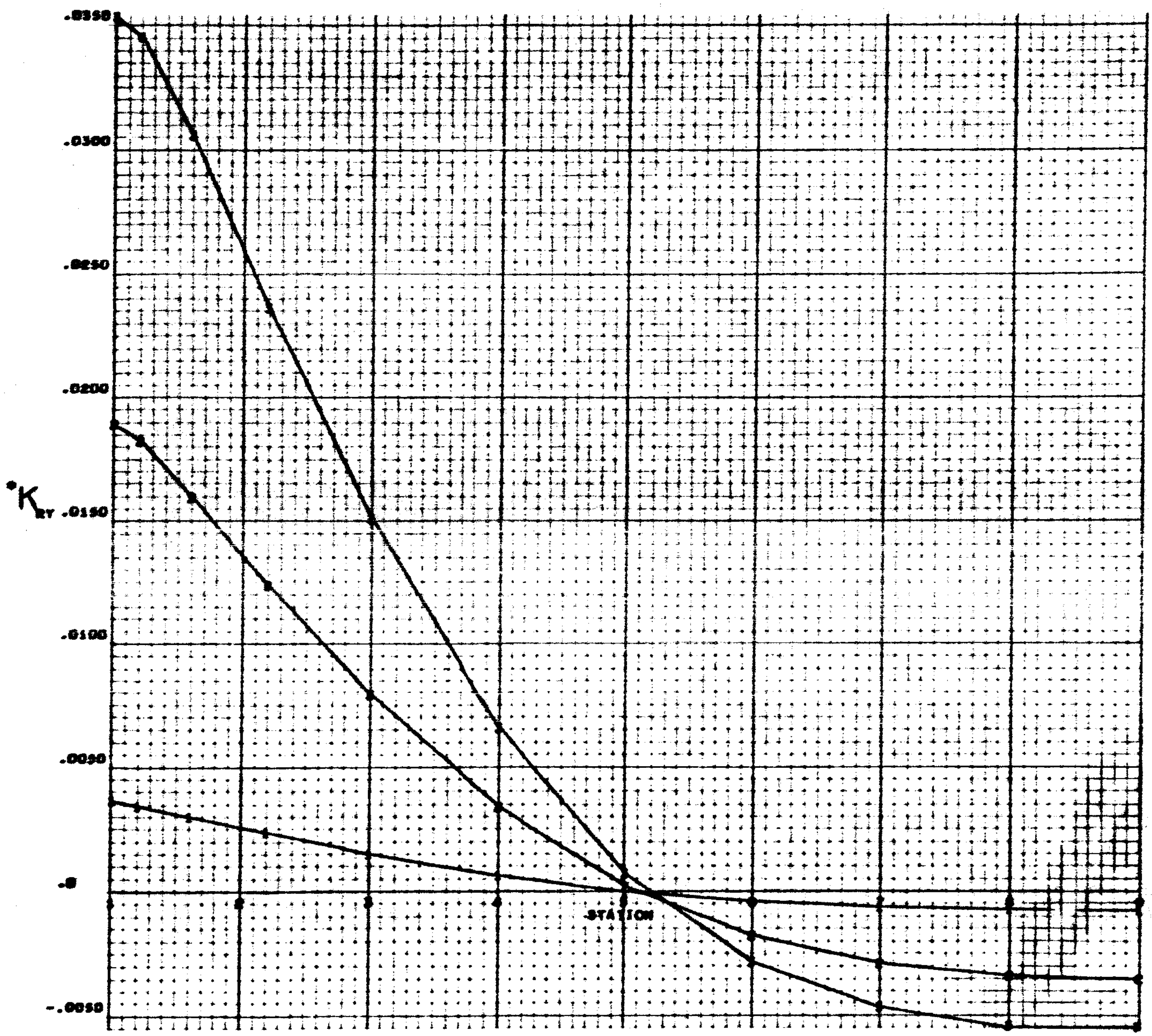
CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.28, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE

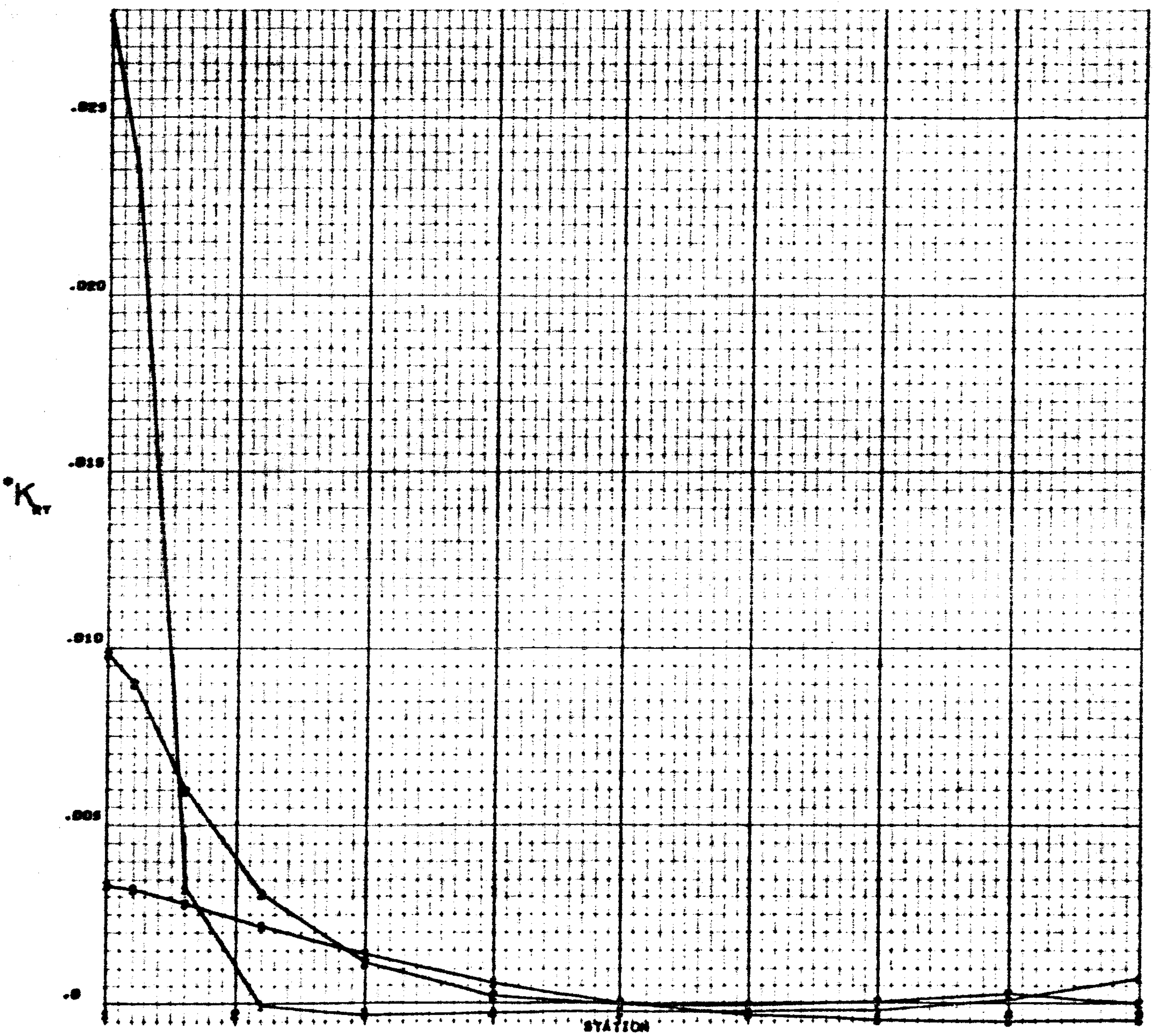


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.01, GJ/EI VARIABLE

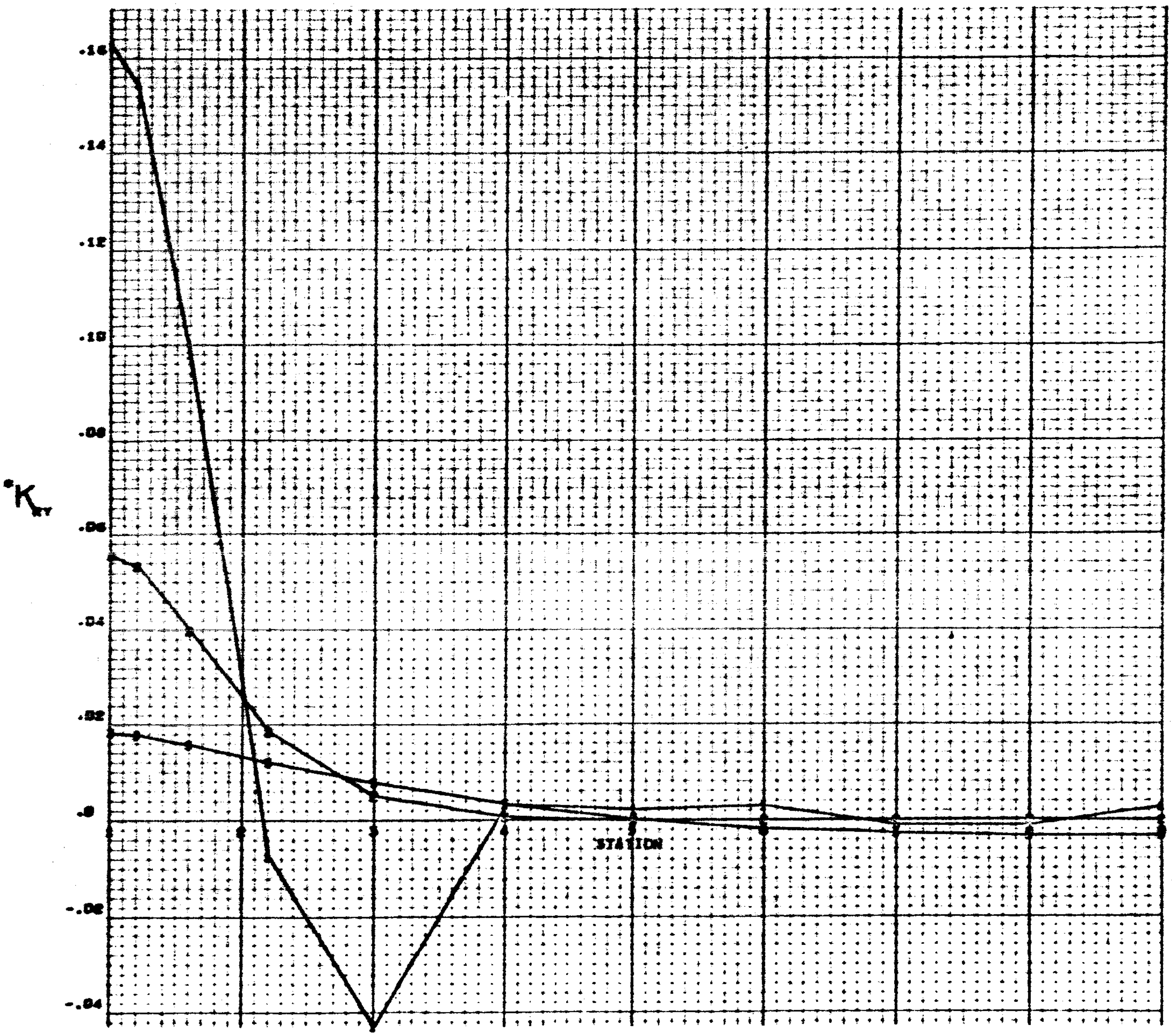


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

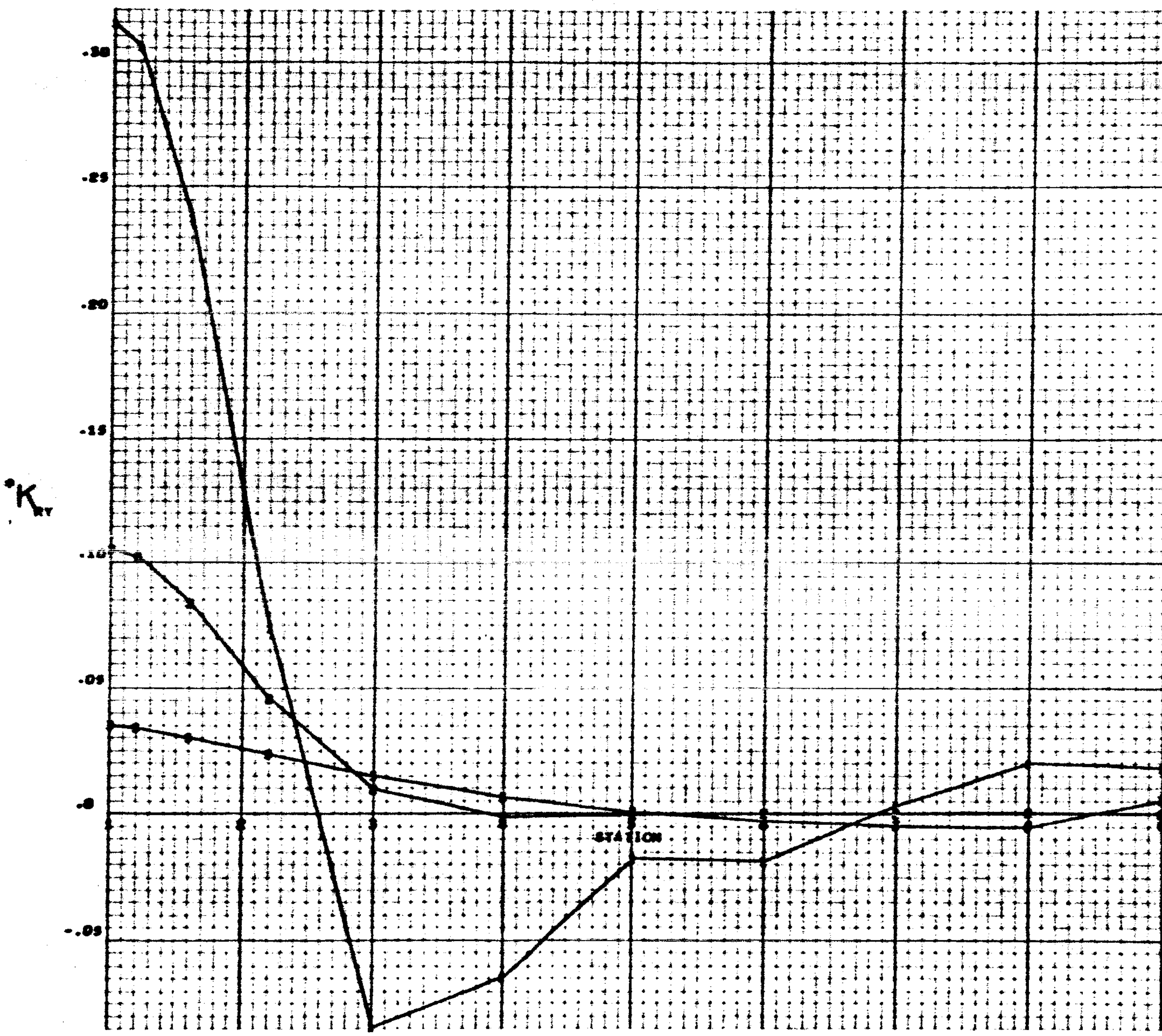
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

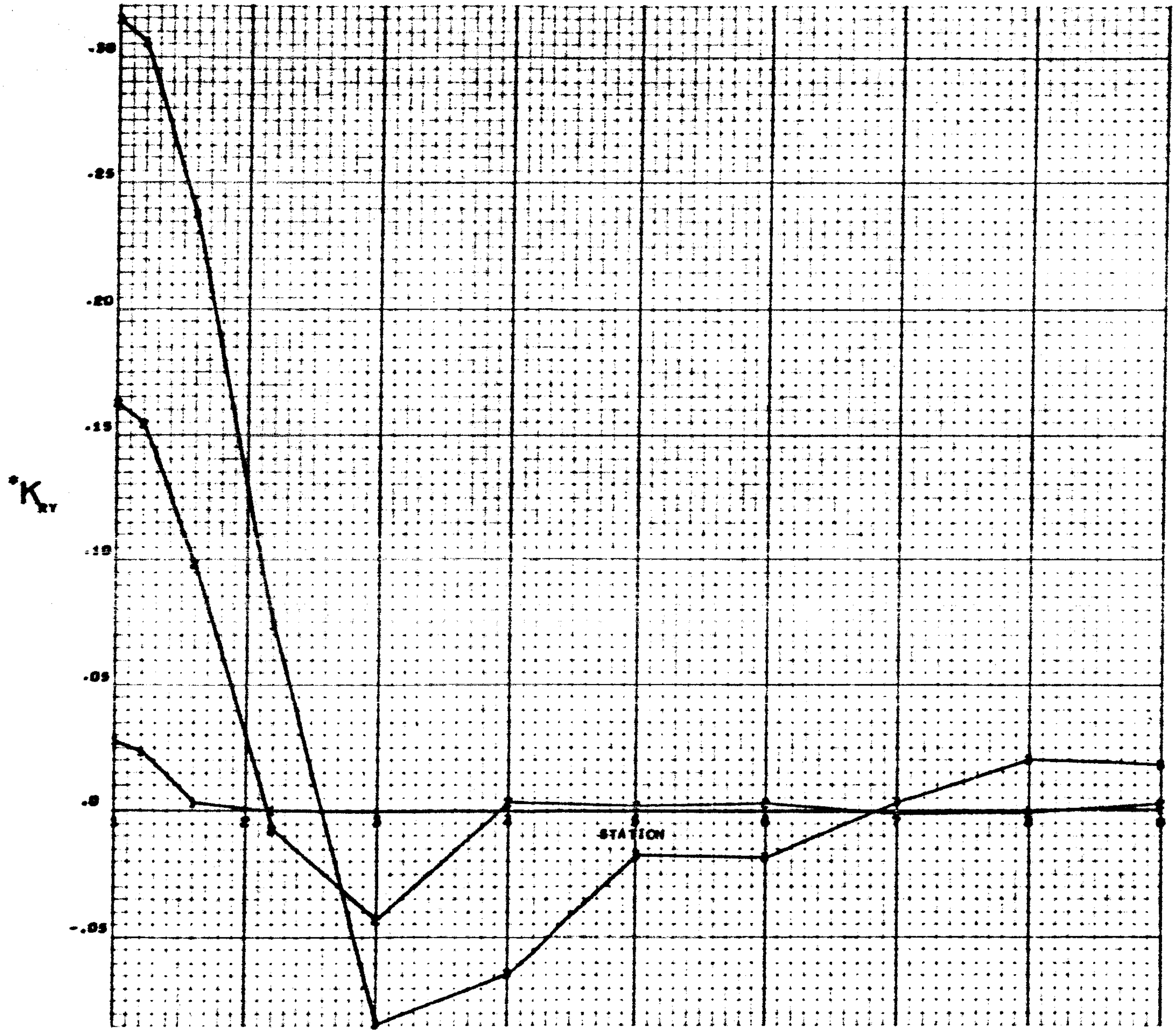
UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE

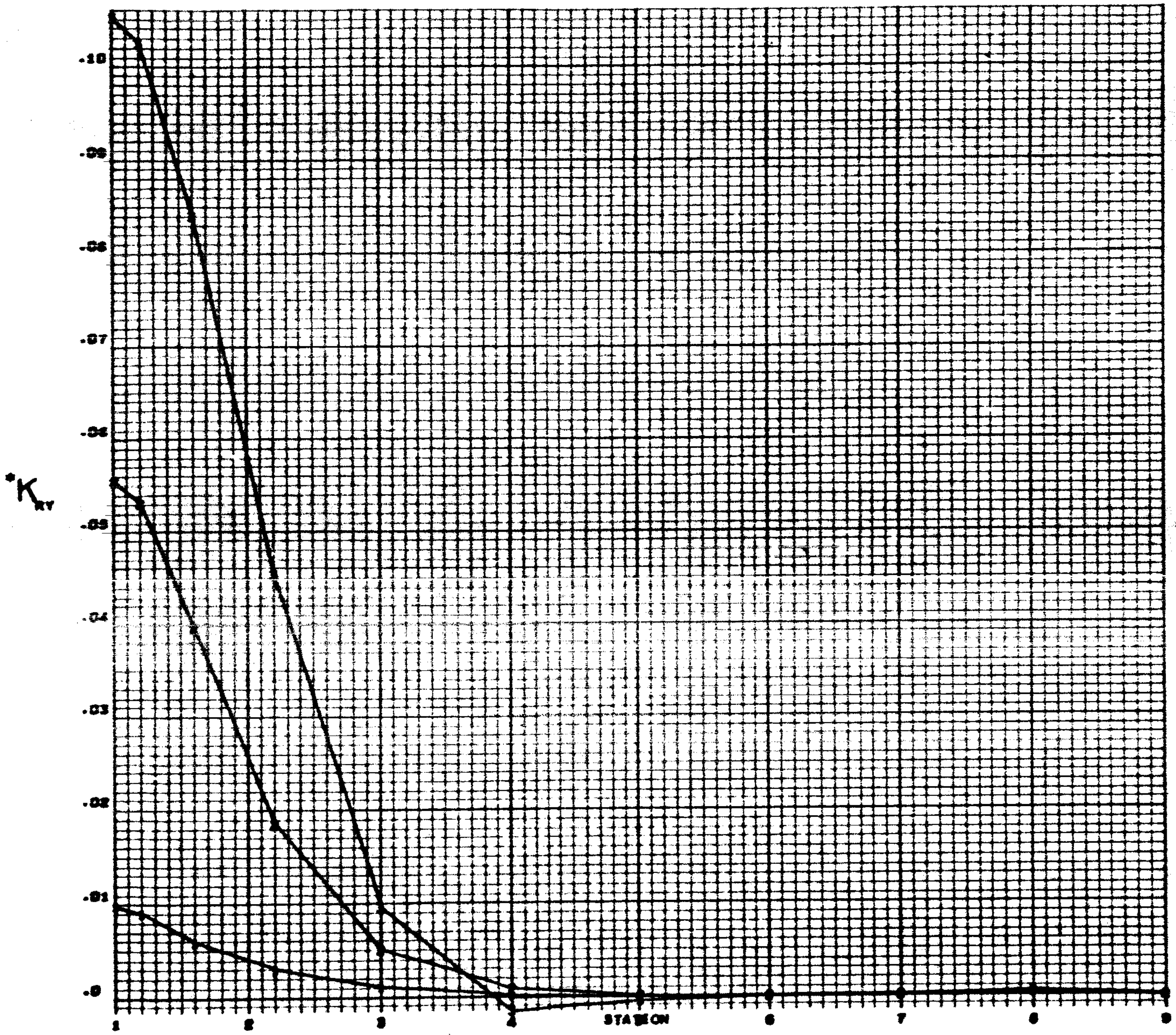


CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

UNIT FORCE DISTRIBUTED OVER ELEMENT 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.20, C/R VARIABLE

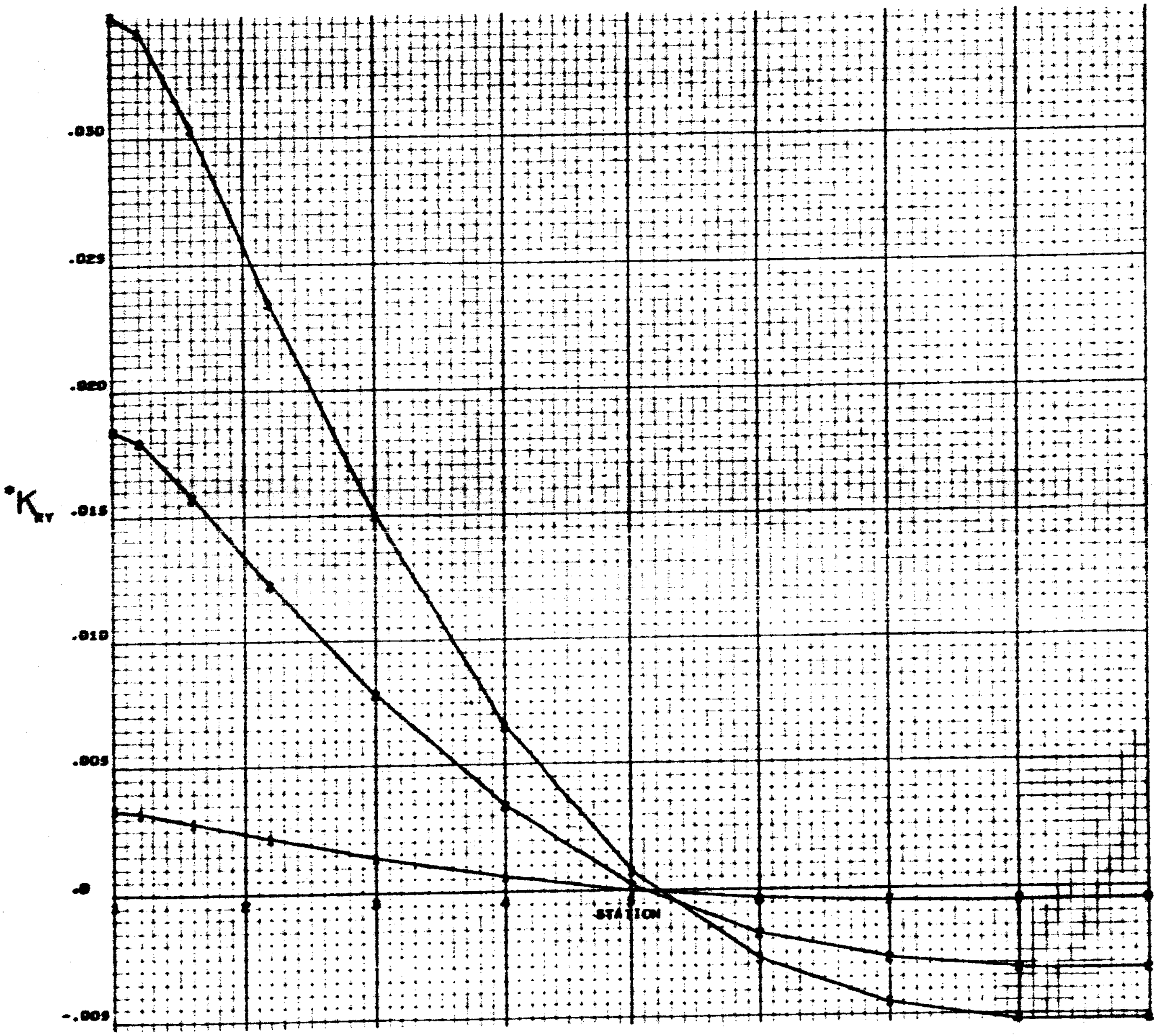


CURVE	C/R
1	-0.01
2	-0.03
3	-0.08

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY} (R^2 / EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

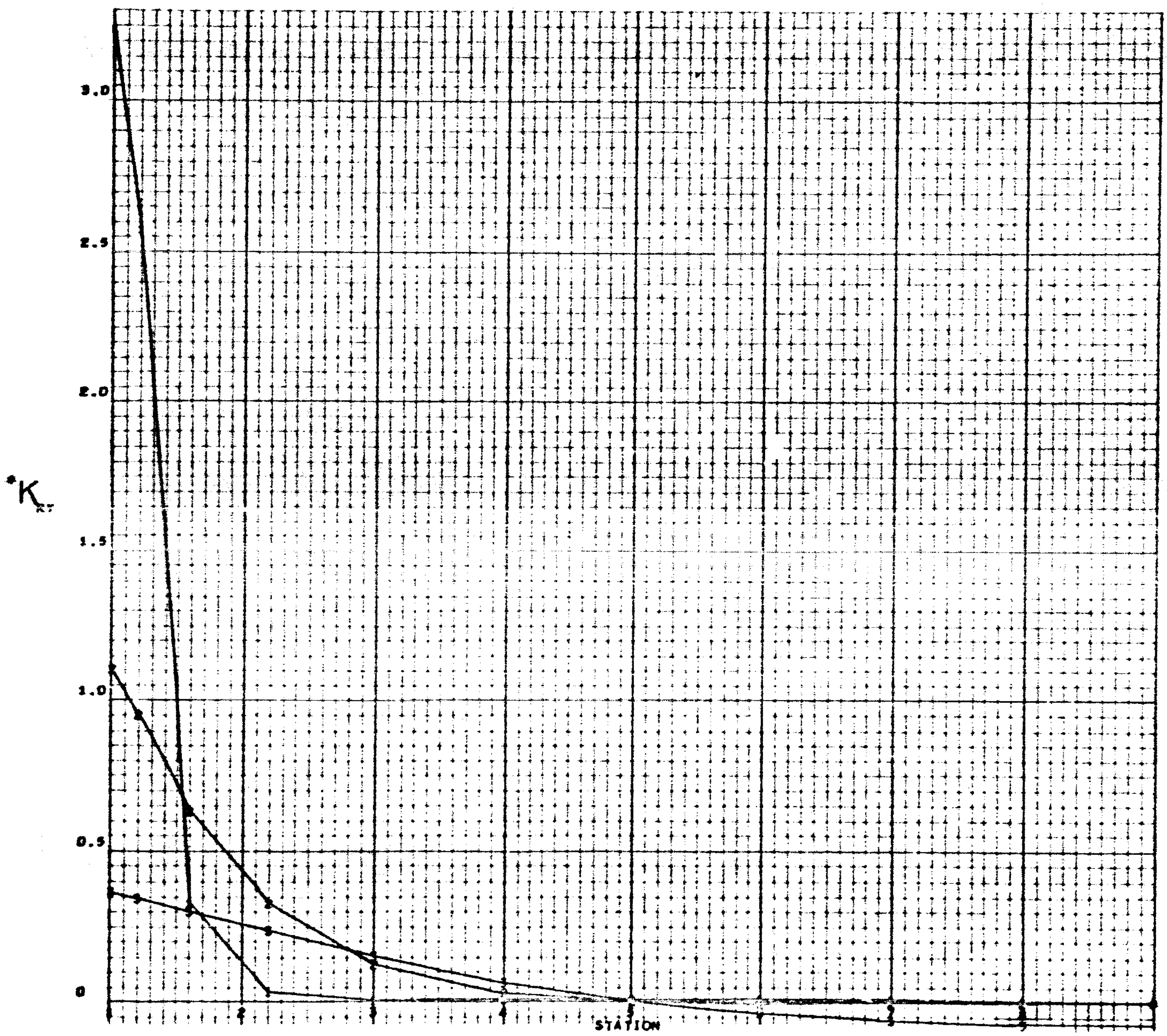
UNIT FORCE DISTRIBUTED OVER ELEMENT I ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R^2/EI)$

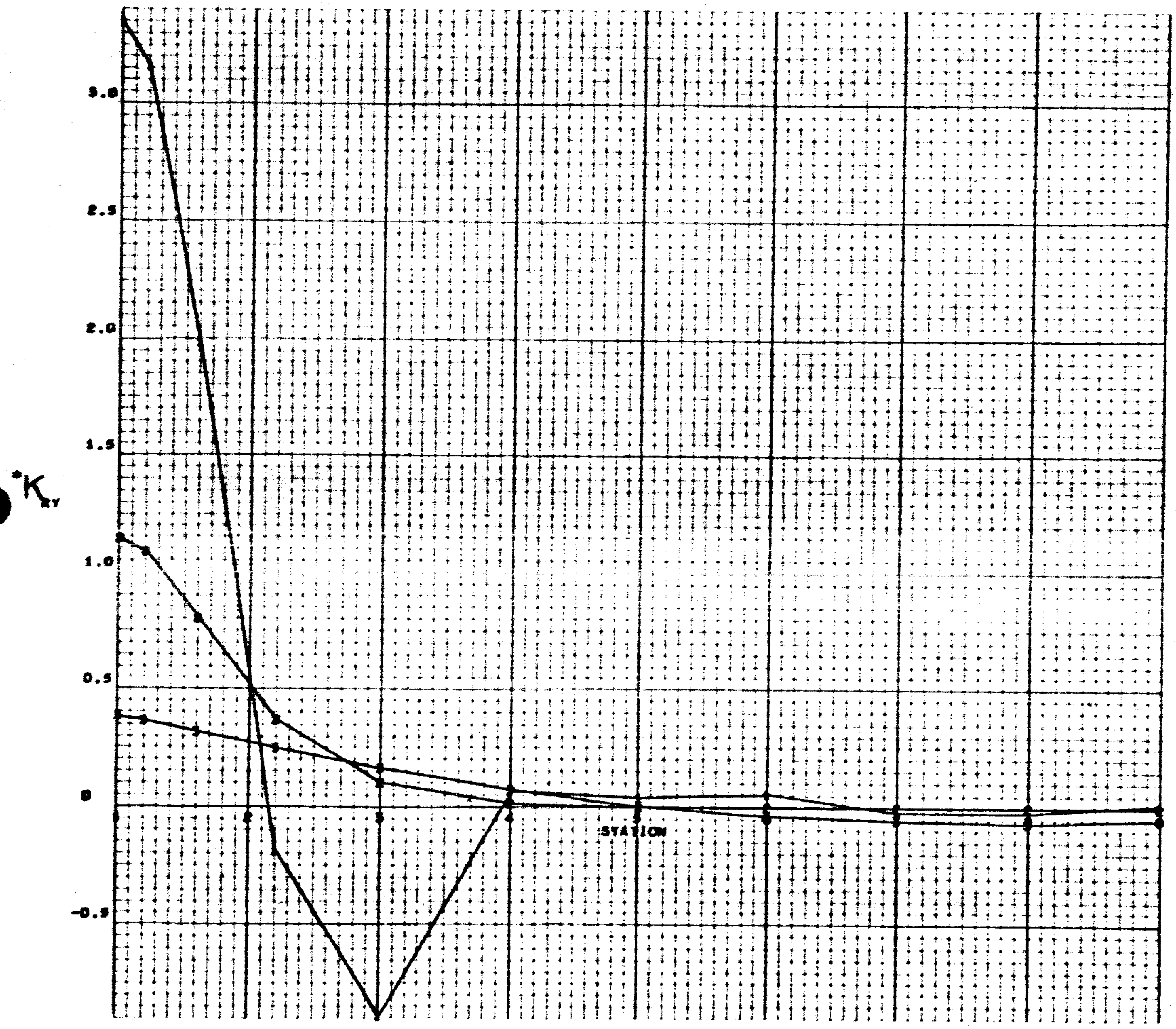
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$(R /EI)

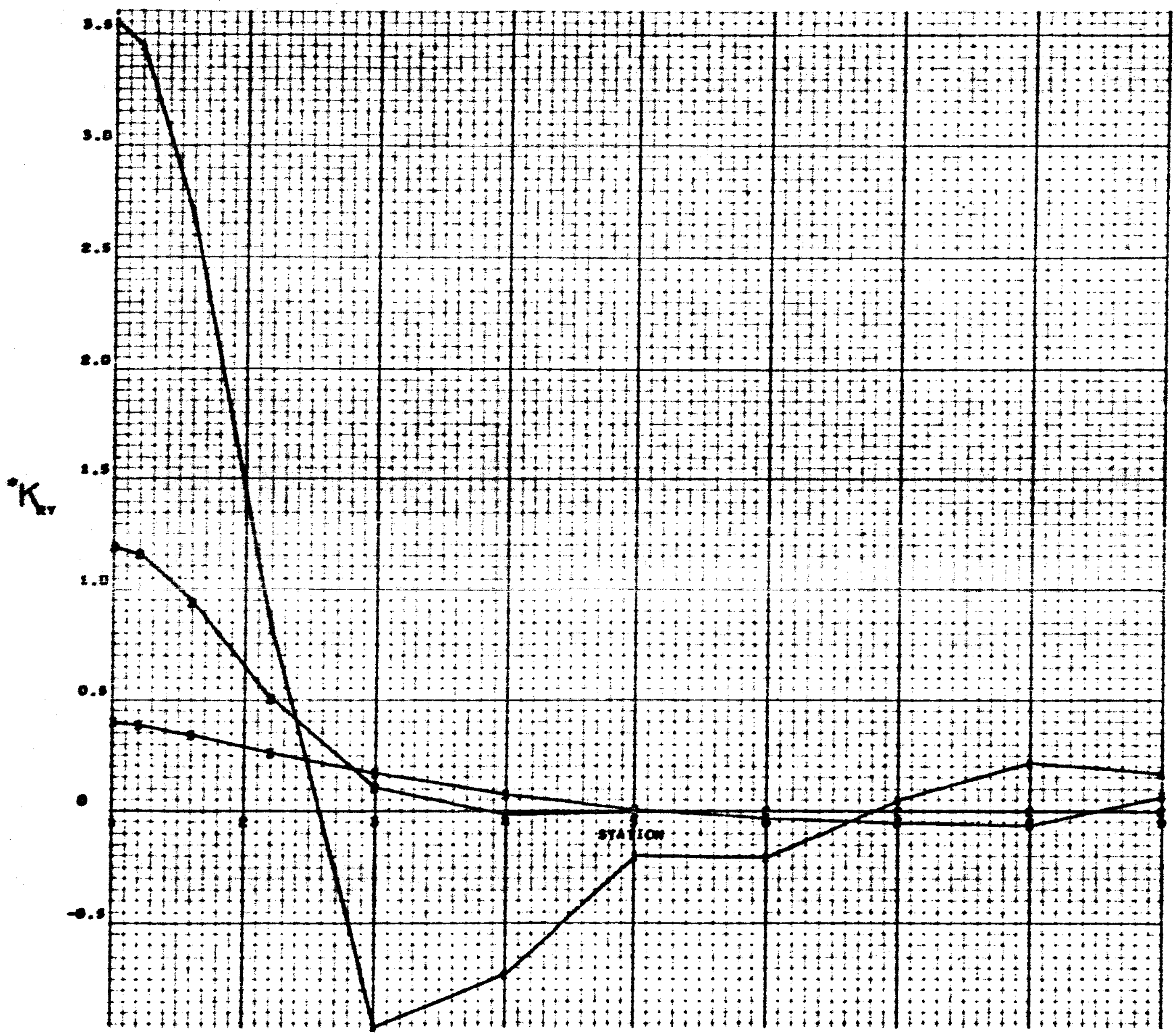
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.05, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$ (R /EI)

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.09, GJ/EI VARIABLE

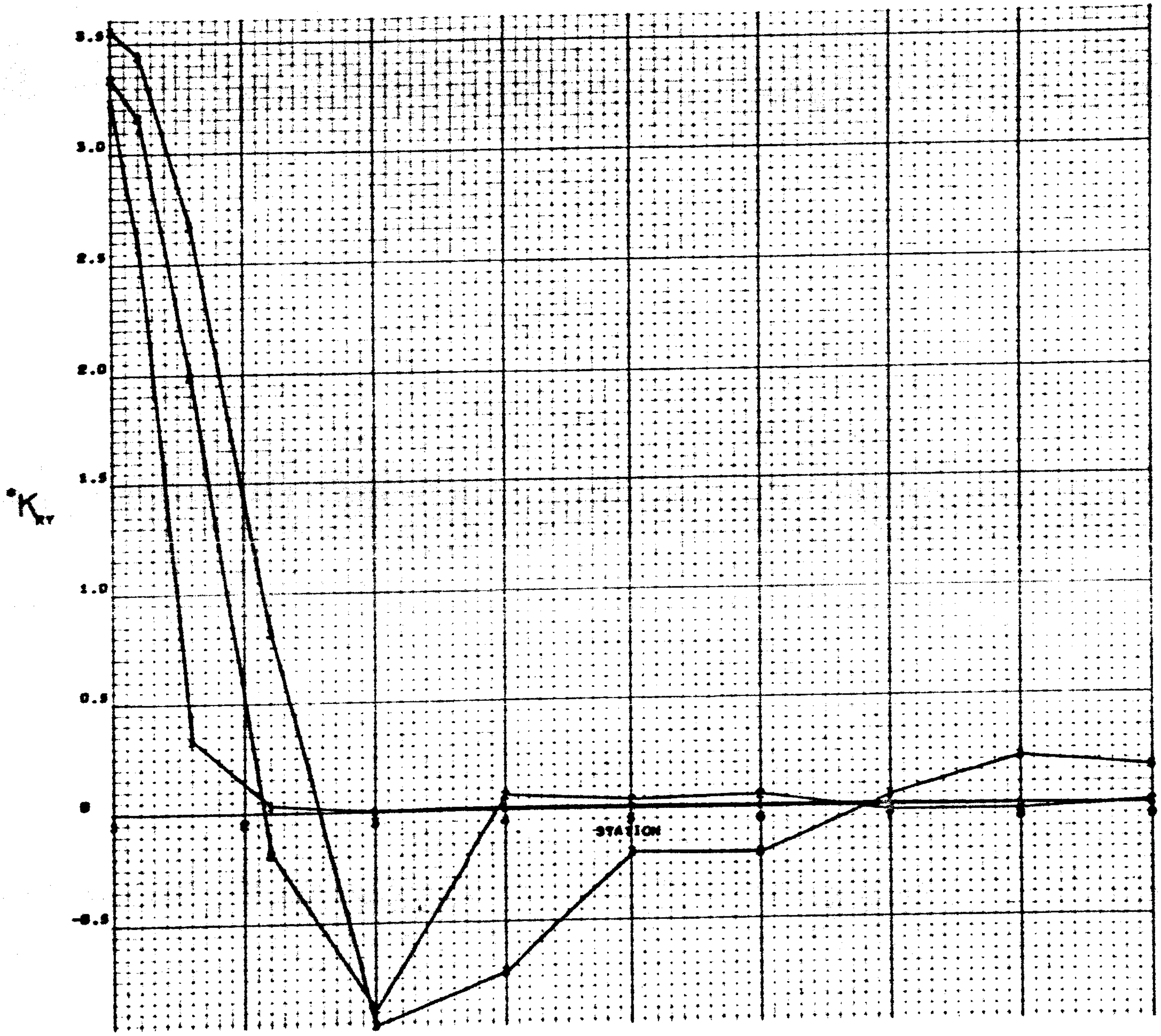


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R \quad /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

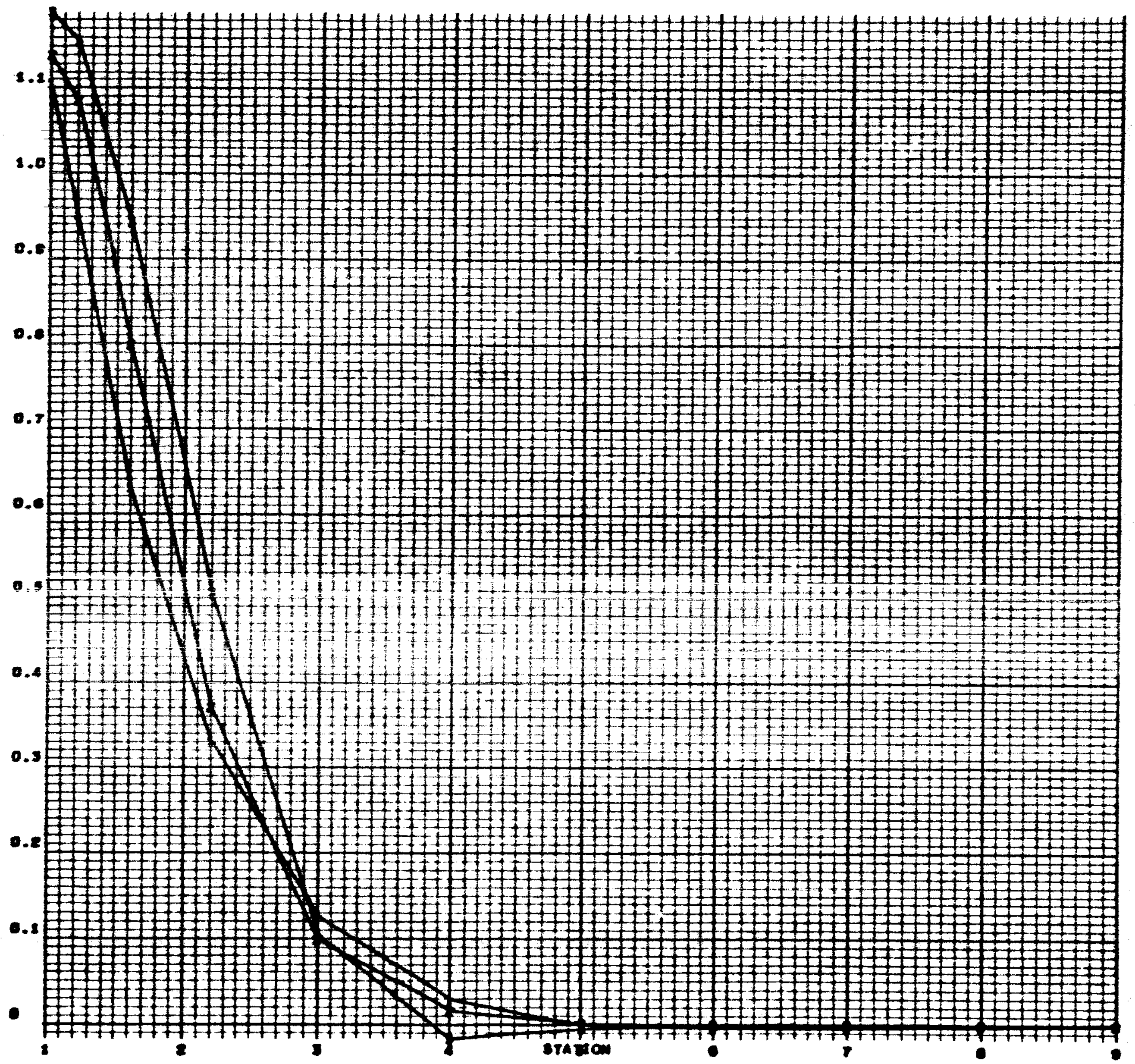
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

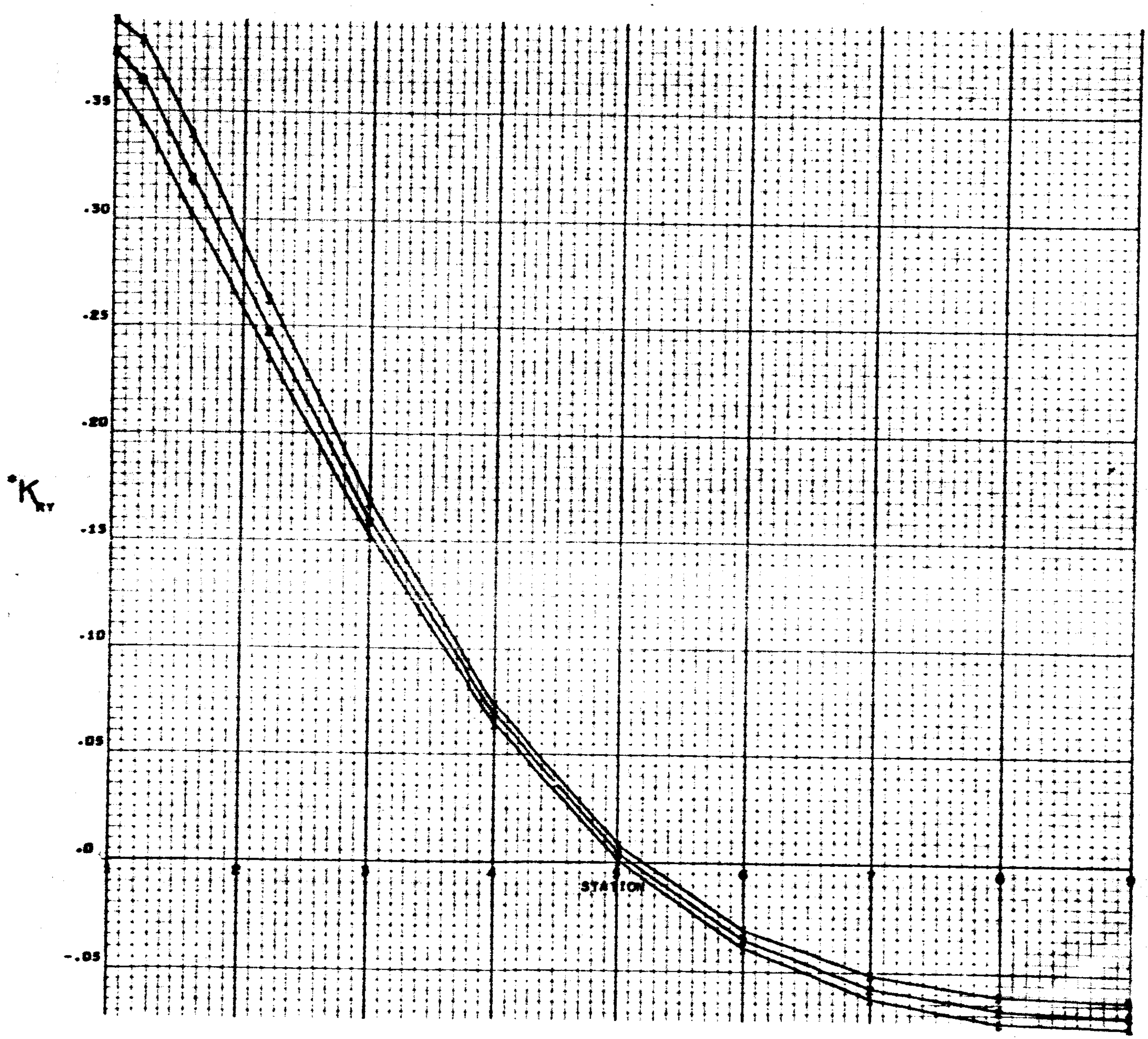
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R \;\; /EI)$

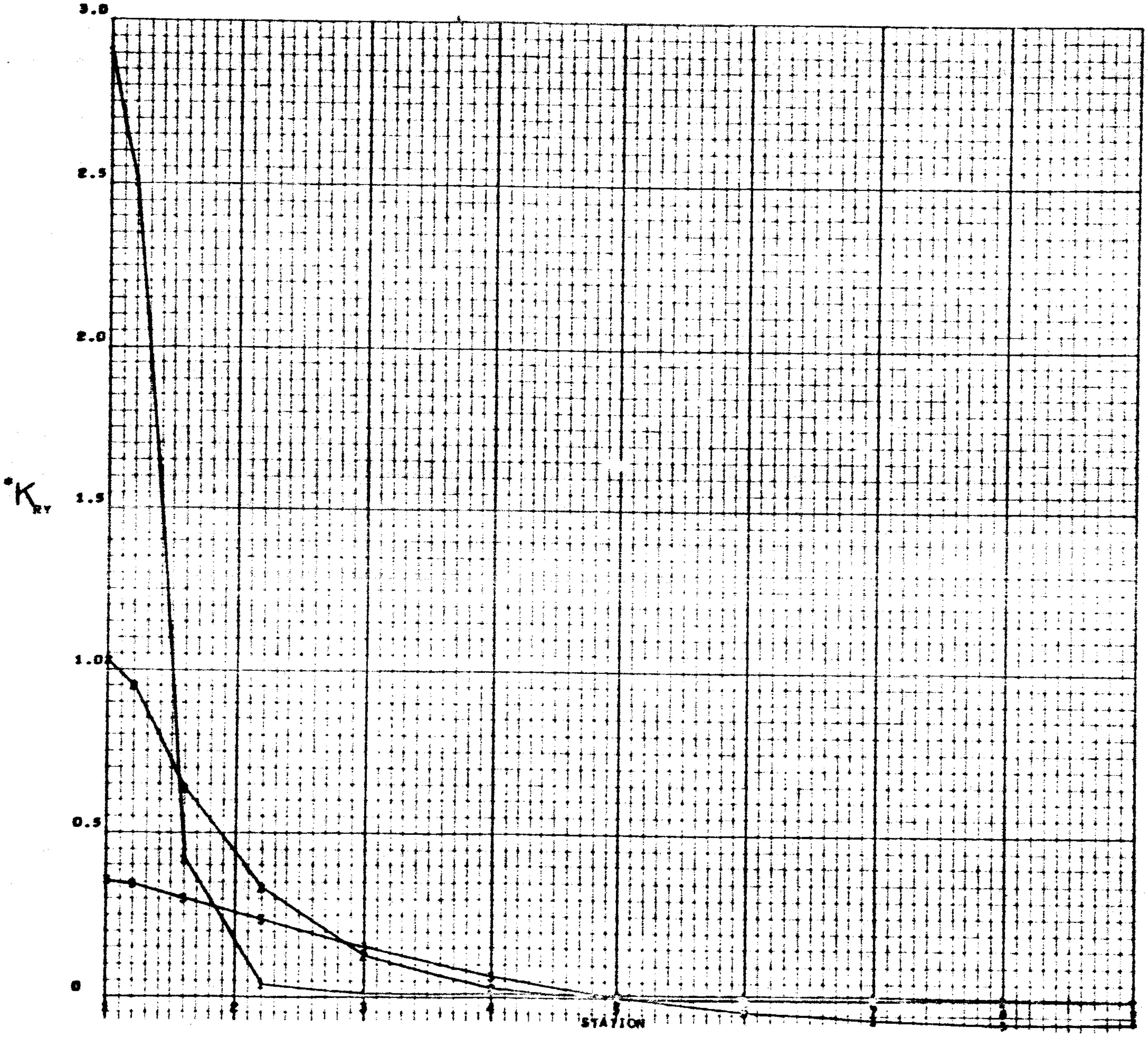
CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

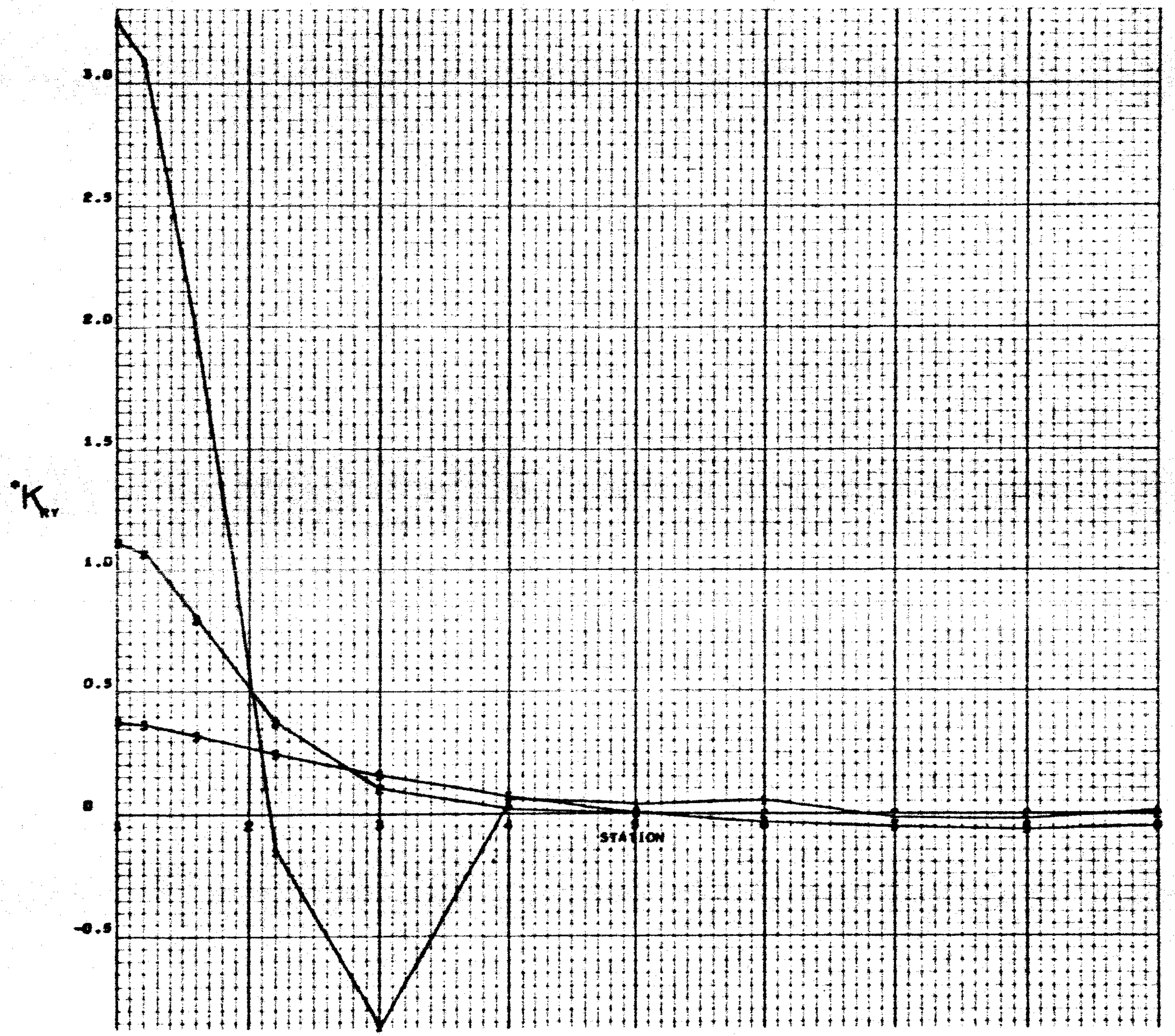
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.01, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.05, GJ/EI VARIABLE

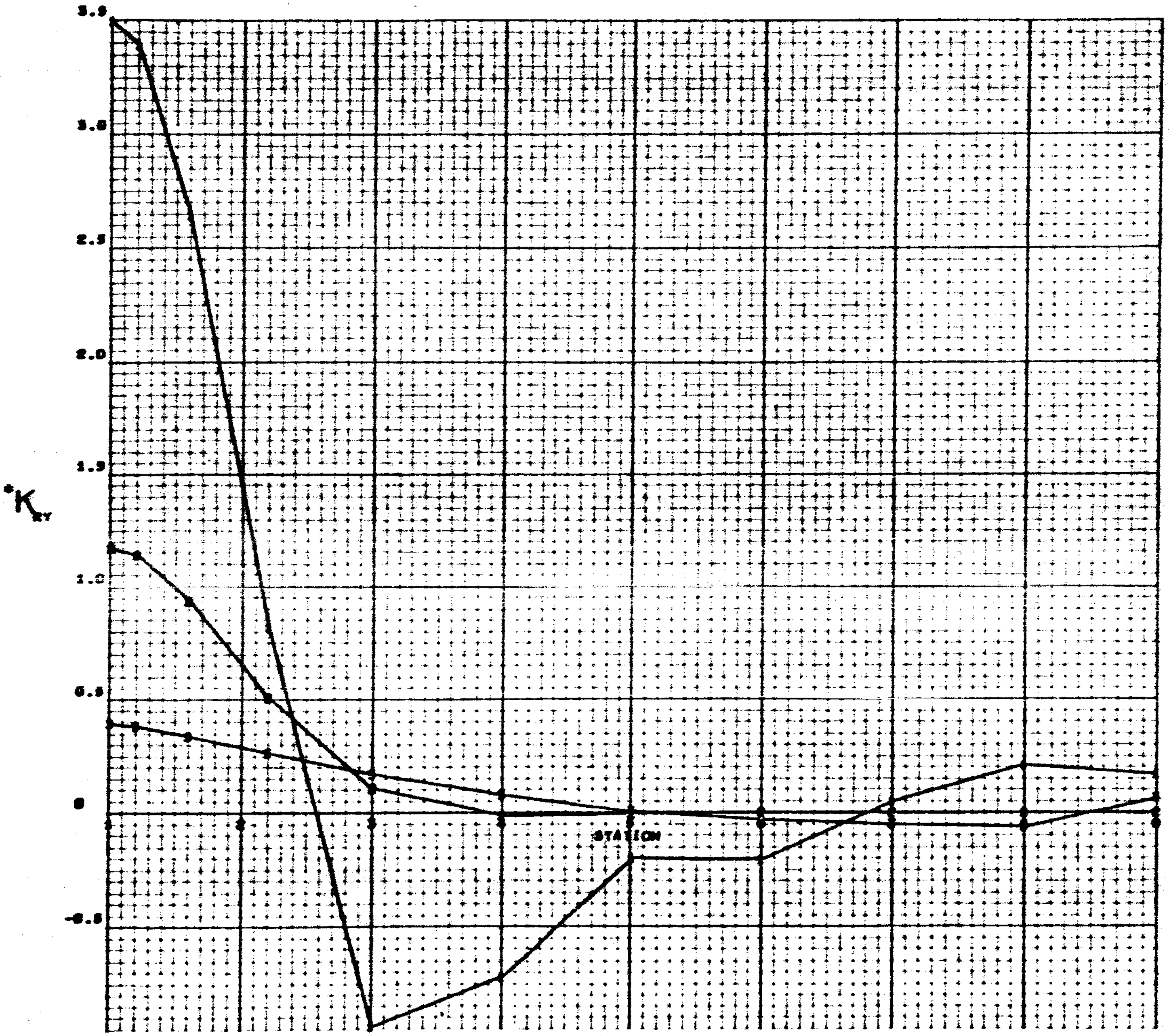


CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

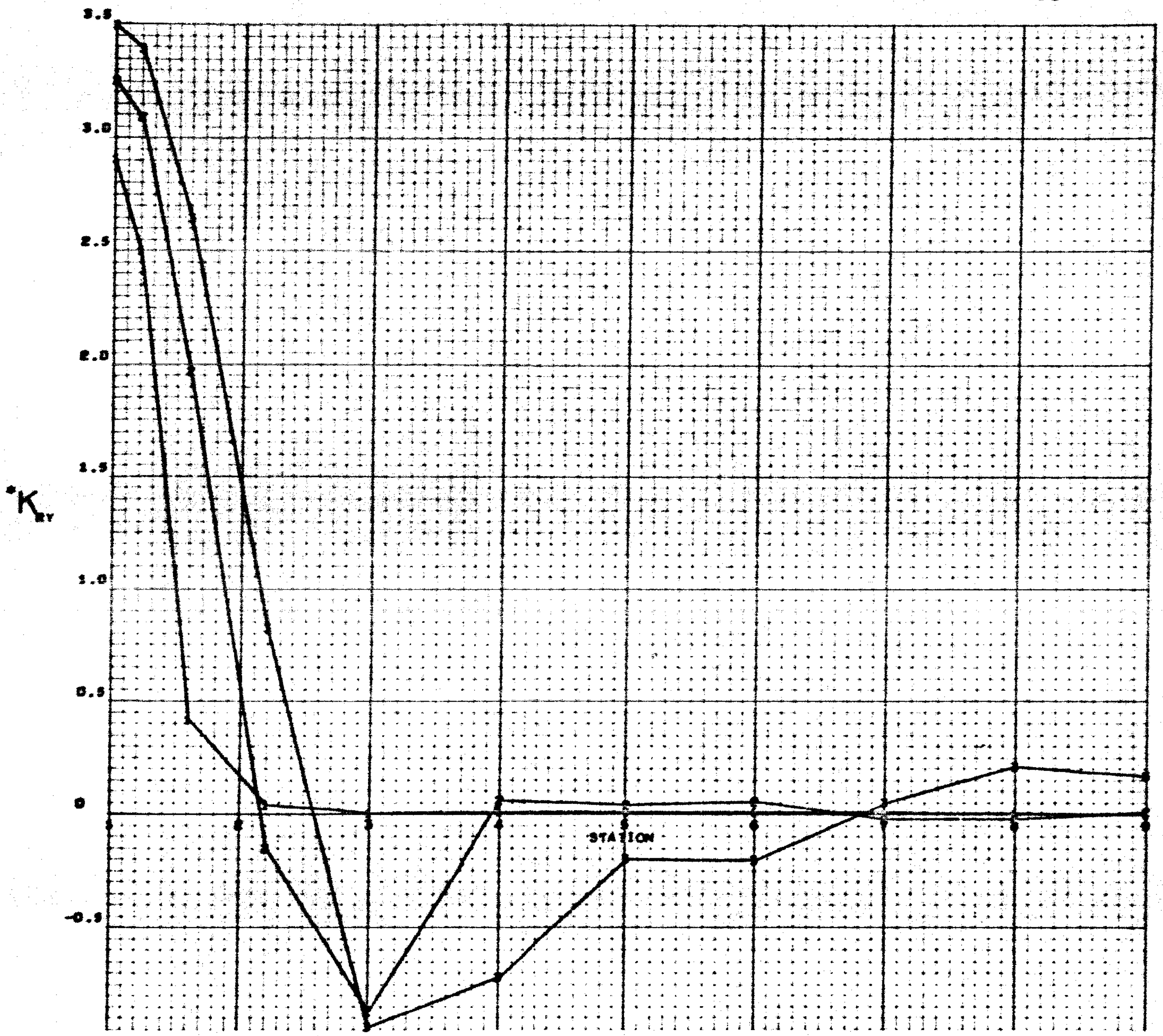
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
C/R = -0.09, GJ/EI VARIABLE



CURVE	GJ/EI
1	0.02
2	0.20
3	2.00

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R \quad /EI)$

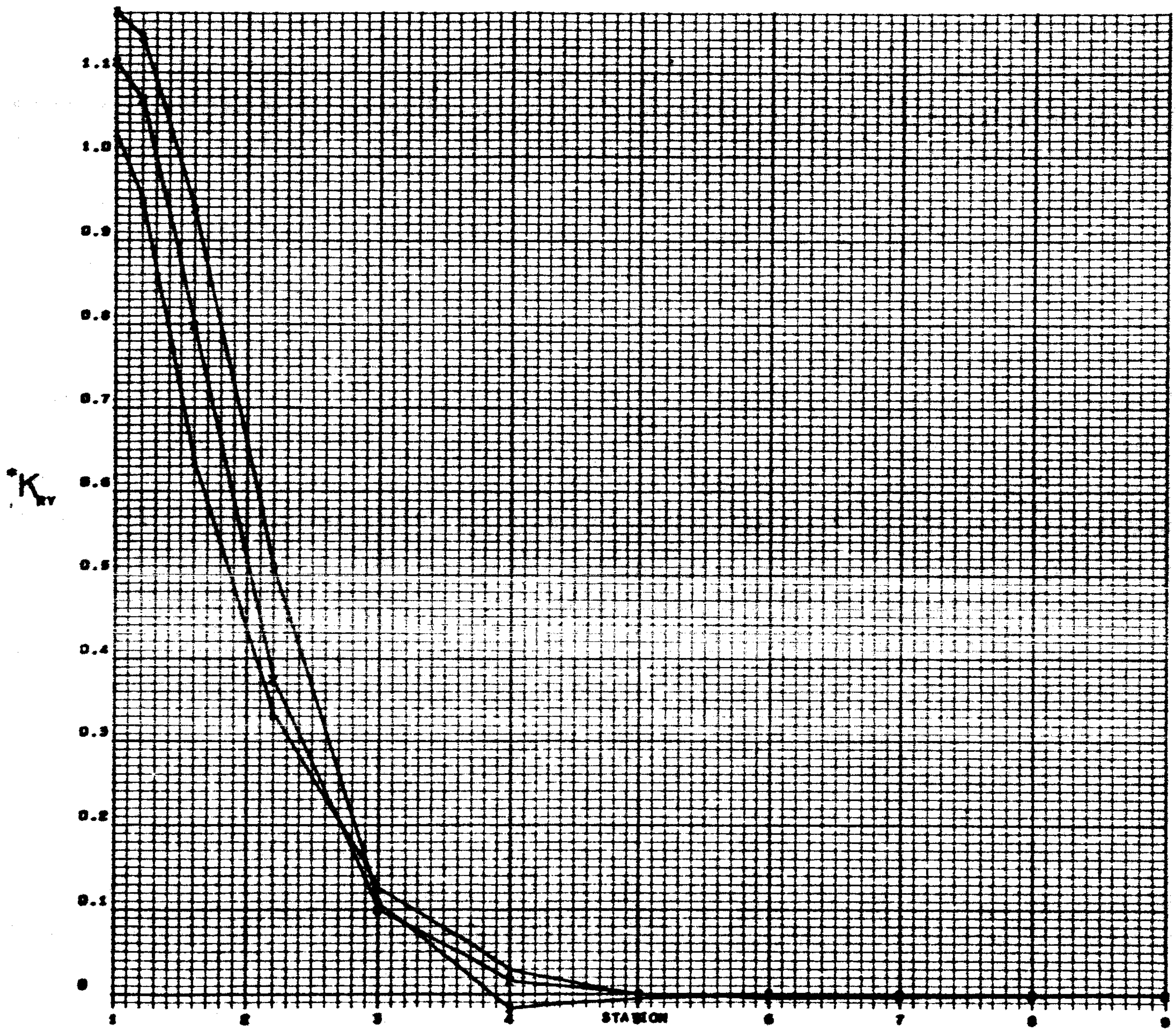
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.02, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}$(R /EI)

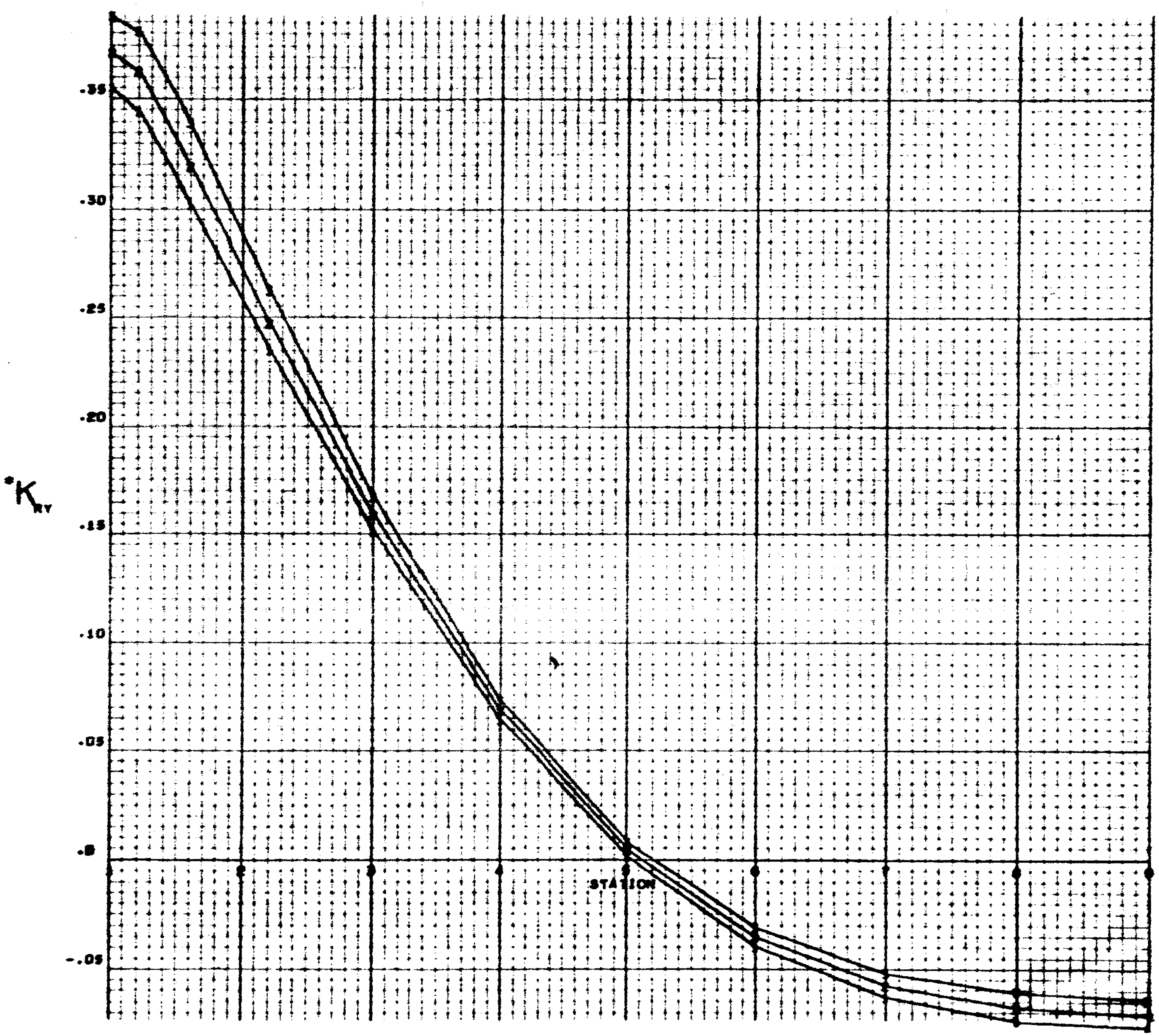
UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT 1
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 0.20, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENT J
R_Y, ROTATION ABOUT THE Y AXIS
GJ/EI = 2.00, C/R VARIABLE



CURVE	C/R
1	-0.01
2	-0.05
3	-0.09

*NOTE . ROTATION ABOUT THE Y AXIS, $R_Y = K_{RY}(R\ \ /EI)$

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.2680747	-0.4071175	-0.4326040	-0.1146203	-0.3506839	-0.4023048	-0.0214179	-0.1925895	-0.2899144
1.1	-0.0673895	-0.2255173	-0.2827321	-0.0161206	-0.1401539	-0.2212842	-0.0053055	-0.0309465	-0.0808027
1.2	-0.0170044	-0.0916119	-0.1434964	-0.0128869	-0.0559813	-0.1004847	-0.0058839	-0.0263243	-0.0434408
2.1	-0.0041429	-0.0300068	-0.0588524	-0.0067068	-0.0280542	-0.0481876	-0.0046493	-0.0218110	-0.0369226
3.0	-0.0007879	-0.0084650	-0.0202599	-0.0032211	-0.0148121	-0.0251681	-0.0035605	-0.0167425	-0.0285415
4.0	-0.0001576	-0.0024147	-0.0068675	-0.0013201	-0.0071110	-0.0130964	-0.0025881	-0.0123515	-0.0212770
5.0	-0.0000311	-0.0007394	-0.0024607	-0.0006445	-0.0056724	-0.0071248	-0.0018454	-0.0088688	-0.0153782
6.0	-0.0000060	-0.0002313	-0.0009064	-0.0002917	-0.0018455	-0.0037919	-0.0012256	-0.0059576	-0.0103646
7.0	0.0000004	-0.0000705	-0.0003261	-0.0001222	-0.0008460	-0.0018306	-0.0007025	-0.0034182	-0.0059893
8.0	-0.0000048	-0.0000182	-0.0000825	-0.0000374	-0.0002499	-0.0005470	-0.0002277	-0.0011117	-0.0019929
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0000004	0.0000705	0.0003261	0.0001222	0.0008460	0.0018306	0.0007025	0.0034182	0.0059893
11.0	0.0000060	0.0002313	0.0009064	0.0002917	0.0018455	0.0037919	0.0012256	0.0059576	0.0103646
12.0	0.0000311	0.0007394	0.0024607	0.0006445	0.0056724	0.0071248	0.0018454	0.0088688	0.0153782
13.0	0.0001576	0.0024147	0.0068675	0.0013201	0.0071110	0.0130964	0.0025881	0.0123515	0.0212770
14.0	0.0007879	0.0084650	0.0202599	0.0032211	0.0148121	0.0251681	0.0035605	0.0167425	0.0285415
15.0	0.0041429	0.0300068	0.0588524	0.0067068	0.0280542	0.0481876	0.0046493	0.0218110	0.0369226
15.1	0.0170044	0.0916119	0.1434964	0.0128869	0.0559813	0.1004847	0.0058839	0.0263243	0.0434408
16.1	0.0673895	0.2255173	0.2827321	0.0161206	0.1401539	0.2212842	0.0053055	0.0309465	0.0808027
16.2	0.2680747	0.4071175	0.4326040	0.1146203	0.3506839	0.4023048	0.0214179	0.1925895	0.2899144

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.3379814	-0.4217296	-0.4407205	-0.2546569	-0.3798211	-0.4160904	-0.2156070	-0.2911766	-0.3410592
1.1	-0.0814636	-0.2337775	-0.2881553	-0.0210466	-0.1521784	-0.2294537	-0.0000964	-0.0410602	-0.0941194
1.2	-0.0182826	-0.0945203	-0.1460773	-0.0131574	-0.0557136	-0.1028961	-0.0069300	-0.0255827	-0.0432877
2.1	-0.0045245	-0.0308403	-0.0598364	-0.0071391	-0.0284415	-0.0467920	-0.0047034	-0.0221413	-0.0371392
3.0	-0.0008462	-0.0066662	-0.0209645	-0.0033756	-0.0149690	-0.0253628	-0.0036775	-0.0168044	-0.0268211
4.0	-0.0001692	-0.0024556	-0.0069439	-0.0013304	-0.0071421	-0.0131394	-0.0025711	-0.0123515	-0.0212746
5.0	-0.0000100	-0.0007141	-0.0024334	-0.0005926	-0.0036191	-0.0070761	-0.0017463	-0.0087747	-0.0152952
6.0	0.0000726	-0.0001066	-0.0007466	-0.0000206	-0.0016376	-0.0036136	-0.0010109	-0.0057302	-0.0101666
7.0	0.0002560	0.0004553	0.0002149	0.0001712	-0.0005209	-0.0014564	-0.0003871	-0.0031656	-0.0037696
8.0	0.0058067	0.0025104	0.0018160	0.0020190	0.0016051	0.0010193	0.0002958	-0.0004736	-0.0012628
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0002560	-0.0004553	-0.0002149	-0.0001712	0.0005209	0.0014564	0.0003871	0.0031656	0.0037696
11.0	-0.0000726	0.0001066	0.0007466	0.0000206	0.0016376	0.0036136	0.0010109	0.0057302	0.0101666
12.0	0.0000100	0.0007141	0.0024334	0.0005926	0.0036191	0.0070761	0.0017463	0.0087747	0.0152952
13.0	0.0001692	0.0024556	0.0069439	0.0013304	0.0071421	0.0131394	0.0025711	0.0123515	0.0212746
14.0	0.0008462	0.0066662	0.0209645	0.0033756	0.0149690	0.0253628	0.0036775	0.0168044	0.0268211
15.0	0.0045245	0.0308403	0.0598364	0.0071391	0.0284415	0.0467920	0.0047034	0.0221413	0.0371392
15.1	0.0182826	0.0945203	0.1460773	0.0131574	0.0557136	0.1028961	0.0069300	0.0255827	0.0432877
16.1	0.0814636	0.2337775	0.2881553	0.0210466	0.1521784	0.2294537	0.0000964	0.0410602	0.0941194
16.2	-0.1998791	-0.0760924	-0.0591632	-0.2449051	-0.1201520	-0.0836600	-0.2842066	-0.2087463	-0.1589464

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	26.8087153	8.1418689	4.8067974	11.4465171	7.0129498	4.4700084	2.1472865	3.8502454	3.2214339
1.1	6.7205042	4.5101749	3.1413740	1.6157621	2.8033286	2.4588031	0.5361000	0.6191071	0.8923724
1.2	1.7007989	1.8322681	1.5944305	1.2877799	1.0796799	1.1165228	0.5889226	0.5264971	0.4826638
2.1	0.4143932	0.6002099	0.6539109	0.6708502	0.5612580	0.5354774	0.4645611	0.4361996	0.4102534
3.0	0.0788166	0.1693727	0.2251017	0.3221097	0.2963239	0.2796836	0.3561117	0.3348592	0.3171068
4.0	0.0157158	0.0483270	0.0763003	0.1318022	0.1422629	0.1455378	0.2588629	0.2470414	0.2363868
5.0	0.0031771	0.0148083	0.0273238	0.0640978	0.0734777	0.0791881	0.1845118	0.1773619	0.1708523
6.0	0.0009004	0.0046354	0.0100572	0.0289225	0.0369333	0.0421566	0.1225999	0.1187878	0.1151334
7.0	0.0002542	0.0014307	0.0036094	0.0119282	0.0169402	0.0203613	0.0702618	0.0683909	0.0665187
8.0	0.0007941	0.0003818	0.0009040	0.0034829	0.0050223	0.0060999	0.0227953	0.0222644	0.0216717
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0002542	-0.0014307	-0.0036094	-0.0119282	-0.0169402	-0.0203613	-0.0702618	-0.0683909	-0.0665187
11.0	-0.0009004	-0.0046354	-0.0100572	-0.0289225	-0.0369333	-0.0421566	-0.1225999	-0.1187878	-0.1151334
12.0	-0.0031771	-0.0148083	-0.0273238	-0.0640978	-0.0734777	-0.0791881	-0.1845118	-0.1773619	-0.1708523
13.0	-0.0157158	-0.0483270	-0.0763003	-0.1318022	-0.1422629	-0.1455378	-0.2588629	-0.2470414	-0.2363868
14.0	-0.0788166	-0.1693727	-0.2251017	-0.3221097	-0.2963239	-0.2796836	-0.3561117	-0.3348592	-0.3171068
15.0	-0.4143932	-0.6002099	-0.6539109	-0.6708502	-0.5612580	-0.5354774	-0.4645611	-0.4361996	-0.4102534
15.1	-1.7007989	-1.8322681	-1.5944305	-1.2877799	-1.0796799	-1.1165228	-0.5889226	-0.5264971	-0.4826638
16.1	-6.7205042	-4.5101749	-3.1413740	-1.6157621	-2.8033286	-2.4588031	-0.5361000	-0.6191071	-0.8923724
16.2	-26.8087153	-8.1418689	-4.8067974	-11.4465171	-7.0129498	-4.4700084	-2.1472865	-3.8502454	-3.2214339

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	9.5791278	3.4645256	2.1310322	3.5605049	2.7443077	1.8901376	1.0954168	1.4479379	1.2420904
1.1	8.4139713	4.6962971	3.2112244	2.8187806	3.1968413	2.5921015	0.7561597	1.0387077	1.1767301
1.2	1.7636287	1.6957351	1.0268915	1.1724121	1.1186296	1.1516063	0.5565913	0.4642479	0.4742492
2.1	0.4316048	0.6163796	0.6656628	0.6904656	0.5639786	0.5414593	0.4697399	0.4420500	0.4107426
3.0	0.0632518	0.1750510	0.2286345	0.3217576	0.2975500	0.2606634	0.3547382	0.3334721	0.3167255
4.0	0.0156799	0.0491565	0.0773267	0.1327799	0.1427916	0.1459905	0.2569576	0.2471242	0.2362152
5.0	0.0036015	0.0150666	0.0276732	0.0646733	0.0736610	0.0794711	0.1642670	0.1771465	0.1707055
6.0	0.0009051	0.0047200	0.0101776	0.0268754	0.0370266	0.0422728	0.1225274	0.1187114	0.1150409
7.0	0.0003531	0.0014622	0.0036536	0.0121943	0.0170592	0.0204424	0.0701991	0.0663296	0.0664619
8.0	0.0005121	0.0005971	0.0009054	0.0052962	0.0049457	0.0061011	0.0227795	0.0222450	0.0216523
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0003531	-0.0014622	-0.0036536	-0.0121943	-0.0170592	-0.0204424	-0.0701991	-0.0663296	-0.0664619
11.0	-0.0009051	-0.0047200	-0.0101776	-0.0268754	-0.0370266	-0.0422728	-0.1225274	-0.1187114	-0.1150409
12.0	-0.0036015	-0.0150666	-0.0276732	-0.0646733	-0.0736610	-0.0794711	-0.1642670	-0.1771465	-0.1707055
13.0	-0.0156799	-0.0491585	-0.0773267	-0.1327799	-0.1427916	-0.1459905	-0.2569576	-0.2471242	-0.2362152
14.0	-0.0632518	-0.1730510	-0.2286345	-0.3217576	-0.2975500	-0.2606634	-0.3547382	-0.3334721	-0.3167255
15.0	-0.4316048	-0.6163796	-0.6656628	-0.6904656	-0.5639786	-0.5414593	-0.4697399	-0.4420500	-0.4107426
15.1	-1.7636267	-1.6957351	-1.0268915	-1.1724121	-1.1186296	-1.1516063	-0.5565913	-0.4642479	-0.4742492
16.1	-8.4139713	-4.6962971	-3.2112244	-2.8187806	-3.1968413	-2.5921015	-0.7561597	-1.0387077	-1.1767301
16.2	-9.5791278	-3.4645296	-2.1310322	-3.5605049	-2.7443077	-1.8901376	-1.0954168	-1.4479379	-1.2420904

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0012645	-0.0012672	-0.0012228	-0.0033655	-0.0050655	-0.0049655	-0.0046350	-0.0144743	-0.0172418
1.1	-0.0014174	-0.0029187	-0.0032313	-0.0033070	-0.0103356	-0.0122882	-0.0044008	-0.0204791	-0.0322415
1.2	-0.0008633	-0.0026684	-0.0037065	-0.0022184	-0.0082294	-0.0134444	-0.0038202	-0.0179887	-0.0306618
2.1	-0.0002171	-0.0015239	-0.0026838	-0.0012932	-0.0080278	-0.0100549	-0.0051365	-0.0148754	-0.0255290
3.0	-0.0000924	-0.0006254	-0.0014042	-0.0006515	-0.0033719	-0.0061254	-0.0024157	-0.0115851	-0.0200733
4.0	-0.0000092	-0.0001966	-0.0005442	-0.0003016	-0.0017443	-0.0033999	-0.0017709	-0.0085666	-0.0150109
5.0	-0.0000032	-0.0000617	-0.0002110	-0.0001422	-0.0008911	-0.0018546	-0.0012569	-0.0061526	-0.0108362
6.0	-0.0000039	-0.0000180	-0.0000618	-0.0000662	-0.0004451	-0.0009840	-0.0008360	-0.0041260	-0.0073183
7.0	-0.0000057	-0.0000033	-0.0000309	-0.0000335	-0.0002041	-0.0004741	-0.0004771	-0.0023711	-0.0042184
8.0	-0.0000064	0.0000022	-0.0000066	-0.0000147	-0.0000567	-0.0001378	-0.0001540	-0.0007735	-0.0013798
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0000057	0.0000033	0.0000309	0.0000335	0.0002041	0.0004741	0.0004771	0.0023711	0.0042184
11.0	0.0000039	0.0000180	0.0000618	0.0000662	0.0004451	0.0009840	0.0008360	0.0041260	0.0073103
12.0	0.0000032	0.0000617	0.0002110	0.0001422	0.0008911	0.0018546	0.0012569	0.0061526	0.0108362
13.0	0.0000092	0.0001966	0.0005442	0.0003016	0.0017443	0.0033999	0.0017709	0.0085666	0.0150109
14.0	0.0000924	0.0006254	0.0014042	0.0006515	0.0033719	0.0061254	0.0024157	0.0115851	0.0200733
15.0	0.0002171	0.0015239	0.0026838	0.0012932	0.0080278	0.0100549	0.0051365	0.0148754	0.0255290
15.1	0.0008633	0.0026684	0.0037065	0.0022184	0.0082294	0.0134444	0.0038202	0.0179887	0.0306618
16.1	0.0014174	0.0029187	0.0032313	0.0033070	0.0103356	0.0122882	0.0044008	0.0204791	0.0322415
16.2	0.0012645	0.0012672	0.0012224	0.0033655	0.0050655	0.0049685	0.0046390	0.0144743	0.0172412

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI =	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0007453	-0.0008224	-0.0007841	-0.0020871	-0.0058716	-0.0059967	-0.0027945	-0.0097043	-0.0128421
1.1	-0.0014960	-0.0029134	-0.0032170	-0.0034628	-0.0100869	-0.0119787	-0.0046625	-0.0202314	-0.0313039
1.2	-0.0007211	-0.0027357	-0.0037375	-0.0023438	-0.0093201	-0.0134604	-0.0039928	-0.0181838	-0.0308798
2.1	-0.0002355	-0.0015557	-0.0027147	-0.0013628	-0.0061083	-0.0101231	-0.0032599	-0.0149695	-0.0258427
3.0	-0.0000572	-0.0006367	-0.0014214	-0.0006629	-0.0034111	-0.0061675	-0.0024767	-0.0116488	-0.0201337
4.0	-0.0000100	-0.0001999	-0.0005493	-0.0003079	-0.0017548	-0.0034130	-0.0017658	-0.0085838	-0.0150098
5.0	-0.0000021	-0.0000598	-0.0002090	-0.0001258	-0.0008753	-0.0018405	-0.0011656	-0.0060659	-0.0107735
6.0	0.0000027	-0.0000078	-0.0000702	-0.0000198	-0.0003983	-0.0009367	-0.0006932	-0.0039980	-0.0071841
7.0	0.0000209	0.0000298	0.0000008	0.0000053	-0.0001012	-0.0003810	-0.0002524	-0.0021579	-0.0040139
8.0	0.0001708	0.0001138	0.0000733	0.0000019	0.0000018	-0.0000025	0.0000098	-0.0004785	-0.0011161
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0000209	-0.0000298	-0.0000008	-0.0000753	0.0001012	0.0003810	0.0002524	0.0021579	0.0040139
11.0	-0.0000027	0.0000078	0.0000702	0.0000198	0.0003983	0.0009367	0.0006932	0.0039980	0.0071841
12.0	0.0000021	0.0000598	0.0002090	0.0001258	0.0008753	0.0018405	0.0011656	0.0060659	0.0107735
13.0	0.0000100	0.0001999	0.0005493	0.0003079	0.0017548	0.0034130	0.0017658	0.0085838	0.0150098
14.0	0.0000572	0.0006367	0.0014214	0.0006629	0.0034111	0.0061675	0.0024767	0.0116488	0.0201337
15.0	0.0002355	0.0015557	0.0027147	0.0013628	0.0061083	0.0101231	0.0032599	0.0149695	0.0258427
15.1	0.0007211	0.0027357	0.0037375	0.0023438	0.0093201	0.0134604	0.0039928	0.0181838	0.0308798
16.1	0.0014960	0.0029134	0.0032170	0.0034628	0.0100869	0.0119787	0.0046625	0.0202314	0.0313039
16.2	0.0007453	0.0008224	0.0007841	0.0020871	0.0058716	0.0059967	0.0027945	0.0097043	0.0128421

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	0.1265469	0.0257674	0.0135798	0.3367386	0.1017464	0.0551741	0.4634097	0.2899607	0.1915529
1.1	0.1422428	0.0363739	0.0359152	.0.3307986	0.2088972	0.1364979	0.4399178	0.4098774	0.3562240
1.2	0.0667734	0.0537463	0.0411865	0.2221173	0.1845712	0.1493672	0.3616775	0.3593790	0.3409014
2.1	0.0221461	0.0304410	0.0298277	0.1297181	0.1205246	0.1116975	0.3135700	0.2975174	0.2836446
3.0	0.0055727	0.0124898	0.0156104	0.0655275	0.0674141	0.0680400	0.2415436	0.2317121	0.2230264
4.0	0.0010421	0.0039133	0.0060506	0.0303497	0.0348779	0.0377700	0.1771168	0.1717454	0.1667780
5.0	0.0001875	0.0012414	0.0023443	0.0141054	0.0178352	0.0206178	0.1257673	0.1230800	0.1203903
6.0	0.0000916	0.0005970	0.0009010	0.0063944	0.0089386	0.0108800	0.0837516	0.0825300	0.0812067
7.0	0.0001077	0.0001285	0.0003264	0.0026336	0.0041386	0.0053123	0.0479028	0.0474383	0.0468475
8.0	0.0002182	0.0000377	0.0000715	0.0005239	0.0012047	0.0015697	0.0155962	0.0154932	0.0152960
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0001077	-0.0001285	-0.0003264	-0.0026336	-0.0041386	-0.0053123	-0.0479028	-0.0474383	-0.0468475
11.0	-0.0000916	-0.0005970	-0.0009010	-0.0063944	-0.0089386	-0.0108800	-0.0837516	-0.0825300	-0.0812067
12.0	-0.0001875	-0.0012414	-0.0023443	-0.0141054	-0.0178352	-0.0206178	-0.1257673	-0.1230800	-0.1203903
13.0	-0.0010421	-0.0039133	-0.0060506	-0.0303497	-0.0348779	-0.0377700	-0.1771168	-0.1717454	-0.1667780
14.0	-0.0055727	-0.0124898	-0.0156104	-0.0655275	-0.0674141	-0.0680400	-0.2415436	-0.2317121	-0.2230264
15.0	-0.0221461	-0.0304410	-0.0298277	-0.1297181	-0.1205246	-0.1116975	-0.3135700	-0.2975174	-0.2836446
15.1	-0.0667734	-0.0537463	-0.0411865	-0.2221173	-0.1845712	-0.1493672	-0.3616775	-0.3593790	-0.3409014
16.1	-0.1422428	-0.0363739	-0.0359152	-0.3307986	-0.2088972	-0.1364979	-0.4399178	-0.4098774	-0.3562240
16.2	-0.1265469	-0.0257674	-0.0135798	-0.3367386	-0.1017464	-0.0551741	-0.4634097	-0.2899607	-0.1915529

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	0.0662537	0.0151959	0.0079469	0.1711515	0.0694128	0.0403931	0.2244331	0.1611998	0.1211946
1.1	0.1436015	0.0572101	0.0352490	0.3242451	0.1943753	0.1288080	0.4378222	0.3896217	0.3338814
1.2	0.0697253	0.0542483	0.0412985	0.2238468	0.1841423	0.1479498	0.3817482	0.3609306	0.3412737
2.1	0.0231355	0.0309394	0.0300956	0.1304835	0.1210119	0.1118291	0.3133155	0.2970263	0.2833450
3.0	0.0058118	0.0126843	0.0157791	0.0658866	0.0676931	0.0682468	0.2413517	0.2315644	0.2228507
4.0	0.0010988	0.0039834	0.0061189	0.0305304	0.0350256	0.0378935	0.1769794	0.1715962	0.1666380
5.0	0.0001881	0.0012605	0.0023689	0.0141782	0.0179033	0.0206811	0.1256887	0.1229628	0.1202909
6.0	0.0000535	0.0004030	0.0009106	0.0064333	0.0089783	0.0109969	0.0836863	0.0824626	0.0811414
7.0	0.0001088	0.0001306	0.0003304	0.0026478	0.0041534	0.0053281	0.0478655	0.0474003	0.0468090
8.0	0.0002248	0.0000405	0.0000734	0.0005344	0.0012136	0.0015968	0.0155840	0.0154808	0.0152855
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0001088	-0.0001306	-0.0003304	-0.0026478	-0.0041534	-0.0053281	-0.0478655	-0.0474003	-0.0468090
11.0	-0.0000535	-0.0004030	-0.0009106	-0.0064333	-0.0089783	-0.0109969	-0.0836863	-0.0824626	-0.0811414
12.0	-0.0001881	-0.0012605	-0.0023689	-0.0141762	-0.0179033	-0.0206811	-0.1256887	-0.1229628	-0.1202909
13.0	-0.0010988	-0.0039834	-0.0061189	-0.0305304	-0.0350256	-0.0378935	-0.1769794	-0.1715962	-0.1666380
14.0	-0.0058118	-0.0126843	-0.0157791	-0.0658866	-0.0676931	-0.0682468	-0.2413517	-0.2315644	-0.2228507
15.0	-0.0231355	-0.0309394	-0.0300956	-0.1304835	-0.1210119	-0.1118291	-0.3133155	-0.2970263	-0.2633450
15.1	-0.0697253	-0.0542483	-0.0412985	-0.2238468	-0.1841423	-0.1479498	-0.3817482	-0.3609306	-0.3412737
16.1	-0.1436015	-0.0572101	-0.0352490	-0.3242451	-0.1943753	-0.1288080	-0.4378222	-0.3896217	-0.3338814
16.2	-0.0662537	-0.0151959	-0.0079469	-0.1711515	-0.0694128	-0.0403931	-0.2244331	-0.1611998	-0.1211946

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0368203	-0.1013965	-0.1402231	-0.0167965	-0.0741690	-0.1130517	-0.0044975	-0.0298207	-0.0531397
1.1	-0.0156557	-0.0695079	-0.1063248	-0.0080540	-0.0470115	-0.0618085	-0.0051785	-0.0158245	-0.0317127
1.2	-0.0094713	-0.0344692	-0.0623293	-0.0080372	-0.0265772	-0.0489104	-0.0030361	-0.0141766	-0.0241474
2.1	-0.0018033	-0.0134201	-0.0292392	-0.0035125	-0.0159842	-0.0283072	-0.0025476	-0.0121991	-0.0211273
3.0	-0.0003601	-0.0043973	-0.0114467	-0.0017986	-0.0090072	-0.0162277	-0.0020683	-0.0100020	-0.0175179
4.0	-0.0000660	-0.0012763	-0.0039455	-0.0007779	-0.0044562	-0.0086519	-0.0016129	-0.0079303	-0.0141466
5.0	-0.0000092	-0.0003958	-0.0014301	-0.0003733	-0.0023213	-0.0047944	-0.0012677	-0.0064326	-0.0116560
6.0	0.0000021	-0.0001263	-0.0005350	-0.0001731	-0.0012147	-0.0026979	-0.0010536	-0.0053726	-0.0098466
7.0	0.0000034	-0.0000416	-0.0002068	-0.0000828	-0.0006573	-0.0015809	-0.0008966	-0.0046520	-0.0086339
8.0	0.0000017	-0.0000153	-0.0000693	-0.0000455	-0.0004014	-0.0010413	-0.0008090	-0.0042353	-0.0079295
9.0	0.0000066	-0.0000053	-0.0000302	-0.0000011	-0.0003130	-0.0008790	-0.0007810	-0.0040900	-0.0077000
10.0	0.0000017	-0.0000153	-0.0000693	-0.0000455	-0.0004014	-0.0010413	-0.0008090	-0.0042353	-0.0079295
11.0	0.0000034	-0.0000416	-0.0002068	-0.0000828	-0.0006573	-0.0015809	-0.0008966	-0.0046520	-0.0086339
12.0	0.0000021	-0.0001263	-0.0005350	-0.0001731	-0.0012147	-0.0026979	-0.0010536	-0.0053726	-0.0098466
13.0	-0.0000092	-0.0003958	-0.0014301	-0.0003733	-0.0023213	-0.0047944	-0.0012677	-0.0064326	-0.0116560
14.0	-0.0000660	-0.0012763	-0.0039455	-0.0007779	-0.0044562	-0.0086519	-0.0016129	-0.0079303	-0.0141466
15.0	-0.0003601	-0.0043973	-0.0114467	-0.0017986	-0.0090072	-0.0162277	-0.0020683	-0.0100020	-0.0175179
15.1	-0.0018033	-0.0134201	-0.0292392	-0.0035125	-0.0159842	-0.0283072	-0.0025476	-0.0121991	-0.0211273
16.1	-0.0094713	-0.0344692	-0.0623293	-0.0080372	-0.0265772	-0.0489104	-0.0030361	-0.0141766	-0.0241474
16.2	-0.0156557	-0.0695079	-0.1063248	-0.0080540	-0.0470115	-0.0618083	-0.0051785	-0.0158245	-0.0317127

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0254248	-0.0852821	-0.1231895	-0.0093009	-0.0594538	-0.0967738	0.0002282	-0.0199438	-0.0403094
1.1	-0.0184654	-0.0718451	-0.1082803	-0.0090562	-0.0495634	-0.0840354	-0.0026868	-0.0174676	-0.0341633
1.2	-0.0058988	-0.0355053	-0.0634089	-0.0082906	-0.0271972	-0.0498051	-0.0034055	-0.0141889	-0.0242755
2.1	-0.0017463	-0.0137789	-0.0297156	-0.0037315	-0.0162156	-0.0266329	-0.0027102	-0.0124376	-0.0213368
3.0	-0.0003880	-0.0045022	-0.0116213	-0.0019030	-0.0091407	-0.0163837	-0.0022529	-0.0101722	-0.0176966
4.0	-0.0000746	-0.0013084	-0.0040057	-0.0008331	-0.0045349	-0.0087471	-0.0017752	-0.0081203	-0.0143198
5.0	-0.0000118	-0.0004110	-0.0014619	-0.0004268	-0.0023919	-0.0048777	-0.0014548	-0.0068215	-0.0118276
6.0	-0.0000083	-0.0001507	-0.0005769	-0.0002408	-0.0013002	-0.0027949	-0.0012317	-0.0055518	-0.0100288
7.0	-0.0000357	-0.0001118	-0.0003076	-0.0002390	-0.0008088	-0.0017308	-0.0011054	-0.0048602	-0.0088415
8.0	-0.0001285	-0.0002733	-0.0003926	-0.0002751	-0.0006393	-0.0013030	-0.0010518	-0.0044592	-0.0081432
9.0	-0.0007813	-0.0010071	-0.0010451	-0.0009500	-0.0012200	-0.0017100	-0.0011000	-0.0044500	-0.0080800
10.0	-0.0001285	-0.0002733	-0.0003926	-0.0002751	-0.0006393	-0.0013030	-0.0010518	-0.0044592	-0.0081432
11.0	-0.0000357	-0.0001118	-0.0003076	-0.0002390	-0.0008088	-0.0017308	-0.0011054	-0.0048602	-0.0088415
12.0	-0.0000083	-0.0001507	-0.0005769	-0.0002408	-0.0013002	-0.0027949	-0.0012317	-0.0055518	-0.0100288
13.0	-0.0000118	-0.0004110	-0.0014619	-0.0004268	-0.0023919	-0.0048777	-0.0014548	-0.0068215	-0.0118276
14.0	-0.0000746	-0.0013084	-0.0040057	-0.0008331	-0.0045349	-0.0087471	-0.0017752	-0.0081203	-0.0143198
15.0	-0.0003880	-0.0045022	-0.0116213	-0.0019030	-0.0091407	-0.0163837	-0.0022529	-0.0101722	-0.0176966
15.1	-0.0017463	-0.0137789	-0.0297156	-0.0037315	-0.0162156	-0.0266329	-0.0027102	-0.0124376	-0.0213368
16.1	-0.0058988	-0.0355053	-0.0634089	-0.0082906	-0.0271972	-0.0498051	-0.0034055	-0.0141889	-0.0242755
16.2	-0.0184654	-0.0718451	-0.1082803	-0.0090562	-0.0495634	-0.0840354	-0.0026868	-0.0174676	-0.0341633

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	3.6785687	2.0279541	1.5580228	1.6768021	1.4854348	1.2559500	0.4510054	0.5963117	0.5904786
1.1	1.5828158	1.3901824	1.1813666	0.8057842	0.9405492	0.9090275	0.3186840	0.3169090	0.3523870
1.2	0.5473540	0.6694355	0.6825439	0.6035193	0.5316188	0.5434787	0.3055424	0.2835258	0.2663066
2.1	0.1609617	0.2684427	0.3248770	0.3512671	0.3197389	0.3145446	0.2545353	0.2439698	0.2347523
3.0	0.0363069	0.0879558	0.1271847	0.1798520	0.1801267	0.1803026	0.2067044	0.2000378	0.1946452
4.0	0.0071719	0.0255359	0.0438430	0.0777748	0.0890593	0.0961048	0.1611250	0.1590021	0.1572187
5.0	0.0013544	0.0078674	0.0158964	0.0374142	0.0463392	0.0532323	0.1266053	0.1290482	0.1295254
6.0	0.0001399	0.0024693	0.0059567	0.0175257	0.0242032	0.0299317	0.1052439	0.1074463	0.1094509
7.0	-0.0001936	0.0007830	0.0023182	0.0085646	0.0130664	0.0175207	0.0897887	0.0930217	0.0958543
8.0	-0.0002519	0.0002652	0.0010105	0.0048681	0.0079739	0.0115338	0.0806933	0.0846860	0.0881282
9.0	-0.0002351	-0.0000583	0.0003131	0.0037200	0.0064600	0.0097300	0.0780000	0.0819000	0.0853000
10.0	-0.0002519	0.0002652	0.0010105	0.0048681	0.0079739	0.0115338	0.0806933	0.0846860	0.0881282
11.0	-0.0001936	0.0007830	0.0023182	0.0085646	0.0130664	0.0175207	0.0897887	0.0930217	0.0958543
12.0	0.0001399	0.0024693	0.0059567	0.0175257	0.0242032	0.0299317	0.1052439	0.1074463	0.1094509
13.0	0.0013544	0.0078674	0.0158964	0.0374142	0.0463392	0.0532323	0.1266053	0.1290482	0.1295254
14.0	0.0071719	0.0255359	0.0438430	0.0777748	0.0890593	0.0961048	0.1611250	0.1590021	0.1572187
15.0	0.0363069	0.0879558	0.1271847	0.1798520	0.1801267	0.1803026	0.2067044	0.2000378	0.1946452
15.1	0.1609617	0.2684427	0.3248770	0.3512671	0.3197389	0.3145446	0.2545353	0.2439698	0.2347523
16.1	0.5473540	0.6694355	0.6825439	0.6035193	0.5316188	0.5434787	0.3055424	0.2835258	0.2663066
16.2	1.5828158	1.3901824	1.1813666	0.8057842	0.9405492	0.9090275	0.3186840	0.3169090	0.3523870

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	2.0029015	1.6930806	1.3528759	1.2221170	1.1992522	1.0681196	0.3963611	0.4562787	0.4673815
1.1	1.8750192	1.4416738	1.2056867	0.9747160	1.0087012	0.9424099	0.3475631	0.3760104	0.3989453
1.2	0.5731961	0.7111317	0.7057642	0.5820980	0.5423680	0.5546684	0.2971378	0.2746378	0.2662733
2.1	0.1674991	0.2752345	0.3304394	0.3575220	0.3211848	0.3170942	0.2557531	0.2454497	0.2347968
3.0	0.0361058	0.0897833	0.1291030	0.1801346	0.1808649	0.1809991	0.2062012	0.1995091	0.1944419
4.0	0.0072996	0.0259852	0.0444229	0.0783405	0.0894207	0.0964139	0.1610918	0.1569864	0.1570950
5.0	0.0014897	0.0080139	0.0160951	0.0376630	0.0485491	0.0534107	0.1284798	0.1289203	0.1294164
6.0	0.0001397	0.0025124	0.0060284	0.0175753	0.0242881	0.0300228	0.1051685	0.1073653	0.1093607
7.0	-0.0001985	0.0007945	0.0023417	0.0066479	0.0131298	0.0175802	0.0897161	0.0929442	0.0958741
8.0	-0.0002939	0.0002648	0.0010199	0.0048515	0.0079959	0.0115873	0.0808309	0.0846177	0.0660535
9.0	-0.0001980	-0.0000320	0.0003294	0.0037900	0.0063000	0.0097700	0.0779000	0.0819000	0.0653000
10.0	-0.0002939	0.0002648	0.0010199	0.0048515	0.0079959	0.0115873	0.0808309	0.0846177	0.0660535
11.0	-0.0001985	0.0007945	0.0023417	0.0066479	0.0131298	0.0175802	0.0897161	0.0929442	0.0958741
12.0	0.0001397	0.0025124	0.0060284	0.0175753	0.0242881	0.0300228	0.1051685	0.1073653	0.1093607
13.0	0.0014897	0.0080139	0.0160951	0.0376630	0.0485491	0.0534107	0.1284798	0.1289203	0.1294164
14.0	0.0072996	0.0259852	0.0444229	0.0783405	0.0894207	0.0964139	0.1610918	0.1569864	0.1570950
15.0	0.0361058	0.0897833	0.1291030	0.1801346	0.1808649	0.1809991	0.2062012	0.1995091	0.1944419
15.1	0.1674991	0.2752345	0.3304394	0.3575220	0.3211848	0.3170942	0.2557531	0.2454497	0.2347968
16.1	0.5731961	0.7111317	0.7057642	0.5820980	0.5423680	0.5546684	0.2971378	0.2746378	0.2662733
16.2	1.8750192	1.4416738	1.2056867	0.9747160	1.0087012	0.9424099	0.3475631	0.3760104	0.3989453

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	0.0005423	0.0023343	0.0063316	0.0001080	0.0018291	0.0050608	0.0000313	0.0008315	0.0025805
1.1	0.0005079	0.0022105	0.0061482	0.0000955	0.0017436	0.0049186	0.0000296	0.0008046	0.0024951
1.2	0.0004216	0.0016390	0.0051726	0.0000703	0.0013885	0.0042061	0.0000264	0.0007284	0.0022872
2.1	0.0003470	0.0008510	0.0034803	0.0000456	0.0009139	0.0030298	0.0000226	0.0006265	0.0019913
3.0	0.0002793	0.0002870	0.0018502	0.0000265	0.0005191	0.0018787	0.0000186	0.0005190	0.0016651
4.0	0.0001956	0.0000461	0.0008064	0.0000141	0.0002645	0.0010442	0.0000150	0.0004135	0.0013470
5.0	0.0001162	-0.0000104	0.0003343	0.0000072	0.0001351	0.0005790	0.0000124	0.0003353	0.0011088
6.0	0.0000531	-0.0000107	0.0001342	0.0000034	0.0000715	0.0003266	0.0000105	0.0002794	0.0009367
7.0	0.0000147	-0.0000023	0.0000523	0.0000014	0.0000402	0.0001929	0.0000092	0.0002420	0.0008205
8.0	0.0000001	0.0000015	0.0000217	0.0000005	0.0000254	0.0001278	0.0000083	0.0002205	0.0007535
9.0	0.0000000	0.0000005	0.0000078	0.0000004	0.0000207	0.0001080	0.0000080	0.0002130	0.0007310
10.0	0.0000001	0.0000015	0.0000217	0.0000005	0.0000254	0.0001278	0.0000083	0.0002205	0.0007535
11.0	0.0000147	-0.0000023	0.0000523	0.0000014	0.0000402	0.0001929	0.0000092	0.0002420	0.0008205
12.0	0.0000531	-0.0000107	0.0001342	0.0000034	0.0000715	0.0003266	0.0000105	0.0002794	0.0009367
13.0	0.0001162	-0.0000104	0.0003343	0.0000072	0.0001351	0.0005790	0.0000124	0.0003353	0.0011088
14.0	0.0001956	0.0000461	0.0008064	0.0000141	0.0002645	0.0010442	0.0000150	0.0004135	0.0013470
15.0	0.0002793	0.0002870	0.0018502	0.0000265	0.0005191	0.0018787	0.0000186	0.0005190	0.0016651
15.1	0.0003470	0.0008510	0.0034803	0.0000456	0.0009139	0.0030298	0.0000226	0.0006265	0.0019913
16.1	0.0004216	0.0016390	0.0051726	0.0000703	0.0013885	0.0042061	0.0000264	0.0007284	0.0022872
16.2	0.0005079	0.0022105	0.0061482	0.0000955	0.0017436	0.0049186	0.0000296	0.0008046	0.0024951

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	0.0004890	0.0023132	0.0063042	0.0001146	0.0018173	0.0050401	0.0000329	0.0008329	0.0025510
1.1	0.0004639	0.0022067	0.0061434	0.0001067	0.0017485	0.0049183	0.0000319	0.0008146	0.0025095
1.2	0.0003799	0.0016564	0.0051963	0.0000803	0.0014053	0.0042288	0.0000285	0.0007396	0.0023079
2.1	0.0003046	0.0008863	0.0035095	0.0000536	0.0009270	0.0030540	0.0000245	0.0006385	0.0020100
3.0	0.0002427	0.0002935	0.0018705	0.0000325	0.0005270	0.0018959	0.0000203	0.0005283	0.0016824
4.0	0.0001698	0.0000461	0.0008174	0.0000181	0.0002695	0.0010556	0.0000167	0.0004222	0.0013632
5.0	0.0001012	-0.0000091	0.0003414	0.0000097	0.0001393	0.0005889	0.0000141	0.0003441	0.0011250
6.0	0.0000465	-0.0000084	0.0001425	0.0000051	0.0000770	0.0003386	0.0000124	0.0002888	0.0009539
7.0	0.0000136	0.0000053	0.0000897	0.0000032	0.0000495	0.0002112	0.0000113	0.0002526	0.0008398
8.0	0.0000040	0.0000222	0.0000571	0.0000041	0.0000432	0.0001569	0.0000108	0.0002330	0.0007760
9.0	0.0000031	0.0000208	0.0000437	0.0000075	0.0000490	0.0001520	0.0000111	0.0002290	0.0007580
10.0	0.0000040	0.0000222	0.0000571	0.0000041	0.0000432	0.0001569	0.0000108	0.0002330	0.0007760
11.0	0.0000136	0.0000053	0.0000897	0.0000032	0.0000495	0.0002112	0.0000113	0.0002526	0.0008398
12.0	0.0000465	-0.0000084	0.0001425	0.0000051	0.0000770	0.0003386	0.0000124	0.0002888	0.0009539
13.0	0.0001012	-0.0000091	0.0003414	0.0000097	0.0001393	0.0005889	0.0000141	0.0003441	0.0011250
14.0	0.0001698	0.0000461	0.0008174	0.0000181	0.0002695	0.0010556	0.0000167	0.0004222	0.0013632
15.0	0.0002427	0.0002935	0.0018705	0.0000325	0.0005270	0.0018959	0.0000203	0.0005283	0.0016824
15.1	0.0003046	0.0008863	0.0035095	0.0000536	0.0009270	0.0030540	0.0000245	0.0006385	0.0020100
16.1	0.0003799	0.0016564	0.0051963	0.0000803	0.0014053	0.0042288	0.0000285	0.0007396	0.0023079
16.2	0.0004639	0.0022067	0.0061434	0.0001067	0.0017485	0.0049183	0.0000319	0.0008146	0.0025095

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0277996	-0.0908273	-0.0682320	-0.0065230	-0.0373313	-0.0567166	-0.0035725	-0.0166790	-0.0282704
1.1	-0.0244203	-0.0463303	-0.0671965	-0.0072782	-0.0356181	-0.0551362	-0.0053927	-0.0161414	-0.0276548
1.2	-0.0165498	-0.0366346	-0.0563763	-0.0047878	-0.0288972	-0.0472094	-0.0030515	-0.0146156	-0.0253461
2.1	-0.0113217	-0.0206192	-0.0376378	-0.0024322	-0.0191438	-0.0341091	-0.0026094	-0.0126169	-0.0220601
3.0	-0.0067905	-0.0069794	-0.0196663	-0.0007693	-0.0111122	-0.0212534	-0.0021277	-0.0104245	-0.0164419
4.0	-0.0066934	-0.0032505	-0.0063037	0.0000445	-0.0058090	-0.0118766	-0.0016664	-0.0083063	-0.0149188
5.0	-0.0044766	-0.0011694	-0.0033027	0.0002445	-0.0030146	-0.0066025	-0.0013266	-0.0067337	-0.0122666
6.0	-0.0023347	-0.0004343	-0.0012906	0.0001766	-0.0015762	-0.0037114	-0.0010642	-0.0056052	-0.0103663
7.0	-0.0007565	-0.0001366	-0.0003214	0.0000507	-0.0006493	-0.0021696	-0.0009222	-0.0046474	-0.0091065
8.0	-0.0000263	-0.0000317	-0.0002394	-0.0000290	-0.0005113	-0.0014223	-0.0008295	-0.0044117	-0.0083704
9.0	-0.0000011	-0.0000106	-0.0000874	-0.0000404	-0.0004160	-0.0012000	-0.0007990	0.0042700	-0.0081300
10.0	-0.0000263	-0.0000317	-0.0002394	-0.0000290	-0.0005113	-0.0014223	-0.0008295	-0.0044117	-0.0083704
11.0	-0.0007565	-0.0001366	-0.0003214	0.0000507	-0.0006493	-0.0021696	-0.0009222	-0.0046474	-0.0091065
12.0	-0.0023347	-0.0004343	-0.0012906	0.0001766	-0.0015762	-0.0037114	-0.0010642	-0.0056052	-0.0103663
13.0	-0.0044766	-0.0011694	-0.0033027	0.0002445	-0.0030146	-0.0066025	-0.0013266	-0.0067337	-0.0122666
14.0	-0.0066934	-0.0032505	-0.0063037	0.0000445	-0.0058090	-0.0118766	-0.0016664	-0.0083063	-0.0149188
15.0	-0.0067905	-0.0069794	-0.0196663	-0.0007693	-0.0111122	-0.0212534	-0.0021277	-0.0104245	-0.0164419
15.1	-0.0113217	-0.0206192	-0.0376378	-0.0024322	-0.0191438	-0.0341091	-0.0026094	-0.0126169	-0.0220601
16.1	-0.0165498	-0.0366346	-0.0563763	-0.0047878	-0.0288972	-0.0472094	-0.0030515	-0.0146156	-0.0253461
16.2	-0.0244203	-0.0463303	-0.0671965	-0.0072782	-0.0356181	-0.0551362	-0.0053927	-0.0161414	-0.0276548

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB D2)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0260575	-0.0493876	-0.0679407	-0.0078744	-0.0365377	-0.0557044	-0.0034758	-0.0163616	-0.0278698
1.1	-0.0240413	-0.0474576	-0.0662618	-0.0072281	-0.0353067	-0.0544708	-0.0033687	-0.0160613	-0.0274784
1.2	-0.0168750	-0.0368257	-0.0561702	-0.0048426	-0.0287223	-0.0470919	-0.0030495	-0.0148134	-0.0253311
2.1	-0.0114308	-0.0210178	-0.0377571	-0.0024502	-0.0192211	-0.0341730	-0.0026073	-0.0126048	-0.0220411
3.0	-0.0066062	-0.0090960	-0.0198093	-0.0007827	-0.0111577	-0.0213179	-0.0021260	-0.0104165	-0.0184268
4.0	-0.0066977	-0.0033019	-0.0063878	0.0000386	-0.0056326	-0.0119145	-0.0016651	-0.0082996	-0.0149065
5.0	-0.0044670	-0.0012030	-0.0033379	0.0002413	-0.0050261	-0.0086230	-0.0013256	-0.0067284	-0.0122768
6.0	-0.0023314	-0.0004392	-0.0013057	0.0001748	-0.0015827	-0.0037234	-0.0010834	-0.0056007	-0.0103797
7.0	-0.0007582	-0.0001413	-0.0005285	0.0000500	-0.0008525	-0.0021768	-0.0009215	-0.0048435	-0.0091010
8.0	-0.0000280	-0.0000341	-0.0002436	-0.0000294	-0.0005137	-0.0014271	-0.0008268	-0.0044081	-0.0083635
9.0	-0.0000003	-0.0000097	-0.0000875	-0.0000405	-0.0004180	-0.0012100	-0.0007980	-0.0042700	-0.0081200
10.0	-0.0000280	-0.0000341	-0.0002436	-0.0000294	-0.0005137	-0.0014271	-0.0008268	-0.0044081	-0.0083635
11.0	-0.0007582	-0.0001413	-0.0005285	0.0000500	-0.0008525	-0.0021768	-0.0009215	-0.0048435	-0.0091010
12.0	-0.0023314	-0.0004392	-0.0013057	0.0001748	-0.0015827	-0.0037234	-0.0010834	-0.0056007	-0.0103797
13.0	-0.0044670	-0.0012030	-0.0033379	0.0002413	-0.0050261	-0.0086230	-0.0013256	-0.0067284	-0.0122768
14.0	-0.0066977	-0.0033019	-0.0063878	0.0000386	-0.0056326	-0.0119145	-0.0016651	-0.0082996	-0.0149065
15.0	-0.0066062	-0.0090960	-0.0198093	-0.0007827	-0.0111577	-0.0213179	-0.0021260	-0.0104165	-0.0184268
15.1	-0.0114308	-0.0210178	-0.0377571	-0.0024502	-0.0192211	-0.0341730	-0.0026073	-0.0126048	-0.0220411
16.1	-0.0168750	-0.0368257	-0.0561702	-0.0048426	-0.0287223	-0.0470919	-0.0030495	-0.0148134	-0.0253311
16.2	-0.0240413	-0.0474576	-0.0662618	-0.0072281	-0.0353067	-0.0544708	-0.0033687	-0.0160613	-0.0274784

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	-0.0000000	-0.0000000	0.0000000	0.0000000	-0.0000000	0.0000000
1.1	0.0019334	0.0066076	0.0095831	0.0009264	0.0046874	0.0075824	0.0002942	0.0017702	0.0033054
1.2	0.0023564	0.0128068	0.0208688	0.0016266	0.0082416	0.0163990	0.0007236	0.0036525	0.0072968
2.1	0.0013853	0.0122975	0.0239724	0.0018503	0.0104919	0.0200343	0.0011904	0.0060801	0.0110518
3.0	0.0008485	0.0072349	0.0176051	0.0014762	0.0087208	0.0174760	0.0015005	0.0075697	0.0137112
4.0	0.0002022	0.0026950	0.0068310	0.0008804	0.0055631	0.0118813	0.0015302	0.0077429	0.0140705
5.0	0.0001309	0.0008811	0.0035202	0.0004316	0.0029506	0.0065429	0.0013165	0.0067183	0.0123014
6.0	0.0001010	0.0002043	0.0011575	0.0001829	0.0013483	0.0031626	0.0009941	0.0051250	0.0094670
7.0	0.0000591	0.0000243	0.0002977	0.0000657	0.0005228	0.0013008	0.0006478	0.0033722	0.0062807
8.0	0.0000167	-0.0000024	0.0000486	0.0000183	0.0001592	0.0004201	0.0003156	0.0016546	0.0031002
9.0	-0.0000003	-0.0000008	-0.0000007	-0.0000004	-0.0000001	0.0000000	0.0000000	0.0000000	0.0000000
10.0	-0.0000167	0.0000024	-0.0000486	-0.0000183	-0.0001592	-0.0004201	-0.0003156	-0.0016546	-0.0031002
11.0	-0.0000591	-0.0000243	-0.0002977	-0.0000657	-0.0005228	-0.0013008	-0.0006478	-0.0033722	-0.0062807
12.0	-0.0001010	-0.0002043	-0.0011575	-0.0001829	-0.0013483	-0.0031626	-0.0009941	-0.0051250	-0.0094670
13.0	-0.0001309	-0.0008811	-0.0035202	-0.0004316	-0.0029506	-0.0065429	-0.0013165	-0.0067183	-0.0123014
14.0	-0.0002022	-0.0026950	-0.0068310	-0.0008804	-0.0055631	-0.0118813	-0.0015302	-0.0077429	-0.0140705
15.0	-0.0008485	-0.0072349	-0.0176051	-0.0014762	-0.0087208	-0.0174760	-0.0015005	-0.0075697	-0.0137112
15.1	-0.0013853	-0.0122975	-0.0239724	-0.0018503	-0.0104919	-0.0200343	-0.0011904	-0.0060801	-0.0110518
16.1	-0.0023564	-0.0128068	-0.0208688	-0.0016266	-0.0082416	-0.0163990	-0.0007236	-0.0036525	-0.0072968
16.2	-0.0019334	-0.0066076	-0.0095831	-0.0009264	-0.0046874	-0.0075824	-0.0002942	-0.0017702	-0.0033054

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	-0.0000000	-0.0000000	0.0000000	0.0000000	-0.0000000	0.0000000
1.1	0.0018067	0.0063394	0.0092676	0.0009455	0.0044602	0.0072976	0.0003466	0.0017106	0.0031609
1.2	0.0025526	0.0128703	0.0206369	0.0017279	0.0093204	0.0164005	0.0007650	0.0039254	0.0073254
2.1	0.0014821	0.0124862	0.0241315	0.0019543	0.0106380	0.0201784	0.0012845	0.0081516	0.0111499
3.0	0.0005822	0.0073770	0.0177837	0.0015863	0.0088492	0.0176339	0.0016276	0.0077037	0.0138491
4.0	0.0001891	0.0029206	0.0069446	0.0009464	0.0056615	0.0118077	0.0016963	0.0079047	0.0142375
5.0	0.0001209	0.0009146	0.0035944	0.0004906	0.0050367	0.0066539	0.0014863	0.0066939	0.0124819
6.0	0.0000948	0.0002534	0.0012475	0.0002652	0.0014549	0.0032911	0.0011637	0.0052994	0.0096435
7.0	0.0001061	0.0001536	0.0004643	0.0001862	0.0006676	0.0014655	0.0007971	0.0035246	0.0064360
8.0	0.0002240	0.0002264	0.0002709	0.0001829	0.0003403	0.0006036	0.0004141	0.0017581	0.0032074
9.0	0.0000001	0.0000001	0.0000001	-0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000
10.0	-0.0002240	-0.0002264	-0.0002709	-0.0001829	-0.0003403	-0.0006036	-0.0004141	-0.0017581	-0.0032074
11.0	-0.0001061	-0.0001536	-0.0004643	-0.0001862	-0.0006676	-0.0014655	-0.0007971	-0.0035246	-0.0064360
12.0	-0.0000948	-0.0002534	-0.0012475	-0.0002652	-0.0014549	-0.0032911	-0.0011637	-0.0052994	-0.0096435
13.0	-0.0001209	-0.0009146	-0.0035944	-0.0004906	-0.0050367	-0.0066539	-0.0014863	-0.0066938	-0.0124819
14.0	-0.0001891	-0.0029206	-0.0069446	-0.0009464	-0.0056615	-0.0118077	-0.0016963	-0.0079047	-0.0142375
15.0	-0.0005822	-0.0073770	-0.0177837	-0.0015863	-0.0088492	-0.0176339	-0.0016276	-0.0077037	-0.0138491
15.1	-0.0014821	-0.0124862	-0.0241315	-0.0019543	-0.0106380	-0.0201784	-0.0012845	-0.0081516	-0.0111499
16.1	-0.0025526	-0.0128703	-0.0206369	-0.0017279	-0.0093204	-0.0164005	-0.0007650	-0.0039254	-0.0073254
16.2	-0.0018067	-0.0063394	-0.0092676	-0.0009455	-0.0044602	-0.0072976	-0.0003466	-0.0017106	-0.0031609

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	0.0000000	0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000	0.0000000	-0.0000000	0.0000000
1.1	-0.1931161	-0.1321485	-0.1065902	-0.0926233	-0.0937546	-0.0842518	-0.0295078	-0.0353997	-0.0367291
1.2	-0.2344704	-0.2561306	-0.2316599	-0.1626764	-0.1848570	-0.1822222	-0.0725013	-0.0770478	-0.0806361
2.1	-0.1358822	-0.2460100	-0.2663307	-0.1849926	-0.2096909	-0.2226261	-0.1191595	-0.1211966	-0.1226039
3.0	-0.0493663	-0.1450149	-0.1955382	-0.1475849	-0.1745230	-0.1942480	-0.1501272	-0.1513660	-0.1523532
4.0	-0.0114392	-0.0579072	-0.0979633	-0.0879426	-0.1114301	-0.1298671	-0.1530688	-0.1548408	-0.1563472
5.0	-0.0031455	-0.0187491	-0.0388970	-0.0429946	-0.0592063	-0.0727846	-0.1316805	-0.1343553	-0.1366931
6.0	-0.0020396	-0.0051622	-0.0126128	-0.0181054	-0.0271310	-0.0352144	-0.0994362	-0.1024873	-0.1052014
7.0	-0.0016694	-0.0011620	-0.0031253	-0.0064622	-0.0105523	-0.0144971	-0.0648034	-0.0674318	-0.0697958
8.0	-0.0008074	-0.0001670	-0.0004754	-0.0018252	-0.0032101	-0.0046775	-0.0315756	-0.0330854	-0.0344528
9.0	0.0000276	0.0000225	0.0000163	0.0000067	0.0000023	0.0000004	0.0000002	0.0000001	0.0000000
10.0	0.0008074	0.0001670	0.0004754	0.0018252	0.0032101	0.0046775	0.0315756	0.0330854	0.0344528
11.0	0.0016694	0.0011620	0.0031253	0.0064622	0.0105523	0.0144971	0.0648034	0.0674318	0.0697958
12.0	0.0020396	0.0051622	0.0126128	0.0181054	0.0271310	0.0352144	0.0994362	0.1024873	0.1052014
13.0	0.0031455	0.0187491	0.0388970	0.0429946	0.0592063	0.0727846	0.1316805	0.1343553	0.1366931
14.0	0.0114392	0.0579072	0.0979633	0.0879426	0.1114301	0.1298671	0.1530688	0.1548408	0.1563472
15.0	0.0493663	0.1450149	0.1955382	0.1475849	0.1745230	0.1942480	0.1501272	0.1513660	0.1523532
15.1	0.1358822	0.2460100	0.2663307	0.1849926	0.2096909	0.2226261	0.1191595	0.1211966	0.1226039
16.1	0.2344704	0.2561306	0.2316599	0.1626764	0.1848570	0.1822222	0.0725013	0.0770478	0.0806361
16.2	0.1931161	0.1321485	0.1065902	0.0926233	0.0937546	0.0842518	0.0295078	0.0353997	0.0367291

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000	0.0000000	-0.0000000	0.0000000
1.1	-0.1670294	-0.1207172	-0.0968971	-0.0829175	-0.0849031	-0.0775794	-0.0280921	-0.0317697	-0.0330574
1.2	-0.2443130	-0.2532466	-0.2284337	-0.1681486	-0.1839387	-0.1800612	-0.0728752	-0.0776920	-0.0807467
2.1	-0.1418780	-0.2478228	-0.2663760	-0.1854163	-0.2107259	-0.2227705	-0.1189445	-0.1209308	-0.1226735
3.0	-0.0512114	-0.1469778	-0.1967306	-0.1485645	-0.1752472	-0.1948205	-0.1500393	-0.1513011	-0.1522323
4.0	-0.0124319	-0.0589060	-0.0968721	-0.0884179	-0.1118910	-0.1302848	-0.1529447	-0.1547170	-0.1562171
5.0	-0.0029634	-0.0190052	-0.0392637	-0.0432205	-0.0594401	-0.0730135	-0.1315778	-0.1342470	-0.1365800
6.0	-0.0019946	-0.0052263	-0.0127380	-0.0182171	-0.0272474	-0.0353298	-0.0993568	-0.1024045	-0.1051143
7.0	-0.0016836	-0.0011847	-0.0031615	-0.0064936	-0.0105930	-0.0145423	-0.0647526	-0.0673772	-0.0697381
8.0	-0.0008784	-0.0001823	-0.0004868	-0.0018440	-0.0032255	-0.0046935	-0.0315510	-0.0330589	-0.0344242
9.0	0.0000119	0.0000102	0.0000076	0.0000032	0.0000010	0.0000001	0.0000000	0.0000000	0.0000000
10.0	0.0008784	0.0001825	0.0004868	0.0018440	0.0032255	0.0046935	0.0315510	0.0330589	0.0344242
11.0	0.0016858	0.0011847	0.0031615	0.0064936	0.0105930	0.0145423	0.0647526	0.0673772	0.0697381
12.0	0.0019946	0.0052263	0.0127380	0.0182171	0.0272474	0.0353298	0.0993568	0.1024045	0.1051143
13.0	0.0029634	0.0190052	0.0392637	0.0432205	0.0594401	0.0730135	0.1315778	0.1342470	0.1365800
14.0	0.0124319	0.0589060	0.0968721	0.0884179	0.1118910	0.1302848	0.1529447	0.1547170	0.1562171
15.0	0.0512114	0.1469778	0.1967306	0.1485645	0.1752472	0.1948205	0.1500393	0.1513011	0.1522323
15.1	0.1418780	0.2478228	0.2663760	0.1854163	0.2107259	0.2227705	0.1189445	0.1209308	0.1226735
16.1	0.2443130	0.2532466	0.2284337	0.1681486	0.1839387	0.1800612	0.0728752	0.0776920	0.0807467
16.2	0.1670294	0.1207172	0.0968971	0.0829175	0.0849031	0.0775794	0.0280921	0.0317697	0.0330574

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0184722	-0.0504644	-0.0695634	-0.0098693	-0.0374565	-0.0566432	-0.0035557	-0.0166486	-0.0282977
1.1	-0.0149880	-0.0475998	-0.0669847	-0.0085789	-0.0354845	-0.0546396	-0.0033631	-0.0160216	-0.0275076
1.2	-0.0069070	-0.0344291	-0.0533266	-0.0059109	-0.0272148	-0.0445351	-0.0029470	-0.0140751	-0.0243519
2.1	-0.0018546	-0.0186717	-0.0304258	-0.0032513	-0.0160501	-0.0279845	-0.0023032	-0.0110398	-0.0191571
3.0	-0.0001740	-0.0049024	-0.0108991	-0.0013052	-0.0068760	-0.0124655	-0.0014861	-0.0071353	-0.0124040
4.0	0.0001590	-0.0006192	-0.0011548	-0.0002908	-0.0015474	-0.0026404	-0.0006253	-0.0029562	-0.0050663
5.0	0.0001892	0.0001133	0.0009919	0.0000519	0.0003468	0.0011087	0.0000055	0.0001686	0.0009170
6.0	0.0001847	0.0000846	0.0009205	0.0000833	0.0007452	0.0019558	0.0004162	0.0022500	0.0043146
7.0	0.0001556	0.0000045	0.0005238	0.0000762	0.0006415	0.0017354	0.0006518	0.0034770	0.0068071
8.0	0.0000906	-0.0000149	0.0002570	0.0000512	0.0004764	0.0013561	0.0007660	0.0040886	0.0077775
9.0	0.0000012	0.0000106	0.0000675	0.0000405	0.0004160	0.0012000	0.0007990	0.0042700	0.0081200
10.0	0.0000906	-0.0000149	0.0002570	0.0000512	0.0004764	0.0013561	0.0007660	0.0040886	0.0077775
11.0	0.0001556	0.0000045	0.0005238	0.0000762	0.0006415	0.0017354	0.0006518	0.0034770	0.0068071
12.0	0.0001847	0.0000846	0.0009205	0.0000833	0.0007452	0.0019558	0.0004162	0.0022500	0.0043146
13.0	0.0001892	0.0001133	0.0009919	0.0000519	0.0003468	0.0011087	0.0000055	0.0001686	0.0005170
14.0	0.0001590	-0.0006192	-0.0011548	-0.0002908	-0.0015474	-0.0026404	-0.0006253	-0.0023562	-0.0050663
15.0	-0.0001740	-0.0049024	-0.0106991	-0.0013052	-0.0068760	-0.0124655	-0.0014861	-0.0071353	-0.0124040
15.1	-0.0018546	-0.0186717	-0.0304258	-0.0032513	-0.0160501	-0.0279845	-0.0023032	-0.0110398	-0.0191571
16.1	-0.0069070	-0.0344291	-0.0533266	-0.0059109	-0.0272148	-0.0445351	-0.0029470	-0.0140751	-0.0243519
16.2	-0.0149880	-0.0475998	-0.0669847	-0.0085789	-0.0354845	-0.0546396	-0.0033631	-0.0160216	-0.0275076

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	-0.0181053	-0.0500633	-0.0692425	-0.0098624	-0.0372294	-0.0564192	-0.0037254	-0.0166607	-0.0283010
1.1	-0.0196315	-0.0476312	-0.0669363	-0.0090275	-0.0356091	-0.0546599	-0.0035997	-0.0162344	-0.0276783
1.2	-0.0079646	-0.0348541	-0.0536103	-0.0082464	-0.0275511	-0.0447990	-0.0031623	-0.0142916	-0.0245704
2.1	-0.0020492	-0.0169601	-0.0306969	-0.0034327	-0.0162774	-0.0262178	-0.0024791	-0.0112210	-0.0193394
3.0	-0.0002360	-0.0050022	-0.0108218	-0.0013606	-0.0069629	-0.0125654	-0.0016140	-0.0072648	-0.0125361
4.0	0.0001306	-0.0006347	-0.0011778	-0.0003117	-0.0015613	-0.0026604	-0.0006696	-0.0030229	-0.0051362
5.0	0.0001634	0.0001129	0.0009953	0.0000344	0.0003457	0.0011080	0.0000052	0.0001679	0.0005156
6.0	0.0001626	0.0000955	0.0009422	0.0001250	0.0007799	0.0019952	0.0004659	0.0023195	0.0043643
7.0	0.0001812	0.0000909	0.0006300	0.0001870	0.0007560	0.0018581	0.0008001	0.0036246	0.0067541
8.0	0.0004139	0.0003380	0.0009915	0.0003661	0.0007655	0.0016546	0.0009991	0.0043175	0.0080035
9.0	0.0005129	0.0008220	0.0008807	0.0007290	0.0009800	0.0016900	0.0011100	0.0045700	0.0064200
10.0	0.0004139	0.0003380	0.0009915	0.0003661	0.0007655	0.0016546	0.0009991	0.0043175	0.0080035
11.0	0.0001812	0.0000909	0.0006300	0.0001870	0.0007560	0.0018581	0.0008001	0.0036246	0.0067541
12.0	0.0001626	0.0000955	0.0009422	0.0001250	0.0007799	0.0019952	0.0004659	0.0023195	0.0043643
13.0	0.0001634	0.0001129	0.0009953	0.0000344	0.0003457	0.0011080	0.0000052	0.0001679	0.0005156
14.0	0.0001306	-0.0006347	-0.0011778	-0.0003117	-0.0015613	-0.0026604	-0.0006696	-0.0030229	-0.0051362
15.0	-0.0002360	-0.0050022	-0.0108218	-0.0013606	-0.0069629	-0.0125654	-0.0016140	-0.0072648	-0.0125361
15.1	-0.0020492	-0.0169601	-0.0306969	-0.0034327	-0.0162774	-0.0262178	-0.0024791	-0.0112210	-0.0193394
16.1	-0.0079646	-0.0348541	-0.0536103	-0.0082464	-0.0275511	-0.0447990	-0.0031623	-0.0142916	-0.0245704
16.2	-0.0196315	-0.0476312	-0.0669363	-0.0090275	-0.0356091	-0.0546599	-0.0035997	-0.0162344	-0.0276783

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	1.8761981	1.0063413	0.7737547	0.9883167	0.7484452	0.6290222	0.3551954	0.3329471	0.3144599
1.1	1.5252036	0.9489508	0.7451256	0.8591928	0.7089915	0.6067146	0.3359451	0.3204046	0.3056808
1.2	0.7146193	0.6654940	0.5932813	0.5924361	0.5436146	0.4944969	0.2943436	0.2814745	0.2706191
2.1	0.2051979	0.3304902	0.3367962	0.3264426	0.3203530	0.3106166	0.2299822	0.2207684	0.2126984
3.0	0.0331117	0.0954466	0.1195448	0.1318113	0.1369778	0.1382113	0.1483196	0.1426781	0.1378645
4.0	-0.0025969	0.0101066	0.0134416	0.0303410	0.0304239	0.0290708	0.0822874	0.0590968	0.0363554
5.0	-0.0059941	-0.0044822	-0.0104256	-0.0019604	-0.0074237	-0.0125701	-0.0007264	-0.0033984	-0.0057075
6.0	-0.0080756	-0.0036572	-0.0098305	-0.0081521	-0.0153502	-0.0219633	-0.0417391	-0.0450224	-0.0479096
7.0	-0.0058168	-0.0019634	-0.0052720	-0.0066131	-0.0131863	-0.0194725	-0.0652559	-0.0695571	-0.0733916
8.0	-0.0040577	-0.0008459	-0.0024945	-0.0044884	-0.0097335	-0.0151792	-0.0766376	-0.0817602	-0.0864052
9.0	-0.0001148	-0.0002574	-0.0010409	-0.0040400	-0.0083100	-0.0134000	-0.0799000	-0.0854000	-0.0903000
10.0	-0.0040577	-0.0008459	-0.0024945	-0.0044884	-0.0097335	-0.0151792	-0.0766376	-0.0817602	-0.0864052
11.0	-0.0058168	-0.0019634	-0.0052720	-0.0066131	-0.0131863	-0.0194725	-0.0652559	-0.0695571	-0.0733916
12.0	-0.0080756	-0.0036572	-0.0098305	-0.0081521	-0.0153502	-0.0219633	-0.0417391	-0.0450224	-0.0479096
13.0	-0.0059941	-0.0044822	-0.0104256	-0.0019604	-0.0074237	-0.0125701	-0.0007264	-0.0033984	-0.0057075
14.0	-0.0025969	0.0101066	0.0134416	0.0303410	0.0304239	0.0290708	0.0822874	0.0590968	0.0363554
15.0	0.0331117	0.0954466	0.1195448	0.1318113	0.1369778	0.1382113	0.1483196	0.1426781	0.1378645
15.1	0.2051979	0.3304902	0.3367962	0.3264426	0.3203530	0.3106166	0.2299822	0.2207684	0.2126984
16.1	0.7146193	0.6654940	0.5932813	0.5924361	0.5436146	0.4944969	0.2943436	0.2814745	0.2706191
16.2	1.5252036	0.9489508	0.7451256	0.8591928	0.7089915	0.6067146	0.3359451	0.3204046	0.3056808

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	0.01	0.05	0.09	0.01	0.05	0.09	0.01	0.05	0.09
STATION									
1.0	1.7001256	0.9775256	0.7593635	0.9235000	0.7285634	0.6177711	0.3455270	0.3269982	0.3100052
1.1	1.4083000	0.9323062	0.7354615	0.8549438	0.6994339	0.5998235	0.3356502	0.3190647	0.3040017
1.2	0.7490348	0.6660119	0.5916015	0.5972209	0.5443528	0.4936728	0.2940410	0.2612736	0.2704200
2.1	0.2146590	0.3340048	0.3401874	0.3281586	0.3216640	0.3113414	0.2296570	0.2206339	0.2127266
3.0	0.0344561	0.0968416	0.1204969	0.1325573	0.1375472	0.1386528	0.1461766	0.1425362	0.1377470
4.0	-0.0023003	0.0103062	0.0136030	0.0305347	0.0305547	0.0291672	0.0622486	0.0590567	0.0563097
5.0	-0.0059720	-0.0045258	-0.0105270	-0.0019619	-0.0074540	-0.0126102	-0.0007266	-0.0033986	-0.0057030
6.0	-0.0061155	-0.0039213	-0.0097386	-0.0062113	-0.0154169	-0.0220355	-0.0417056	-0.0449652	-0.0478699
7.0	-0.0059017	-0.0020125	-0.0053424	-0.0066512	-0.0132403	-0.0195340	-0.0652050	-0.0695009	-0.0733308
8.0	-0.0041993	-0.0008897	-0.0025411	-0.0045256	-0.0097777	-0.0152299	-0.0765776	-0.0817138	-0.0863335
9.0	-0.0000262	-0.0002045	-0.0010202	-0.0040500	-0.0083400	-0.0154000	-0.0799000	-0.0853000	-0.0902000
10.0	-0.0041993	-0.0008897	-0.0025411	-0.0045256	-0.0097777	-0.0152299	-0.0765776	-0.0817138	-0.0863335
11.0	-0.0059017	-0.0020125	-0.0053424	-0.0066512	-0.0132403	-0.0195340	-0.0652050	-0.0695009	-0.0733308
12.0	-0.0061155	-0.0039213	-0.0097386	-0.0062113	-0.0154169	-0.0220355	-0.0417056	-0.0449652	-0.0478699
13.0	-0.0059720	-0.0045258	-0.0105270	-0.0019619	-0.0074540	-0.0126102	-0.0007266	-0.0033986	-0.0057030
14.0	-0.0023003	0.0103062	0.0136030	0.0305347	0.0305547	0.0291672	0.0622486	0.0590567	0.0563097
15.0	0.0344561	0.0968416	0.1204969	0.1325573	0.1375472	0.1386528	0.1461766	0.1425362	0.1377470
15.1	0.2146590	0.3340048	0.3401874	0.3281586	0.3216640	0.3113414	0.2296570	0.2206339	0.2127266
16.1	0.7490348	0.6660119	0.5916015	0.5972209	0.5443528	0.4936728	0.2940410	0.2612736	0.2704200
16.2	1.4083000	0.9323062	0.7354615	0.8549438	0.6994339	0.5998235	0.3356502	0.3190647	0.3040017

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER
COEFFICIENT FOR
INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.3257065	-0.4524251	-0.4728013	-0.0986060	-0.3615645	-0.4155865	-0.0083425	-0.1738751	-0.2763452
1.1	0.1106984	-0.2595636	-0.3535678	0.0332722	-0.0798660	-0.1970940	0.0083465	0.0317510	0.0005863
1.2	0.0453396	0.0945936	-0.0638043	0.0149235	0.0883349	0.0390549	0.0057639	0.0334278	0.0637263
2.1	-0.0039151	0.2901277	0.2441073	0.0079114	0.0727720	0.1426689	0.0048934	0.0263569	0.0527167
3.0	0.0006736	-0.0443847	0.2753683	0.0033511	0.0203408	0.0835225	0.0036642	0.0197314	0.0385272
4.0	-0.0001369	-0.0658433	-0.0564211	0.0012204	0.0036686	0.0067595	0.0026582	0.0140270	0.0268746
5.0	0.0000392	0.0361594	-0.1722209	0.0005837	0.0016694	-0.0065569	0.0018815	0.0098308	0.0185383
6.0	-0.0000125	0.0009292	-0.0230284	0.0002290	0.0004050	-0.0029503	0.0012463	0.0064417	0.0120037
7.0	0.0000089	-0.0078960	0.1034124	0.0001011	0.0001667	-0.0002992	0.0007115	0.0036549	0.0067477
8.0	-0.0000155	0.0024229	0.0620109	0.0000209	0.0000112	0.0000988	0.0002305	0.0011792	0.0021094
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0000089	0.0078960	-0.1034124	-0.0001011	-0.0001667	0.0002992	-0.0007115	-0.0036549	-0.0067477
11.0	0.0000125	-0.0009292	0.0230284	-0.0002290	-0.0004050	0.0029503	-0.0012463	-0.0064417	-0.0120037
12.0	-0.0000392	-0.0361594	0.1722209	-0.0005837	-0.0016694	0.0065569	-0.0018815	-0.0098308	-0.0185383
13.0	0.0001369	0.0658433	0.0564211	-0.0012204	-0.0036686	-0.0067595	-0.0026582	-0.0140270	-0.0268746
14.0	-0.0006736	0.0443847	-0.2753683	-0.0033511	-0.0203408	-0.0835225	-0.0036642	-0.0197314	-0.0385272
15.0	0.0039151	-0.2901277	-0.2441073	-0.0079114	-0.0727720	-0.1426689	-0.0048934	-0.0263569	-0.0527167
15.1	-0.0453396	-0.0945936	0.0638043	-0.0149235	-0.0883349	-0.0390549	-0.0057639	-0.0334278	-0.0637263
16.1	-0.1106984	0.2595636	0.3535678	-0.0332722	0.0798660	0.1970940	-0.0083465	-0.0317510	-0.0005863
16.2	0.3257065	0.4524251	0.4728013	0.0986060	0.3615645	0.4155865	0.0083425	0.1738751	0.2763452

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.3275087	-0.4420151	-0.4657646	-0.2446637	-0.3728118	-0.4164642	-0.2074070	-0.2715534	-0.3211672
1.1	0.0760760	-0.2574252	-0.3492324	0.0267071	-0.0929412	-0.2017189	0.0136604	0.0184931	-0.0162950
1.2	0.0492809	0.0876162	-0.0838614	0.0149675	0.0837259	0.0346352	0.0047060	0.0342552	0.0628836
2.1	-0.0041868	0.2821598	0.2396787	0.0074248	0.0722348	0.1402055	0.0048327	0.0259974	0.0525380
3.0	0.0007373	-0.0411326	0.2716276	0.0032337	0.0203896	0.0832315	0.0035481	0.0196687	0.0384340
4.0	-0.0001442	-0.0643155	-0.0559923	0.0012237	0.0037261	0.0070353	0.0026767	0.0140364	0.0269002
5.0	0.0000411	0.0346143	-0.1703470	0.0006354	0.0017344	-0.0063980	0.0019878	0.0099564	0.0186772
6.0	0.0000847	-0.0005263	-0.0209434	0.0005150	0.0006201	-0.0023278	0.0014622	0.0066628	0.0122498
7.0	-0.0001061	-0.0031793	0.1043345	0.0005065	0.0014091	0.0011251	0.0010701	0.0041110	0.0072843
8.0	0.0000151	0.0016995	0.0583859	0.0004127	0.0003086	-0.0009108	0.0006709	0.0014164	0.0021964
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0001061	0.0031793	-0.1043345	-0.0005065	-0.0014091	-0.0011251	-0.0010701	-0.0041110	-0.0072843
11.0	-0.0000847	0.0005263	0.0209434	-0.0005150	-0.0006201	0.0023278	-0.0014622	-0.0066628	-0.0122498
12.0	-0.0000411	-0.0346143	0.1703470	-0.0006354	-0.0017344	0.0063980	-0.0019878	-0.0099564	-0.0186772
13.0	0.0001442	0.0643155	0.0559923	-0.0012237	-0.0037261	-0.0070353	-0.0026767	-0.0140364	-0.0269002
14.0	-0.0007373	0.0411326	-0.2716276	-0.0032337	-0.0203896	-0.0832315	-0.0035481	-0.0196687	-0.0384340
15.0	0.0041868	-0.2821598	-0.2396787	-0.0074248	-0.0722348	-0.1402055	-0.0048327	-0.0259974	-0.0525380
15.1	-0.0492809	-0.0876162	0.0838614	-0.0149675	-0.0837259	-0.0346352	-0.0047060	-0.0342552	-0.0628836
16.1	-0.0760760	0.2574252	0.3492324	-0.0267071	0.0929412	0.2017189	-0.0136604	-0.0184931	0.0162950
16.2	-0.1618465	-0.0576741	-0.0341976	-0.2553769	-0.1270563	-0.0835240	-0.2924209	-0.2263679	-0.1787963

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
COEFFICIENT FOR
INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-32.5096426	-9.0489269	-5.2531982	-9.9006238	-7.2302062	-4.6174504	-0.8295684	-3.4781612	-3.0705494
1.1	11.8252305	-5.1908987	-3.9285990	3.3258536	-1.5966588	-2.1898540	0.8313266	0.6353266	0.0068608
1.2	4.5466089	1.8915440	-0.9311168	1.4882467	1.7671690	0.4339502	0.5765435	0.6686624	0.7081510
2.1	-0.3948456	5.8019433	2.7125036	0.7897125	1.4558312	1.5851255	0.4893468	0.5272151	0.5858252
3.0	0.0668101	-0.8874997	3.0597249	0.3351200	0.4068408	0.9279800	0.3665502	0.3946595	0.4281437
4.0	-0.0139618	-1.3165801	-0.6268445	0.1216597	0.0735063	0.0750615	0.2658653	0.2805253	0.2986677
5.0	0.0034410	0.7237920	-1.9135752	0.0585344	0.0334747	-0.0728876	0.1882762	0.1966273	0.2060370
6.0	-0.0015866	0.0186185	-0.2558856	0.0226570	0.0081504	-0.0327928	0.1246661	0.1288386	0.1334260
7.0	0.0003239	-0.1578991	1.1490263	0.0098912	0.0033829	-0.0033295	0.0712406	0.0731028	0.0750180
8.0	-0.0020069	0.0484696	0.6890148	0.0018075	0.0002776	0.0010968	0.0231046	0.0235885	0.0241458
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0003239	0.1578991	-1.1490263	-0.0098912	-0.0033829	0.0033295	-0.0712406	-0.0731028	-0.0750180
11.0	0.0015866	-0.0186185	0.2558856	-0.0226570	-0.0081504	0.0327928	-0.1246661	-0.1288386	-0.1334260
12.0	-0.0034410	-0.7237920	1.9135752	-0.0585344	-0.0334747	0.0728876	-0.1882762	-0.1966273	-0.2060370
13.0	0.0139618	1.3165801	0.6268445	-0.1216597	-0.0735063	-0.0750615	-0.2658653	-0.2805253	-0.2986677
14.0	-0.0668101	0.8874997	-3.0597249	-0.3351200	-0.4068408	-0.9279800	-0.3665502	-0.3946595	-0.4281437
15.0	0.3948456	-5.8019433	-2.7125036	-0.7897125	-1.4558312	-1.5851255	-0.4893468	-0.5272151	-0.5858252
15.1	-4.5466089	-1.8915440	0.9311168	-1.4882467	-1.7671690	-0.4339502	-0.5765435	-0.6686624	-0.7081510
16.1	-11.8252305	5.1908987	3.9285990	-3.3258536	1.5966588	2.1898540	-0.8313266	-0.6353266	-0.0068608
16.2	32.5096426	9.0489269	5.2531982	9.9006238	7.2302062	4.6174504	0.8295684	3.4781612	3.0705494

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL NORMAL FORCE AT THE ELASTIC CENTER, (K SUB FZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-9.6520057	-3.8715069	-2.4081018	-2.6673952	-2.5439568	-1.8656937	0.2989749	-0.7084529	-0.8329718
1.1	6.6333252	-5.1936007	-3.8953743	1.8081938	-1.9735194	-2.2650780	0.6408942	0.2130039	-0.2342132
1.2	5.2690179	1.7234118	-0.9474640	1.7028728	1.6620164	0.3755707	0.6032853	0.7040951	0.6995516
2.1	-0.4129402	5.6604723	2.6552134	0.7611072	1.4594290	1.5602363	0.4842484	0.5218070	0.5858948
3.0	0.0709169	-0.8079047	3.0253592	0.3434579	0.4132653	0.9293907	0.3672049	0.3952478	0.4277907
4.0	-0.0124500	-1.3046754	-0.6040761	0.1211561	0.0746901	0.0797048	0.2654112	0.2801053	0.2984748
5.0	0.0024435	0.7000621	-1.8878242	0.0589742	0.0336680	-0.0716018	0.1882011	0.1965393	0.2058927
6.0	-0.0013065	0.0254677	-0.2589117	0.0230014	0.0085226	-0.0327436	0.1245529	0.1287295	0.1333321
7.0	0.0000747	-0.1556839	1.1326143	0.0097171	0.0032004	-0.0035418	0.0711900	0.0730525	0.0749667
8.0	-0.0013869	0.0460545	0.6812518	0.0021277	0.0005410	0.0011284	0.0230904	0.0235792	0.0241357
9.0	......	......	......	......	......	......	......	......	......
10.0	-0.0000747	0.1556839	-1.1326143	-0.0097171	-0.0032004	0.0035418	-0.0711900	-0.0730525	-0.0749667
11.0	0.0013065	-0.0254677	0.2589117	-0.0230014	-0.0085226	0.0327436	-0.1245529	-0.1287295	-0.1333321
12.0	-0.0024435	-0.7000621	1.8878242	-0.0589742	-0.0336680	0.0716018	-0.1882011	-0.1965393	-0.2058927
13.0	0.0124500	1.3046754	0.6040761	-0.1211561	-0.0746901	-0.0797048	-0.2654112	-0.2801053	-0.2984748
14.0	-0.0709169	0.8079047	-3.0253592	-0.3434579	-0.4132653	-0.9293907	-0.3672049	-0.3952478	-0.4277907
15.0	0.4129402	-5.6604723	-2.6552134	-0.7611072	-1.4594290	-1.5602363	-0.4842484	-0.5218070	-0.5858948
15.1	-5.2690179	-1.7234118	0.9474640	-1.7028728	-1.6620164	-0.3755707	-0.6032853	-0.7040951	-0.6995516
16.1	-6.6333252	5.1936007	3.8953743	-1.8081938	1.9735194	2.2650780	-0.6408942	-0.2130039	0.2342132
16.2	9.6520057	3.8715069	2.4081018	2.6673952	2.5439568	1.8656937	-0.2989749	0.7084529	0.8329718

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0011636	0.0015821	0.0017088	0.0037242	0.0062955	0.0068978	0.0047934	0.0158958	0.0195764
1.1	0.0035707	0.0057866	0.0065241	0.0040371	0.0167646	0.0218008	0.0045733	0.0244037	0.0416720
1.2	0.0008771	0.0105759	0.0131283	0.0025087	0.0177775	0.0309577	0.0039471	0.0213128	0.0415840
2.1	-0.0000510	0.0096135	0.0172927	0.0013652	0.0096004	0.0246102	0.0032276	0.0171806	0.0333229
3.0	0.0000381	-0.0053680	0.0088099	0.0006312	0.0029109	0.0087344	0.0024703	0.0129687	0.0246879
4.0	0.0000037	-0.0021064	-0.0092651	0.0002678	0.0007304	-0.0007470	0.0018001	0.0093103	0.0173963
5.0	-0.0000050	0.0020868	-0.0076002	0.0001206	0.0002617	-0.0011774	0.0012715	0.0065000	0.0119611
6.0	-0.0000172	-0.0003484	0.0020330	0.0000577	0.0000709	-0.0003176	0.0008426	0.0042663	0.0077518
7.0	-0.0000256	-0.0003181	0.0050167	0.0000315	0.0000192	0.0000224	0.0004799	0.0024157	0.0043492
8.0	-0.0000303	0.0002076	0.0020591	0.0000183	-0.0000024	0.0000327	0.0001550	0.0007805	0.0013961
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0000256	0.0003181	-0.0050167	-0.0000315	-0.0000192	-0.0000224	-0.0004799	-0.0024157	-0.0043492
11.0	0.0000172	0.0003484	-0.0020330	-0.0000577	-0.0000709	0.0003176	-0.0008426	-0.0042663	-0.0077518
12.0	0.0000050	-0.0020868	0.0076002	-0.0001206	-0.0002617	0.0011774	-0.0012715	-0.0065000	-0.0119611
13.0	-0.0000037	0.0021064	0.0092651	-0.0002678	-0.0007304	0.0007470	-0.0018001	-0.0093103	-0.0173963
14.0	-0.0000381	0.0053680	-0.0088099	-0.0006312	-0.0029109	-0.0087344	-0.0024703	-0.0129687	-0.0246879
15.0	0.0000510	-0.0096135	-0.0172927	-0.0013652	-0.0096004	-0.0246102	-0.0032276	-0.0171806	-0.0333229
15.1	-0.0008771	-0.0105759	-0.0131283	-0.0025087	-0.0177775	-0.0309577	-0.0039471	-0.0213128	-0.0415840
16.1	-0.0035707	-0.0057866	-0.0065241	-0.0040371	-0.0167646	-0.0218008	-0.0045733	-0.0244037	-0.0416720
16.2	-0.0011636	-0.0015821	-0.0017088	-0.0037242	-0.0062955	-0.0068978	-0.0047934	-0.0158958	-0.0195764

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

NA-65-1015

Appendix 1

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0009498	0.0017854	0.0019878	0.0021474	0.0054807	0.0065199	0.0027010	0.0108439	0.0153236
1.1	0.0030491	0.0054734	0.0063239	0.0037913	0.0157783	0.0209373	0.0044195	0.0234858	0.0398371
1.2	0.0009571	0.0102333	0.0128655	0.0024046	0.0174571	0.0303985	0.0037561	0.0211905	0.0413416
2.1	-0.0000509	0.0094337	0.0170441	0.0013027	0.0095706	0.0244160	0.0031054	0.0170447	0.0331982
3.0	0.0000406	-0.0051454	0.0087740	0.0006065	0.0029173	0.0087698	0.0024089	0.0129108	0.0246300
4.0	0.0000040	-0.0020776	-0.0091380	0.0002648	0.0007367	-0.0007007	0.0018068	0.0093200	0.0174115
5.0	-0.0000052	0.0020337	-0.0076038	0.0001368	0.0002758	-0.0011704	0.0013456	0.0065810	0.0120503
6.0	-0.0000134	-0.0004394	0.0020295	0.0001070	0.0001123	-0.0002546	0.0009900	0.0044236	0.0079217
7.0	-0.0000182	-0.0001302	0.0051601	0.0008447	0.0001902	0.0002685	0.0007127	0.0026710	0.0046343
8.0	0.0000179	0.0003647	0.0020469	0.0000548	0.0002909	0.0002381	0.0004895	0.0011253	0.0017350
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0000182	0.0001302	-0.0051601	-0.0008447	-0.0001902	-0.0002685	-0.0007127	-0.0026710	-0.0046343
11.0	0.0000134	0.0004394	-0.0020295	-0.0001070	-0.0001123	0.0002546	-0.0009900	-0.0044236	-0.0079217
12.0	0.0000052	-0.0020337	0.0076038	-0.0001368	-0.0002758	0.0011704	-0.0013456	-0.0065810	-0.0120503
13.0	-0.0000040	0.0020776	0.0091380	-0.0002648	-0.0007367	0.0007007	-0.0018068	-0.0093200	-0.0174115
14.0	-0.0000406	0.0051454	-0.0087740	-0.0006065	-0.0029173	-0.0087698	-0.0024089	-0.0129108	-0.0246300
15.0	0.0000509	-0.0094337	-0.0170441	-0.0013027	-0.0095706	-0.0244160	-0.0031054	-0.0170447	-0.0331982
15.1	-0.0009571	-0.0102333	-0.0128655	-0.0024046	-0.0174571	-0.0303985	-0.0037561	-0.0211905	-0.0413416
16.1	-0.0030491	-0.0054734	-0.0063239	-0.0037913	-0.0157783	-0.0209373	-0.0044195	-0.0234858	-0.0398371
16.2	-0.0009498	-0.0017854	-0.0019878	-0.0021474	-0.0054807	-0.0065199	-0.0027010	-0.0108439	-0.0153236

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.1169685	0.0316224	0.0189976	0.3721757	0.1259508	0.0766594	0.4793925	0.3178808	0.2175080
1.1	0.3560739	0.1157610	0.0724720	0.4042386	0.3352752	0.2422425	0.4572987	0.4880799	0.4630440
1.2	0.0862919	0.2115205	0.1458471	0.2517039	0.3554918	0.3439875	0.3947033	0.4262476	0.4620384
2.1	-0.0071115	0.1922410	0.1921153	0.1374458	0.1919397	0.2734609	0.3227253	0.3436018	0.3702513
3.0	0.0020452	-0.1073923	0.0978505	0.0638183	0.0581584	0.0970676	0.2469937	0.2593695	0.2743160
4.0	-0.0001879	-0.0421911	-0.1029640	0.0269941	0.0145934	-0.0082906	0.1800068	0.1862125	0.1933175
5.0	0.0001479	0.0417195	-0.0844409	0.0117420	0.0052705	-0.0130893	0.1271935	0.1300203	0.1329514
6.0	-0.0000230	-0.0069211	0.0226226	0.0049252	0.0015107	-0.0035555	0.0843461	0.0853569	0.0862074
7.0	-0.0001845	-0.0062179	0.0557954	0.0018985	0.0005298	0.0002028	0.0481224	0.0483508	0.0484216
8.0	-0.0004134	0.0043742	0.0229438	0.0003225	0.0001361	0.0003045	0.0156703	0.0156490	0.0156240
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0001845	0.0062179	-0.0557954	-0.0018985	-0.0005298	-0.0002028	-0.0481224	-0.0483508	-0.0484216
11.0	0.0000230	0.0069211	-0.0226226	-0.0049252	-0.0015107	0.0035555	-0.0843461	-0.0853569	-0.0862074
12.0	-0.0001479	-0.0417195	0.0844409	-0.0117420	-0.0052705	0.0130893	-0.1271935	-0.1300203	-0.1329514
13.0	0.0001879	0.0421911	0.1029640	-0.0269941	-0.0145934	0.0082906	-0.1800068	-0.1862125	-0.1933175
14.0	-0.0020452	0.1073923	-0.0978505	-0.0638183	-0.0581584	-0.0970676	-0.2469937	-0.2593695	-0.2743160
15.0	0.0071115	-0.1922410	-0.1921153	-0.1374458	-0.1919397	-0.2734609	-0.3227253	-0.3436018	-0.3702513
15.1	-0.0862919	-0.2115205	-0.1458471	-0.2517039	-0.3554918	-0.3439875	-0.3947033	-0.4262476	-0.4620384
16.1	-0.3560739	-0.1157610	-0.0724720	-0.4042386	-0.3352752	-0.2422425	-0.4572987	-0.4880799	-0.4630440
16.2	-0.1169685	-0.0316224	-0.0189976	-0.3721757	-0.1259508	-0.0766594	-0.4793925	-0.3178808	-0.2175080

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT THE ELASTIC CENTER, (K SUB T)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0858770	0.0349887	0.0216805	0.1910288	0.1063842	0.0715519	0.2399216	0.2045185	0.1671646
1.1	0.3039155	0.1088276	0.0701775	0.3879755	0.3124785	0.2317456	0.4546572	0.4652271	0.4393895
1.2	0.1031142	0.2046499	0.1429074	0.2563989	0.3510864	0.3381827	0.3948003	0.4279397	0.4609152
2.1	-0.0070695	0.1898389	0.1893646	0.1377154	0.1934917	0.2722999	0.3223946	0.3430563	0.3700450
3.0	0.0022882	-0.1024543	0.0975335	0.0643864	0.0590344	0.0981192	0.2468271	0.2592367	0.2741206
4.0	-0.0001863	-0.0425529	-0.1009633	0.0271363	0.0148071	-0.0075987	0.1798643	0.1860639	0.1931857
5.0	0.0001581	0.0406888	-0.0837098	0.0118317	0.0053367	-0.0129770	0.1270984	0.1299295	0.1328596
6.0	-0.0000275	-0.0064115	0.0219266	0.0049582	0.0015453	-0.0035812	0.0842815	0.0852938	0.0861477
7.0	-0.0001863	-0.0061993	0.0552372	0.0019096	0.0005255	0.0001726	0.0480859	0.0483158	0.0483882
8.0	-0.0004190	0.0042213	0.0226605	0.0003248	0.0001464	0.0003044	0.0156584	0.0156380	0.0156138
9.0	......	......	......	......	......	......	......	......	......
10.0	0.0001863	0.0061993	-0.0552372	-0.0019096	-0.0005255	-0.0001726	-0.0480859	-0.0483158	-0.0483882
11.0	0.0000275	0.0064115	-0.0219266	-0.0049582	-0.0015453	0.0035812	-0.0842815	-0.0852938	-0.0861477
12.0	-0.0001581	-0.0406888	0.0837098	-0.0118317	-0.0053367	0.0129770	-0.1270964	-0.1299296	-0.1328596
13.0	0.0001863	0.0425529	0.1009633	-0.0271363	-0.0148071	0.0075987	-0.1798643	-0.1860639	-0.1931857
14.0	-0.0022882	0.1024543	-0.0975335	-0.0643864	-0.0590344	-0.0981192	-0.2468271	-0.2592367	-0.2741206
15.0	0.0070695	-0.1898389	-0.1893646	-0.1377154	-0.1934917	-0.2722999	-0.3223946	-0.3430563	-0.3700450
15.1	-0.1031142	-0.2046499	-0.1429074	-0.2563989	-0.3510864	-0.3381827	-0.3948003	-0.4279397	-0.4609152
16.1	-0.3039155	-0.1088276	-0.0701775	-0.3879755	-0.3124785	-0.2317456	-0.4546572	-0.4652271	-0.4393895
16.2	-0.0858770	-0.0349887	-0.0216805	-0.1910288	-0.1063842	-0.0715519	-0.2399216	-0.2045185	-0.1671646

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0019646	0.0024212	0.0001487	0.0033407	0.0014739	0.0011867	0.0026200	0.0029845	0.0024280
1.1	0.0276501	0.0380976	0.0374361	0.0113820	0.0303807	0.0343859	0.0036522	0.0178969	0.0256816
1.2	0.0095264	0.0798657	0.0941174	0.0067805	0.0455911	0.0688415	0.0030582	0.0167402	0.0321488
2.1	-0.0010027	0.0599783	0.1170626	0.0038426	0.0288896	0.0669251	0.0026280	0.0138726	0.0269078
3.0	0.0002134	-0.0288800	0.0452141	0.0017702	0.0088787	0.0295274	0.0021001	0.0109658	0.0207643
4.0	-0.0000482	-0.0133593	-0.0608312	0.0006894	0.0019450	-0.0002254	0.0016249	0.0082754	0.0152585
5.0	0.0000046	0.0119962	-0.0420720	0.0003109	0.0007764	-0.0032115	0.0012834	0.0063990	0.0114879
6.0	-0.0000100	-0.0015573	0.0234183	0.0001263	0.0002165	-0.0010714	0.0010409	0.0050740	0.0088714
7.0	-0.0000035	-0.0020659	0.0333889	0.0000568	0.0000832	-0.0000242	0.0008805	0.0042085	0.0071798
8.0	-0.0000046	0.0009484	-0.0057563	0.0000272	0.0000239	0.0001036	0.0007886	0.0037155	0.0062256
9.0	0.0000004	0.0000004	-0.0296000	0.0000004	0.0000004	0.0000004	0.0007640	0.0035600	0.0059200
10.0	-0.0000046	0.0009484	-0.0057563	0.0000272	0.0000239	0.0001036	0.0007886	0.0037155	0.0062256
11.0	-0.0000035	-0.0020659	0.0333889	0.0000568	0.0000832	-0.0000242	0.0008805	0.0042085	0.0071798
12.0	-0.0000100	-0.0015573	0.0234183	0.0001263	0.0002165	-0.0010714	0.0010409	0.0050740	0.0088714
13.0	0.0000046	0.0119962	-0.0420720	0.0003109	0.0007764	-0.0032115	0.0012834	0.0063990	0.0114879
14.0	-0.0000482	-0.0133593	-0.0608312	0.0006894	0.0019450	-0.0002254	0.0016249	0.0082754	0.0152585
15.0	0.0002134	-0.0288800	0.0452141	0.0017702	0.0088787	0.0295274	0.0021001	0.0109658	0.0207643
15.1	-0.0010027	0.0599783	0.1170626	0.0038426	0.0288896	0.0669251	0.0026280	0.0138726	0.0269078
16.1	0.0095264	0.0798657	0.0941174	0.0067805	0.0455911	0.0688415	0.0030582	0.0167402	0.0321488
16.2	0.0276501	0.0380976	0.0374361	0.0113820	0.0303807	0.0343859	0.0036522	0.0178969	0.0256816

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0152918	0.0205300	0.0192218	0.0104622	0.0172348	0.0185941	0.0072727	0.0133974	0.0161900
1.1	0.0218747	0.0357712	0.0363345	0.0102100	0.0273213	0.0321878	0.0041447	0.0159463	0.0229880
1.2	0.0103769	0.0771533	0.0923018	0.0066032	0.0444345	0.0672355	0.0026900	0.0167321	0.0318234
2.1	-0.0010652	0.0588362	0.1151982	0.0036304	0.0287483	0.0662328	0.0024650	0.0136397	0.0267245
3.0	0.0002366	-0.0275550	0.0446739	0.0016921	0.0088980	0.0295539	0.0019176	0.0108037	0.0205980
4.0	-0.0000492	-0.0132392	-0.0598973	0.0006483	0.0019475	-0.0000690	0.0014643	0.0081151	0.0151063
5.0	0.0000065	0.0115199	-0.0412581	0.0002673	0.0007586	-0.0031464	0.0011181	0.0062388	0.0113316
6.0	-0.0000090	-0.0014403	0.0234850	0.0000684	0.0001783	-0.0010668	0.0008627	0.0048961	0.0086953
7.0	-0.0000396	-0.0014060	0.0326247	-0.0000952	-0.0000241	-0.0002421	0.0006751	0.0040052	0.0069735
8.0	0.0000080	-0.0001931	-0.0068300	-0.0002411	-0.0005096	-0.0005831	0.0005333	0.0034323	0.0059191
9.0	0.0000073	0.0000075	-0.0292000	0.0000073	0.0000073	0.0000073	0.0004670	0.0033200	0.0057300
10.0	0.0000080	-0.0001931	-0.0068300	-0.0002411	-0.0005096	-0.0005831	0.0005333	0.0034325	0.0059191
11.0	-0.0000396	-0.0014060	0.0326247	-0.0000952	-0.0000241	-0.0002421	0.0006751	0.0040052	0.0069735
12.0	-0.0000090	-0.0014403	0.0234850	0.0000684	0.0001783	-0.0010668	0.0008627	0.0048961	0.0086953
13.0	0.0000065	0.0115199	-0.0412581	0.0002673	0.0007586	-0.0031464	0.0011181	0.0062388	0.0113316
14.0	-0.0000492	-0.0132392	-0.0598973	0.0006483	0.0019475	-0.0000690	0.0014643	0.0081151	0.0151063
15.0	0.0002366	-0.0275550	0.0446739	0.0016921	0.0088980	0.0295539	0.0019176	0.0108037	0.0205980
15.1	-0.0010652	0.0588362	0.1151982	0.0036304	0.0287483	0.0662328	0.0024650	0.0136397	0.0267245
16.1	0.0103769	0.0771533	0.0923018	0.0066032	0.0444345	0.0672355	0.0026900	0.0167321	0.0318234
16.2	0.0218747	0.0357712	0.0363345	0.0102100	0.0273213	0.0321878	0.0041447	0.0159463	0.0229880

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.1960333	0.0483747	0.0017372	0.3295287	0.0298696	0.0131733	0.2619015	0.0597183	0.0270443
1.1	2.7598513	0.7619333	0.4160314	1.1367750	0.6079235	0.3820409	0.3647603	0.3580146	0.2854227
1.2	0.9544837	1.5972413	1.0458304	0.6768907	0.9120236	0.7648702	0.3058835	0.3348348	0.3572274
2.1	-0.1012885	1.1995704	1.3007616	0.3841915	0.5778683	0.7435773	0.2628425	0.2774553	0.2989729
3.0	0.0215131	-0.5774122	0.5023748	0.1775700	0.1775016	0.3280775	0.2100604	0.2192909	0.2306841
4.0	-0.0042553	-0.2670872	-0.6759505	0.0696398	0.0387854	-0.0024841	0.1624961	0.1654674	0.1694858
5.0	0.0012251	0.2398843	-0.4675444	0.0319798	0.0153493	-0.0356427	0.1283404	0.1279485	0.1275760
6.0	-0.0000737	-0.0314334	0.2601305	0.0133665	0.0041299	-0.0118534	0.1040409	0.1014514	0.0985015
7.0	0.0005426	-0.0416028	0.3709332	0.0063101	0.0014880	-0.0002219	0.0880002	0.0841526	0.0797161
8.0	0.0003534	0.0187351	-0.0639917	0.0031297	0.0003530	0.0011828	0.0788032	0.0743055	0.0691351
9.0	-0.0000404	-0.0000404	-0.3280000	-0.0000404	-0.0000404	-0.0000404	0.0758000	0.0711000	0.0697000
10.0	0.0003534	0.0187351	-0.0639917	0.0031297	0.0003530	0.0011828	0.0788032	0.0743055	0.0691351
11.0	0.0005426	-0.0416028	0.3709332	0.0063101	0.0014880	-0.0002219	0.0880002	0.0841526	0.0797161
12.0	-0.0000737	-0.0314334	0.2601305	0.0133665	0.0041299	-0.0118534	0.1040409	0.1014514	0.0985015
13.0	0.0012251	0.2398843	-0.4675444	0.0319798	0.0153493	-0.0356427	0.1283404	0.1279485	0.1275760
14.0	-0.0042553	-0.2670872	-0.6759505	0.0696398	0.0387854	-0.0024841	0.1624961	0.1654674	0.1694858
15.0	0.0215131	-0.5774122	0.5023748	0.1775700	0.1775016	0.3280775	0.2100604	0.2192909	0.2306841
15.1	-0.1012885	1.1995704	1.3007616	0.3841915	0.5778683	0.7435773	0.2628425	0.2774553	0.2989729
16.1	0.9544837	1.5972413	1.0458304	0.6768907	0.9120236	0.7648702	0.3058835	0.3348348	0.3572274
16.2	2.7598513	0.7619333	0.4160314	1.1367750	0.6079255	0.3820409	0.3647603	0.3580146	0.2854227

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2
COEFFICIENT FOR
INTERNAL MOMENT ABOUT AXIS NORMAL TO ELASTIC CENTER, (K SUB M)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	1.3290678	0.3820959	0.1896065	0.6998251	0.3038396	0.1821526	0.3251190	0.2102965	0.1511044
1.1	2.1139216	0.7087174	0.4001863	0.9440878	0.5317509	0.3540283	0.3401234	0.3016836	0.2493410
1.2	1.1176153	1.5433603	1.0243944	0.7205337	0.8915831	0.7470461	0.3108064	0.3413835	0.3553693
2.1	-0.1051972	1.1838624	1.2824994	0.5781420	0.5812758	0.7381981	0.2614583	0.2760174	0.2968845
3.0	0.0233582	-0.5490715	0.5013894	0.1806683	0.1802613	0.3302148	0.2101863	0.2193931	0.2305082
4.0	-0.0039486	-0.2684416	-0.6633894	0.0696466	0.0393379	-0.0004894	0.1622954	0.1652829	0.1693727
5.0	0.0009301	0.2336500	-0.4632453	0.0322437	0.0155158	-0.0352201	0.1282637	0.1278719	0.1274872
6.0	0.0000249	-0.0286437	0.2544742	0.0134898	0.0042450	-0.0118980	0.1039562	0.1013736	0.0984336
7.0	0.0005362	-0.0413306	0.3662040	0.0065104	0.0014693	-0.0002963	0.0879349	0.0840933	0.0796619
8.0	0.0004430	0.0181329	-0.0624122	0.0032033	0.0004049	0.0011811	0.0787435	0.0742522	0.0690879
9.0	-0.0000405	-0.0000405	-0.3240000	-0.0000405	-0.0000405	-0.0000405	0.0758000	0.0711000	0.0657000
10.0	0.0004430	0.0181329	-0.0624122	0.0032033	0.0004049	0.0011811	0.0787435	0.0742522	0.0690879
11.0	0.0005362	-0.0413306	0.3662040	0.0065104	0.0014693	-0.0002963	0.0879349	0.0840933	0.0796619
12.0	0.0000249	-0.0286437	0.2544742	0.0134898	0.0042450	-0.0118980	0.1039562	0.1013736	0.0984336
13.0	0.0009301	0.2336500	-0.4632453	0.0322437	0.0155158	-0.0352201	0.1282637	0.1278719	0.1274872
14.0	-0.0039486	-0.2684416	-0.6633894	0.0696466	0.0393379	-0.0004894	0.1622954	0.1652829	0.1693727
15.0	0.0233582	-0.5490715	0.5013894	0.1806683	0.1802613	0.3302148	0.2101863	0.2193931	0.2305082
15.1	-0.1051972	1.1838624	1.2824994	0.5781420	0.5812758	0.7381981	0.2614583	0.2760174	0.2968845
16.1	1.1176153	1.5433603	1.0243944	0.7205337	0.8915831	0.7470461	0.3108064	0.3413835	0.3553693
16.2	2.1139216	0.7087174	0.4001863	0.9440878	0.5317509	0.3540283	0.3401234	0.3016836	0.2493410

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0004778	0.0083843	0.0291889	0.0001235	0.0029380	0.0095867	0.0000368	0.0009498	0.0031957
1.1	0.0004117	0.0079139	0.0282428	0.0001081	0.0027970	0.0092957	0.0000349	0.0009167	0.0031191
1.2	0.0001859	0.0048684	0.0214958	0.0000775	0.0020838	0.0075168	0.0000314	0.0008161	0.0027953
2.1	0.0001540	-0.0008718	0.0048709	0.0000495	0.0010485	0.0039789	0.0000268	0.0006848	0.0023141
3.0	0.0001386	-0.0029823	-0.0127605	0.0000296	0.0003823	0.0006803	0.0000218	0.0005443	0.0018029
4.0	0.0001126	0.0008085	-0.0097585	0.0000171	0.0001383	-0.0004242	0.0000170	0.0004126	0.0013323
5.0	0.0000760	0.0004137	0.0039107	0.0000098	0.0000576	-0.0002252	0.0000134	0.0003180	0.0009998
6.0	0.0000399	-0.0003338	0.0059313	0.0000051	0.0000217	-0.0000356	0.0000108	0.0002519	0.0007709
7.0	0.0000130	0.0000528	0.0002739	0.0000021	0.0000066	0.0000105	0.0000090	0.0002086	0.0006226
8.0	0.0000005	0.0000628	-0.0018856	0.0000005	0.0000012	0.0000068	0.0000080	0.0001842	0.0005396
9.0	-0.0000000	-0.0000346	-0.0013400	0.0000004	0.0000004	0.0000004	0.0000077	0.0001760	0.0005130
10.0	0.0000005	0.0000628	-0.0018856	0.0000005	0.0000012	0.0000068	0.0000080	0.0001842	0.0005396
11.0	0.0000130	0.0000528	0.0002739	0.0000021	0.0000066	0.0000105	0.0000090	0.0002086	0.0006226
12.0	0.0000399	-0.0003338	0.0059313	0.0000051	0.0000217	-0.0000356	0.0000108	0.0002519	0.0007709
13.0	0.0000760	0.0004137	0.0039107	0.0000098	0.0000576	-0.0002252	0.0000134	0.0003180	0.0009998
14.0	0.0001126	0.0008085	-0.0097585	0.0000171	0.0001383	-0.0004242	0.0000170	0.0004126	0.0013323
15.0	0.0001386	-0.0029823	-0.0127605	0.0000296	0.0003823	0.0006803	0.0000218	0.0005443	0.0018029
15.1	0.0001540	-0.0008718	0.0048709	0.0000495	0.0010485	0.0039789	0.0000268	0.0006848	0.0023141
16.1	0.0001859	0.0048684	0.0214958	0.0000775	0.0020838	0.0075168	0.0000314	0.0008161	0.0027953
16.2	0.0004117	0.0079139	0.0282428	0.0001081	0.0027970	0.0092957	0.0000349	0.0009167	0.0031191

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0004451	0.0061594	0.0287158	0.0001158	0.0028580	0.0094319	0.0000333	0.0009251	0.0031456
1.1	0.0004049	0.0077324	0.0278147	0.0001080	0.0027408	0.0091694	0.0000323	0.0009027	0.0030859
1.2	0.0001953	0.0048295	0.0212433	0.0000780	0.0020653	0.0074555	0.0000289	0.0008057	0.0027761
2.1	0.0001552	-0.0007697	0.0049235	0.0000498	0.0010462	0.0039760	0.0000246	0.0006752	0.0022977
3.0	0.0001388	-0.0029223	-0.0124891	0.0000297	0.0003817	0.0006989	0.0000198	0.0005358	0.0017884
4.0	0.0001126	0.0007684	-0.0096927	0.0000172	0.0001375	-0.0004146	0.0000152	0.0004047	0.0013190
5.0	0.0000760	0.0004153	0.0037629	0.0000099	0.0000567	-0.0002226	0.0000117	0.0003100	0.0009863
6.0	0.0000398	-0.0003246	0.0059287	0.0000051	0.0000199	-0.0000332	0.0000090	0.0002431	0.0007557
7.0	0.0000130	0.0000485	0.0004302	0.0000021	0.0000014	0.0000050	0.0000069	0.0001963	0.0006042
8.0	0.0000005	0.0000619	-0.0019599	0.0000005	-0.0000170	-0.0000365	0.0000055	0.0001713	0.0005158
9.0	-0.0000000	-0.0000335	-0.0016300	0.0000073	0.0000073	0.0000073	0.0000045	0.0001600	0.0004830
10.0	0.0000005	0.0000619	-0.0019599	0.0000005	-0.0000170	-0.0000365	0.0000055	0.0001713	0.0005158
11.0	0.0000130	0.0000485	0.0004302	0.0000021	0.0000014	0.0000050	0.0000069	0.0001963	0.0006042
12.0	0.0000398	-0.0003246	0.0059287	0.0000051	0.0000199	-0.0000332	0.0000090	0.0002431	0.0007557
13.0	0.0000760	0.0004153	0.0037629	0.0000099	0.0000567	-0.0002226	0.0000117	0.0003100	0.0009863
14.0	0.0001126	0.0007684	-0.0096927	0.0000172	0.0001375	-0.0004146	0.0000152	0.0004047	0.0013190
15.0	0.0001388	-0.0029223	-0.0124891	0.0000297	0.0003817	0.0006989	0.0000198	0.0005358	0.0017884
15.1	0.0001552	-0.0007697	0.0049235	0.0000498	0.0010462	0.0039760	0.0000246	0.0006752	0.0022977
16.1	0.0001953	0.0048295	0.0212433	0.0000780	0.0020653	0.0074555	0.0000289	0.0008057	0.0027761
16.2	0.0004049	0.0077324	0.0278147	0.0001080	0.0027408	0.0091694	0.0000323	0.0009027	0.0030859

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
COEFFICIENT FOR
NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB D2)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0477802	0.1676857	0.3193977	0.0123460	0.0567561	0.1069718	0.0035798	0.0189060	0.0352840
1.1	0.0411687	0.1582776	0.3088996	0.0108110	0.0539397	0.1037367	0.0033896	0.0182455	0.0344333
1.2	0.0185909	0.0973678	0.2340265	0.0077496	0.0397188	0.0839633	0.0030293	0.0162355	0.0308410
2.1	0.0154034	-0.0174354	0.0496178	0.0049508	0.0191469	0.0446265	0.0025664	0.0136176	0.0255099
3.0	0.0138628	-0.0596454	-0.1456035	0.0029578	0.0061029	0.0079168	0.0020688	0.0108243	0.0198598
4.0	0.0112631	0.0161690	-0.1111526	0.0017135	0.0016579	-0.0044538	0.0016025	0.0082131	0.0146796
5.0	0.0075959	0.0082737	0.0418342	0.0009835	0.0004810	-0.0023431	0.0012681	0.0063385	0.0110323
6.0	0.0039863	-0.0066766	0.0651661	0.0005095	0.0001158	-0.0003196	0.0010358	0.0050300	0.0085270
7.0	0.0013028	0.0010553	0.0028405	0.0002069	0.0000329	0.0001397	0.0008838	0.0041712	0.0069042
8.0	0.0000549	0.0012551	-0.0209527	0.0000546	0.0000158	0.0000771	0.0007977	0.0036848	0.0059935
9.0	-0.0000033	-0.0006930	-0.0149000	-0.0000404	-0.0000404	-0.0000404	0.0007700	0.0035300	0.0057000
10.0	0.0000549	0.0012551	-0.0209527	0.0000546	0.0000158	0.0000771	0.0007977	0.0036848	0.0059935
11.0	0.0013028	0.0010553	0.0028405	0.0002069	0.0000329	0.0001397	0.0008834	0.0041712	0.0069042
12.0	0.0039863	-0.0066766	0.0651661	0.0005095	0.0001158	-0.0003196	0.0010358	0.0050300	0.0085270
13.0	0.0075959	0.0082737	0.0418342	0.0009835	0.0004810	-0.0023431	0.0012681	0.0063385	0.0110323
14.0	0.0112631	0.0161690	-0.1111526	0.0017135	0.0016579	-0.0044538	0.0016025	0.0082131	0.0146796
15.0	0.0138628	-0.0596454	-0.1456035	0.0029578	0.0061029	0.0079168	0.0020688	0.0108243	0.0198598
15.1	0.0154034	-0.0174354	0.0496178	0.0049508	0.0191469	0.0446265	0.0025664	0.0136176	0.0255099
16.1	0.0185909	0.0973678	0.2340265	0.0077496	0.0397188	0.0839633	0.0030293	0.0162355	0.0308410
16.2	0.0411687	0.1582776	0.3088996	0.0108110	0.0539397	0.1037367	0.0033896	0.0182455	0.0344333

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

NORMAL DEFLECTION AT ELASTIC CENTER, (K SUB DZ)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0445052	0.1631872	0.3145928	0.0115761	0.0553932	0.1054716	0.0034809	0.0185762	0.0348751
1.1	0.0404903	0.1546476	0.3045933	0.0108002	0.0531123	0.1025747	0.0033858	0.0181525	0.0342239
1.2	0.0195305	0.0965906	0.2316571	0.0077978	0.0397438	0.0835820	0.0030273	0.0162332	0.0308113
2.1	0.0155166	-0.0153942	0.0504064	0.0049758	0.0193602	0.0448325	0.0025644	0.0136060	0.0254928
3.0	0.0138606	-0.0584454	-0.1427146	0.0029678	0.0061951	0.0082146	0.0020672	0.0108168	0.0198459
4.0	0.0112561	0.0153683	-0.1101649	0.0017183	0.0016839	-0.0043492	0.0016013	0.0082071	0.0146694
5.0	0.0075967	0.0083070	0.0406242	0.0009853	0.0004897	-0.0023399	0.0012671	0.0063340	0.0110246
6.0	0.0039841	-0.0064914	0.0644325	0.0005102	0.0001185	-0.0003291	0.0010350	0.0050264	0.0085211
7.0	0.0012991	0.0009704	0.0032280	0.0002072	0.0000335	0.0001357	0.0008831	0.0041681	0.0068995
8.0	0.0000527	0.0012380	-0.0206934	0.0000548	0.0000162	0.0000773	0.0007971	0.0036821	0.0059894
9.0	-0.0000018	-0.0006700	-0.0151000	-0.0000405	-0.0000405	-0.0000405	0.0007690	0.0035200	0.0057000
10.0	0.0000527	0.0012380	-0.0206934	0.0000548	0.0000162	0.0000773	0.0007971	0.0036821	0.0059894
11.0	0.0012991	0.0009704	0.0032280	0.0002072	0.0000335	0.0001357	0.0008831	0.0041681	0.0068995
12.0	0.0039841	-0.0064914	0.0644325	0.0005102	0.0001185	-0.0003291	0.0010350	0.0050264	0.0085211
13.0	0.0075967	0.0083070	0.0406242	0.0009853	0.0004897	-0.0023399	0.0012671	0.0063340	0.0110246
14.0	0.0112561	0.0153683	-0.1101649	0.0017183	0.0016839	-0.0043492	0.0016013	0.0082071	0.0146694
15.0	0.0138606	-0.0584454	-0.1427146	0.0029678	0.0061951	0.0082146	0.0020672	0.0108168	0.0198459
15.1	0.0155166	-0.0153942	0.0504064	0.0049758	0.0193602	0.0448325	0.0025644	0.0136060	0.0254928
16.1	0.0195305	0.0965906	0.2316571	0.0077978	0.0397438	0.0835820	0.0030273	0.0162332	0.0308113
16.2	0.0404903	0.1546476	0.3045933	0.0108002	0.0531123	0.1025747	0.0033858	0.0181525	0.0342239

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	0.0000000	0.0000000	0.0000000	-0.0000000	-0.0000000	0.0000000
1.1	-0.0009036	-0.0012395	-0.0011002	-0.0005183	-0.0011451	-0.0012805	-0.0002388	-0.0007949	-0.0010727
1.2	-0.0003057	-0.0013177	-0.0006140	-0.0014580	-0.0049258	-0.0064710	-0.0007048	-0.0031893	-0.0050552
2.1	-0.0002863	0.0211317	0.0344648	-0.0016928	-0.0064136	-0.0090858	-0.0011778	-0.0057344	-0.0099454
3.0	0.0000469	0.0405696	0.1190557	-0.0013177	-0.0039728	-0.0017836	-0.0014944	-0.0073777	-0.0130717
4.0	-0.0000562	-0.0156533	0.0931211	-0.0007513	-0.0016333	0.0041667	-0.0015206	-0.0074834	-0.0132120
5.0	0.0000128	-0.0078235	-0.0417637	-0.0003560	-0.0005849	0.0023416	-0.0013021	-0.0063406	-0.0110556
6.0	0.0000223	0.0069073	-0.0628505	-0.0001491	-0.0001596	0.0003652	-0.0009777	-0.0047003	-0.0080697
7.0	0.0000266	-0.0002550	-0.0084251	-0.0000533	-0.0000362	-0.0000958	-0.0006338	-0.0030095	-0.0050894
8.0	0.0000098	-0.0006441	0.0080723	-0.0000144	-0.0000060	-0.0000461	-0.0003076	-0.0014473	-0.0024200
9.0	-0.0000003	-0.0000008	-0.0000006	-0.0000003	-0.0000001	0.0000000	0.0000000	0.0000000	0.0000000
10.0	-0.0000098	0.0006441	-0.0080723	0.0000144	0.0000060	0.0000461	0.0003076	0.0014473	0.0024200
11.0	-0.0000266	0.0002550	0.0084251	0.0000533	0.0000362	0.0000958	0.0006338	0.0030095	0.0050894
12.0	-0.0000223	-0.0069073	0.0628505	0.0001491	0.0001596	-0.0003652	0.0009777	0.0047003	0.0080697
13.0	-0.0000128	0.0078235	0.0417637	0.0003560	0.0005849	-0.0023416	0.0013021	0.0063406	0.0110556
14.0	0.0000562	0.0156533	-0.0931211	0.0007513	0.0016333	-0.0041667	0.0015206	0.0074834	0.0132120
15.0	-0.0000469	-0.0405696	-0.1190557	0.0013177	0.0039728	0.0017836	0.0014944	0.0073777	0.0130717
15.1	0.0002863	-0.0211317	-0.0344648	0.0016928	0.0064136	0.0090858	0.0011778	0.0057344	0.0099454
16.1	0.0003057	0.0013177	0.0006140	0.0014580	0.0049258	0.0064710	0.0007048	0.0031893	0.0050552
16.2	0.0009036	0.0012395	0.0011002	0.0005183	0.0011451	0.0012805	0.0002388	0.0007949	0.0010727

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	0.0000000	0.0000000	0.0000000	-0.0000000	-0.0000000	0.0000000
1.1	-0.0011883	-0.0016326	-0.0015667	-0.0005218	-0.0014051	-0.0016325	-0.0001875	-0.0008786	-0.0012576
1.2	-0.0004618	-0.0017214	-0.0011328	-0.0013822	-0.0049700	-0.0066304	-0.0006654	-0.0031311	-0.0050267
2.1	-0.0003427	0.0201428	0.0332792	-0.0016165	-0.0064186	-0.0091940	-0.0010866	-0.0056548	-0.0098698
3.0	0.0000408	0.0397011	0.1168739	-0.0012517	-0.0039780	-0.0019314	-0.0013702	-0.0072594	-0.0129626
4.0	-0.0000504	-0.0150353	0.0926681	-0.0007051	-0.0016330	0.0040760	-0.0013679	-0.0073386	-0.0130767
5.0	0.0000069	-0.0077650	-0.0401244	-0.0003126	-0.0005757	0.0023122	-0.0011356	-0.0061816	-0.0109056
6.0	0.0000220	0.0066509	-0.0826527	-0.0000821	-0.0001304	0.0003402	-0.0008109	-0.0045395	-0.0079162
7.0	0.0000273	-0.0006105	-0.0096747	0.0000540	0.0000320	-0.0000796	-0.0004863	-0.0028662	-0.0049516
8.0	0.0000109	-0.0009809	0.0077219	0.0001315	0.0000929	0.0000328	-0.0002121	-0.0013582	-0.0023378
9.0	-0.0000001	-0.0000002	0.0000002	0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000	-0.0000000
10.0	-0.0000109	0.0009809	-0.0077219	-0.0001315	-0.0000929	-0.0000328	0.0002121	0.0013582	0.0023378
11.0	-0.0000273	0.0006105	0.0096747	-0.0000540	-0.0000320	0.0000796	0.0004863	0.0028662	0.0049516
12.0	-0.0000220	-0.0066509	0.0626527	0.0000821	0.0001304	-0.0003402	0.0008109	0.0045395	0.0079162
13.0	-0.0000069	0.0077650	0.0401244	0.0003126	0.0005757	-0.0023122	0.0011356	0.0061816	0.0109056
14.0	0.0000504	0.0150353	-0.0926681	0.0007051	0.0016330	-0.0040760	0.0013679	0.0073386	0.0130767
15.0	-0.0000408	-0.0397011	-0.1168739	0.0012517	0.0039780	0.0019314	0.0013702	0.0072594	0.0129626
15.1	0.0003427	-0.0201428	-0.0332792	0.0016165	0.0064186	0.0091940	0.0010866	0.0056548	0.0098698
16.1	0.0004618	0.0017214	0.0011328	0.0013822	0.0049700	0.0066304	0.0006654	0.0031311	0.0050267
16.2	0.0011883	0.0016326	0.0015667	0.0005218	0.0014051	0.0016325	0.0001875	0.0008786	0.0012576

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	0.0000000	0.0000000	0.0000000	-0.0000000	-0.0000000	-0.0000000
1.1	-0.0903644	-0.0247909	-0.0122291	-0.0515978	-0.0229281	-0.0142256	-0.0238608	-0.0159012	-0.0119244
1.2	-0.0305662	-0.0263190	-0.0068613	-0.1453258	-0.0985859	-0.0718922	-0.0704263	-0.0637991	-0.0561806
2.1	-0.0286302	0.4226851	0.3827879	-0.1684615	-0.1283999	-0.1009337	-0.1177345	-0.1147046	-0.1105180
3.0	0.0046852	0.8112984	1.3224185	-0.1304814	-0.0796696	-0.0197818	-0.1494009	-0.1475689	-0.1452519
4.0	-0.0056238	-0.3138299	1.0336563	-0.0733400	-0.0329944	0.0463589	-0.1520293	-0.1496758	-0.1468007
5.0	0.0012820	-0.1586453	-0.4654462	-0.0336549	-0.0120791	0.0260948	-0.1301722	-0.1268169	-0.1228320
6.0	0.0022273	0.1271405	-0.6996700	-0.0133264	-0.0035239	0.0041287	-0.0977385	-0.0940094	-0.0896514
7.0	0.0026561	-0.0075037	-0.0944374	-0.0044401	-0.0009180	-0.0010214	-0.0633508	-0.0601923	-0.0565388
8.0	0.0009830	-0.0137295	0.0894422	-0.0011996	-0.0001708	-0.0005000	-0.0307443	-0.0289485	-0.0268842
9.0	-0.0000285	-0.0000266	-0.0000159	-0.0000070	-0.0000024	-0.0000005	-0.0000002	-0.0000001	-0.0000000
10.0	-0.0009830	0.0137295	-0.0894422	0.0011996	0.0001708	0.0005000	0.0307443	0.0289485	0.0268842
11.0	-0.0026561	0.0075037	0.0944374	0.0044401	0.0009180	0.0010214	0.0633508	0.0601923	0.0565388
12.0	-0.0022273	-0.1271405	0.6996700	0.0133264	0.0035239	-0.0041287	0.0977385	0.0940094	0.0896514
13.0	-0.0012820	0.1586453	0.4654462	0.0336549	0.0120791	-0.0260948	0.1301722	0.1268169	0.1228320
14.0	0.0056238	0.3138299	-1.0336563	0.0733400	0.0329944	-0.0463589	0.1520293	0.1496758	0.1468007
15.0	-0.0046852	-0.8112984	-1.3224185	0.1304814	0.0796696	0.0197818	0.1494009	0.1475689	0.1452519
15.1	0.0286302	-0.4226851	-0.3827879	0.1684615	0.1283999	0.1009337	0.1177345	0.1147046	0.1105180
16.1	0.0305662	0.0263190	0.0068613	0.1453258	0.0985859	0.0718922	0.0704263	0.0637991	0.0561806
16.2	0.0903644	0.0247909	0.0122291	0.0515978	0.0229281	0.0142256	0.0238608	0.0159012	0.0119244

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE X AXIS, (K SUB RX)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	-0.0000000	0.0000000	-0.0000000	0.0000000	0.0000000	0.0000000	-0.0000000	-0.0000000	0.0000000
1.1	-0.1168293	-0.0356793	-0.0184125	-0.0607568	-0.0303293	-0.0191273	-0.0249772	-0.0190123	-0.0146908
1.2	-0.0461829	-0.0373939	-0.0132242	-0.1437551	-0.1010008	-0.0744677	-0.0700284	-0.0632897	-0.0562708
2.1	-0.0342671	0.4007194	0.3697168	-0.1703546	-0.1301314	-0.1029795	-0.1177407	-0.1147134	-0.1104332
3.0	0.0040845	0.7974515	1.2992599	-0.1310900	-0.0808272	-0.0219255	-0.1492650	-0.1474450	-0.1451526
4.0	-0.0050433	-0.2988538	1.0256561	-0.0738796	-0.0334735	0.0454096	-0.1519168	-0.1495685	-0.1466995
5.0	0.0006887	-0.1592793	-0.4519969	-0.0338894	-0.0122579	0.0260560	-0.1300734	-0.1267254	-0.1227472
6.0	0.0021974	0.1235805	-0.6912243	-0.0134094	-0.0035805	0.0042266	-0.0976639	-0.0939409	-0.0895896
7.0	0.0027272	-0.0064197	-0.0967407	-0.0044734	-0.0009285	-0.0009822	-0.0633028	-0.0601486	-0.0564997
8.0	0.0010897	-0.0134397	0.0873963	-0.0012017	-0.0001733	-0.0004971	-0.0307207	-0.0289272	-0.0268654
9.0	-0.0000097	-0.0000121	-0.0000059	-0.0000028	-0.0000006	-0.0000000	-0.0000000	-0.0000000	-0.0000000
10.0	-0.0010897	0.0134397	-0.0873963	0.0012017	0.0001733	0.0004971	0.0307207	0.0289272	0.0268654
11.0	-0.0027272	0.0064197	0.0967407	0.0044734	0.0009285	0.0009622	0.0633028	0.0601456	0.0564997
12.0	0.0021974	-0.1235805	0.6912243	0.0134094	0.0035605	-0.0042266	0.0976639	0.0939409	0.0895696
13.0	-0.0006887	0.1592793	0.4519969	0.0338894	0.0122579	-0.0260560	0.1300734	0.1267254	0.1227472
14.0	0.0050433	0.2988538	-1.0256561	0.0738796	0.0334735	-0.0454096	0.1519168	0.1495685	0.1466995
15.0	-0.0040845	-0.7974515	-1.2992599	0.1310900	0.0808272	0.0219255	0.1492650	0.1474450	0.1451526
15.1	0.0342671	-0.4007194	-0.3697168	0.1703546	0.1301314	0.1029795	0.1177407	0.1147134	0.1104332
16.1	0.0461829	0.0373939	0.0132242	0.1437551	0.1010008	0.0744677	0.0700284	0.0632897	0.0562708
16.2	0.1168293	0.0356793	0.0184125	0.0607568	0.0303293	0.0191273	0.0249772	0.0190123	0.0146908

CONCENTRATED UNIT FORCE AT STATION 1 ELASTIC CENTER

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0317567	0.1675647	0.3198723	0.0109779	0.0570744	0.1069313	0.0036479	0.0189135	0.0353423
1.1	0.0251809	0.1585503	0.3102412	0.0094331	0.0543346	0.1039166	0.0034495	0.0182467	0.0345137
1.2	0.0027352	0.0996983	0.2409903	0.0062289	0.0399854	0.0847561	0.0030154	0.0159384	0.0305626
2.1	-0.0001914	-0.0089750	0.0736887	0.0032328	0.0185489	0.0454177	0.0023531	0.0123691	0.0236237
3.0	-0.0003726	-0.0441081	-0.0864683	0.0012040	0.0050122	0.0093764	0.0015148	0.0079379	0.0150810
4.0	-0.0002938	0.0035614	-0.0654050	0.0002371	0.0008597	-0.0016094	0.0006412	0.0034053	0.0065568
5.0	-0.0002889	0.0022809	-0.0177051	-0.0000444	0.0000992	-0.0005493	0.0000079	0.0002020	0.0007035
6.0	-0.0002841	0.0030146	-0.0181161	-0.0000919	-0.0000176	-0.0000738	-0.0003990	-0.0017986	-0.0028316
7.0	-0.0002346	-0.0006376	0.0046584	-0.0000718	-0.0000068	-0.0001198	-0.0006288	-0.0028894	-0.0046802
8.0	-0.0001372	-0.0008192	0.0194557	-0.0000435	0.0000000	-0.0000737	-0.0007383	-0.0033886	-0.0054848
9.0	0.0000033	0.0006930	0.0149000	0.0000004	0.0000004	0.0000004	-0.0007700	-0.0035300	-0.0057000
10.0	-0.0001372	-0.0008192	0.0194557	-0.0000435	0.0000000	-0.0000737	-0.0007383	-0.0033886	-0.0054848
11.0	-0.0002346	-0.0006376	0.0046584	-0.0000718	-0.0000068	-0.0001198	-0.0006288	-0.0028894	-0.0046802
12.0	-0.0002841	0.0030146	-0.0181161	-0.0000919	-0.0000176	-0.0000738	-0.0003990	-0.0017986	-0.0028316
13.0	-0.0002889	0.0022809	-0.0177051	-0.0000444	0.0000992	-0.0005493	0.0000079	0.0002020	0.0007035
14.0	-0.0002938	0.0035614	-0.0654050	0.0002371	0.0008597	-0.0016094	0.0006412	0.0034053	0.0065568
15.0	-0.0003726	-0.0441081	-0.0864683	0.0012040	0.0050122	0.0093764	0.0015148	0.0079379	0.0150810
15.1	-0.0001914	-0.0089750	0.0736887	0.0032328	0.0185489	0.0454177	0.0023531	0.0123691	0.0236237
16.1	0.0027352	0.0996983	0.2409903	0.0062289	0.0399854	0.0847561	0.0030154	0.0159384	0.0305626
16.2	0.0251809	0.1585503	0.3102412	0.0094331	0.0543346	0.1039166	0.0034495	0.0182467	0.0345137

UNIT FORCE DISTRIBUTED OVER ELASTIC CENTER OF ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

GJ/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	0.0277855	0.1626328	0.3146255	0.0098372	0.0554999	0.1052119	0.0033322	0.0184215	0.0347878
1.1	0.0235376	0.1543806	0.3054363	0.0089754	0.0532149	0.1024828	0.0032212	0.0179593	0.0341316
1.2	0.0032212	0.0981348	0.2379870	0.0059476	0.0396217	0.0840182	0.0028000	0.0157401	0.0303521
2.1	-0.0000706	-0.0076351	0.0737497	0.0030834	0.0185233	0.0453271	0.0021791	0.0121955	0.0234597
3.0	-0.0003174	-0.0429839	-0.0843890	0.0011471	0.0050197	0.0095198	0.0013884	0.0078175	0.0149650
4.0	-0.0002486	0.0033476	-0.0645742	0.0002221	0.0008583	-0.0015478	0.0005778	0.0033443	0.0064995
5.0	-0.0002452	0.0022501	-0.0176454	-0.0000417	0.0000991	-0.0005449	0.0000078	0.0002031	0.0007058
6.0	-0.0002424	0.0030736	-0.0185215	-0.0000638	-0.0000022	-0.0000826	-0.0003293	-0.0017285	-0.0027612
7.0	-0.0001860	-0.0010983	0.0034522	0.0000335	0.0000693	-0.0000500	-0.0004803	-0.0027399	-0.0045288
8.0	0.0001114	-0.0010795	0.0202534	0.0002699	0.0003515	0.0004137	-0.0005026	-0.0031459	-0.0052329
9.0	0.0007160	0.0027527	0.0182000	0.0000073	0.0000073	0.0000073	-0.0004500	-0.0032000	-0.0053600
10.0	0.0001114	-0.0010795	0.0202534	0.0002699	0.0003515	0.0004137	-0.0005026	-0.0031459	-0.0052329
11.0	-0.0001860	-0.0010983	0.0034522	0.0000335	0.0000693	-0.0000500	-0.0004803	-0.0027399	-0.0045288
12.0	-0.0002424	0.0030736	-0.0185215	-0.0000638	-0.0000022	-0.0000826	-0.0003293	-0.0017285	-0.0027612
13.0	-0.0002452	0.0022501	-0.0176454	-0.0000417	0.0000991	-0.0005449	0.0000078	0.0002031	0.0007058
14.0	-0.0002486	0.0033476	-0.0645742	0.0002221	0.0008583	-0.0015478	0.0005778	0.0033443	0.0064995
15.0	-0.0003174	-0.0429839	-0.0843890	0.0011471	0.0050197	0.0095198	0.0013884	0.0078175	0.0149650
15.1	-0.0000706	-0.0076351	0.0737497	0.0030834	0.0185233	0.0453271	0.0021791	0.0121955	0.0234597
16.1	0.0032212	0.0981348	0.2379870	0.0059476	0.0396217	0.0840182	0.0028000	0.0157401	0.0303521
16.2	0.0235376	0.1543806	0.3054363	0.0089754	0.0532149	0.1024828	0.0032212	0.0179593	0.0341316

CONCENTRATED UNIT TORQUE AT STATION 1 ELASTIC CENTER
COEFFICIENT FOR
ROTATION ABOUT THE Y AXIS, (K SUB RY)

6J/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	3.2349716	3.3430240	3.5503094	1.1045212	1.1400900	1.1884373	0.3647472	0.3782018	0.3925427
1.1	2.5749224	3.1628087	3.4432608	0.9501433	1.0852788	1.1549343	0.3449098	0.3648671	0.3833357
1.2	0.3290556	1.9855953	2.6739474	0.6294955	0.7983030	0.9420325	0.3015022	0.3186995	0.3394316
2.1	0.0320957	-0.1878861	0.8153021	0.3293594	0.3696371	0.5049296	0.2352617	0.2473132	0.2623329
3.0	0.0076969	-0.8904109	-0.9638742	0.1257077	0.0990187	0.1044591	0.1514176	0.1586928	0.1674177
4.0	0.0104151	0.0633724	-0.7294189	0.0283894	0.0160902	-0.0176255	0.0640454	0.0680531	0.0727180
5.0	0.0097000	0.0380265	-0.1993191	-0.0001143	0.0009505	-0.0058626	0.0007139	0.0039993	0.0077040
6.0	0.0096512	0.0525996	-0.2038398	-0.0052670	-0.0012979	-0.0005990	-0.0399633	-0.0359990	-0.0315462
7.0	0.0098297	-0.0199015	0.0495777	-0.0040380	-0.0009019	-0.0011522	-0.0629283	-0.0578053	-0.0520562
8.0	0.0069940	-0.0210264	0.2148836	-0.0025660	-0.0004416	-0.0007150	-0.0738512	-0.0677800	-0.0609695
9.0	0.0003254	0.0139897	0.1660000	-0.0000404	-0.0000404	-0.0000404	-0.0770000	-0.0709000	-0.0633000
10.0	0.0069940	-0.0210264	0.2148836	-0.0025660	-0.0004416	-0.0007150	-0.0738512	-0.0677800	-0.0609695
11.0	0.0098297	-0.0199015	0.0495777	-0.0040380	-0.0009019	-0.0011522	-0.0629283	-0.0578053	-0.0520562
12.0	0.0096512	0.0525996	-0.2038398	-0.0052670	0.0012979	-0.0005990	-0.0399633	-0.0359990	-0.0315462
13.0	0.0097000	0.0380265	-0.1993191	-0.0001143	0.0009505	-0.0058626	0.0007139	0.0039993	0.0077040
14.0	0.0104151	0.0633724	-0.7294189	0.0283894	0.0160902	-0.0176255	0.0640454	0.0680531	0.0727180
15.0	0.0076969	-0.8904109	-0.9638742	0.1257077	0.0990187	0.1044591	0.1514176	0.1586928	0.1674177
15.1	0.0320957	-0.1878861	0.8153021	0.3293594	0.3696371	0.5049296	0.2352617	0.2473132	0.2623329
16.1	0.3290556	1.9855953	2.6739474	0.6294955	0.7983030	0.9420325	0.3015022	0.3186995	0.3394316
16.2	2.5749224	3.1628087	3.4432608	0.9501433	1.0852788	1.1549343	0.3449098	0.3648671	0.3833357

UNIT MOMENT ABOUT Y AXIS DISTRIBUTED OVER ELEMENTS 1 AND 16.2

COEFFICIENT FOR

ROTATION ABOUT THE Y AXIS, (K SUB RY)

6J/EI=	0.02	0.02	0.02	0.20	0.20	0.20	2.00	2.00	2.00
C/R =	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09	-0.01	-0.05	-0.09
STATION									
1.0	2.9046108	3.2529751	3.4968929	1.0275517	1.1128341	1.1717736	0.3548452	0.3716041	0.3880006
1.1	2.5021958	3.0889407	3.3947704	0.9482741	1.0681138	1.1416023	0.3444333	0.3627575	0.3807850
1.2	0.4179437	1.9667624	2.6453354	0.6348445	0.7982468	0.9370647	0.3013827	0.3187772	0.3390715
2.1	0.0394611	-0.1534090	0.8184449	0.3312473	0.3735566	0.5064627	0.2350274	0.2470479	0.2621639
3.0	0.0087095	-0.8705087	-0.9416588	0.1266239	0.1004872	0.1070008	0.1513270	0.1586051	0.1673002
4.0	0.0101526	0.0575670	-0.7200974	0.0285157	0.0163124	-0.0168705	0.0639883	0.0679960	0.0726683
5.0	0.0096411	0.0368598	-0.1976861	-0.0001032	0.0009674	-0.0057789	0.0007158	0.0039982	0.0076985
6.0	0.0097476	0.0515493	-0.2029270	-0.0053044	-0.0013139	-0.0005648	-0.0399336	-0.0359733	-0.0315245
7.0	0.0099682	-0.0185813	0.0457930	-0.0040711	-0.0009096	-0.0011284	-0.0628804	-0.0577634	-0.0520204
8.0	0.0071647	-0.0207753	0.2126128	-0.0025801	-0.0004500	-0.0007188	-0.0737951	-0.0677311	-0.0609277
9.0	0.0001774	0.0134702	0.1670000	-0.0000405	-0.0000405	-0.0000405	-0.0769000	-0.0705000	-0.0653000
10.0	0.0071647	-0.0207753	0.2126128	-0.0025801	-0.0004500	-0.0007188	-0.0737951	-0.0677311	-0.0609277
11.0	0.0099682	-0.0185813	0.0457930	-0.0040711	-0.0009096	-0.0011284	-0.0628804	-0.0577634	-0.0520204
12.0	0.0097476	0.0515493	-0.2029270	-0.0053044	-0.0013139	-0.0005648	-0.0399336	-0.0359733	-0.0315245
13.0	0.0096411	0.0368598	-0.1976861	-0.0001032	0.0009674	-0.0057789	0.0007158	0.0039982	0.0076985
14.0	0.0101526	0.0575670	-0.7200974	0.0285157	0.0163124	-0.0168705	0.0639883	0.0679960	0.0726683
15.0	0.0087095	-0.8705087	-0.9416588	0.1266239	0.1004872	0.1070008	0.1513270	0.1586051	0.1673002
15.1	0.0394611	-0.1534090	0.8184449	0.3312473	0.3735566	0.5064627	0.2350274	0.2470479	0.2621639
16.1	0.4179437	1.9667624	2.6453354	0.6348445	0.7982468	0.9370647	0.3013827	0.3187772	0.3390715
16.2	2.5021958	3.0889407	3.3947704	0.9482741	1.0681138	1.1416023	0.3444333	0.3627575	0.3807850

NA-65-1015
Appendix 2

SERIAL NO

STUDY OF SHELL SUPPORTED RING FRAMES

WITH

OUT-OF-PLANE LOADING

FINAL REPORT

24 JUNE 1965 TO 28 DECEMBER 1965

CONTRACT NO. NAS8-20097

REQUEST NO. RFQ NO. DCN 1-5-53-01066-01

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National Aeronautics and Space Administration
Huntsville, Alabama

DATE 3 March 1966
NO. OF PAGES i thru iii
1 thru 11

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FOREWORD

Presented herein is Appendix 2 to the Final Report for Contract No. NAS8-20097, for "Study of Shell Supported Ring Frames With Out-of-Plane Loadings".

APPENDIX 2

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APPENDIX 2

LIST OF ILLUSTRATIONS

APPENDIX 2

Two specific ring examples involving four cases of loading (one for Example 1 and three for Example 2) were received via Reference f . These ring examples were analyzed using the method of this report and the computer programs especially developed for this method. The results so obtained are given below with explanations of the steps required in the solutions.

Example 1

Figure 1 (based on information in Reference f) defines the geometry, loading and ring cross-section of Example 1. Figure 2 shows the stations selected for use in the analysis. The principal moments of inertia were $I_X = 1.291 \text{ in.}^4$, $I_Z = 4.271 \text{ in.}^4$. The twist coefficient was $J = 0.02582 \text{ in.}^4$. R, the radius measured from the reference axes orgin to the ring elastic axis, was 132.657 inches. The applied loads were eight concentrated forces spaced around the ring and displaced inward 0.354 inch from the elastic axis. The displacement from the elastic axis induced a torque at each load station. Parameters C/R and GJ/EI had values of 0.018 and 0.0076 respectively.

Parameter C/R was within the range of the results of Appendix 1 but GJ/EI unfortunately was less than the lower GJ/EI limit of 0.02. It was necessary, therefore, to run the ring solution using the above values of I_X, J and R. The tie solution wes run for a unit concentrated force and unit moment. The tie results were then rotated to each load application station. Next the sixteen sets of results (a set for each of the eight stations and for each of the two load types) were summed according to load type. These two sets of sums were in turn multiplied by their respective design force or moment. The moment result was added to the force result to obtain the final result.

The Table I on page 5 shows the internal normal force F_Z, internal torque T, internal moment M and normal deflection D_Z for the stations depicted in figure 2. This table shows a slight difference in value for the deflections D_x at station 3 compared with station 4. The same differences exist between stations 8 and 9, 13 and 14, 18 and 19. Moment M shows similar slight inconsistencies at the same stations. These small differences are the result of "round off error" in the superposition process and do not detract from the basic accuracy of the results.

Normal force F_Z and torque T have inboard values different from outboard values at each station due to the concentrated load or reaction at these points. The values shown in Table I are for the outboard portion of each station measure counterclockwise from station 1.

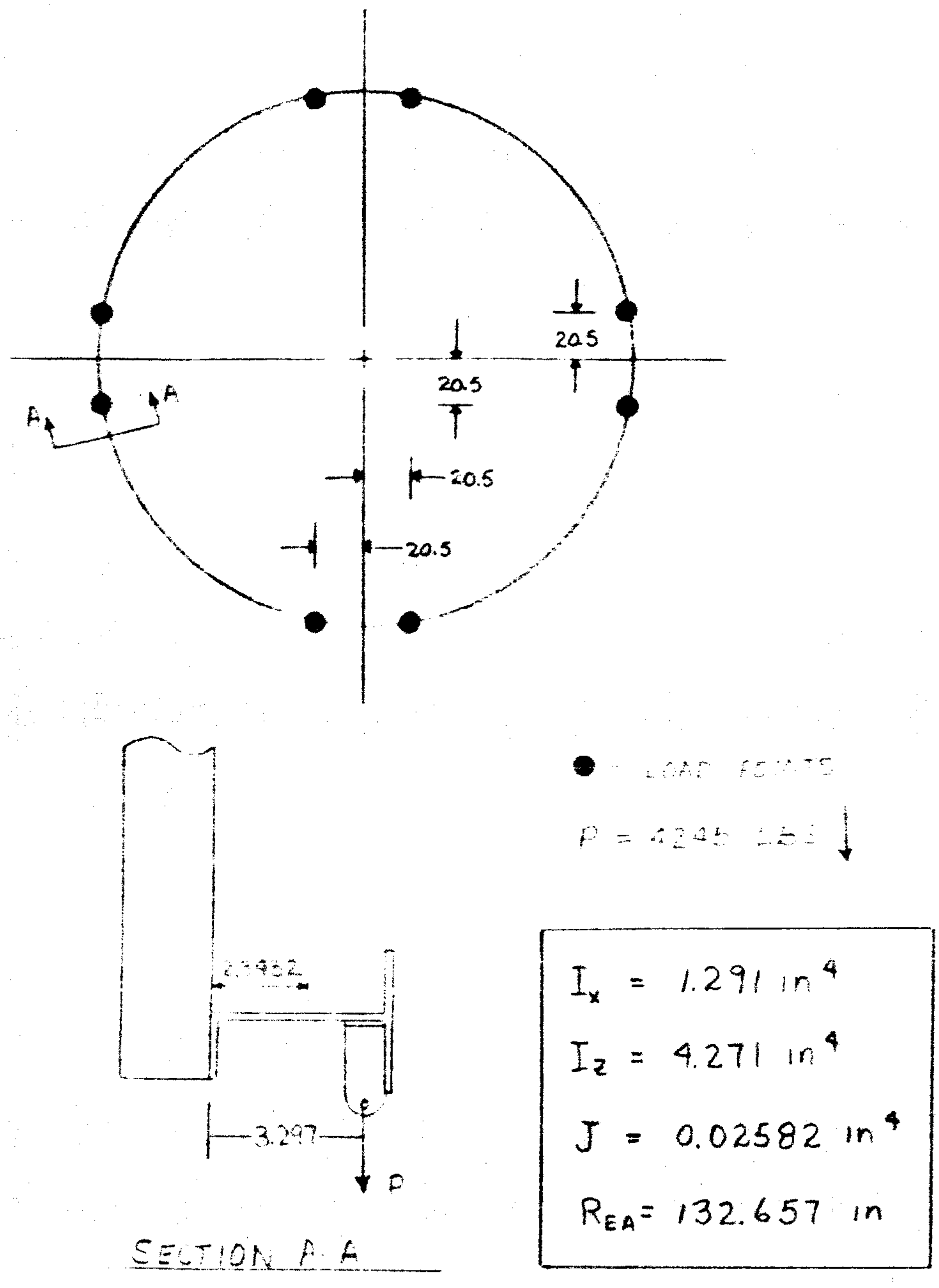
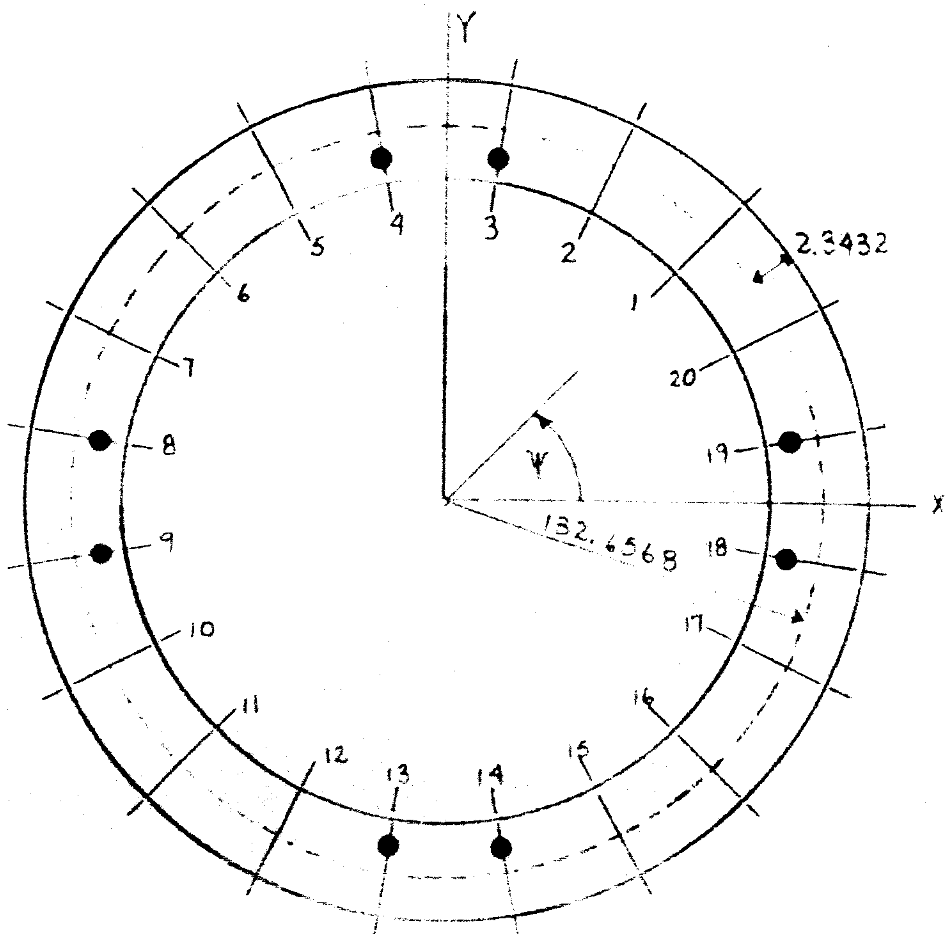


Figure 1. Ring Properties and Loading, Example 1



STA	Ψ	STA	Ψ	STA	Ψ	STA	Ψ
1	45	6	135	11	225	16	315
2	63.1333	7	153.1333	12	243.1333	17	333.1333
3	81.2666	8	171.2666	13	261.2666	18	351.2666
4	98.7333	9	188.7333	14	278.7333	19	8.7333
5	116.8666	10	206.8666	15	296.8666	20	26.8666

Figure 2. Station Numbering System, Example 1

TABLE I

RING SHELL EXAMPLE 1

INTERNAL LOADS AND DEFLECTIONS

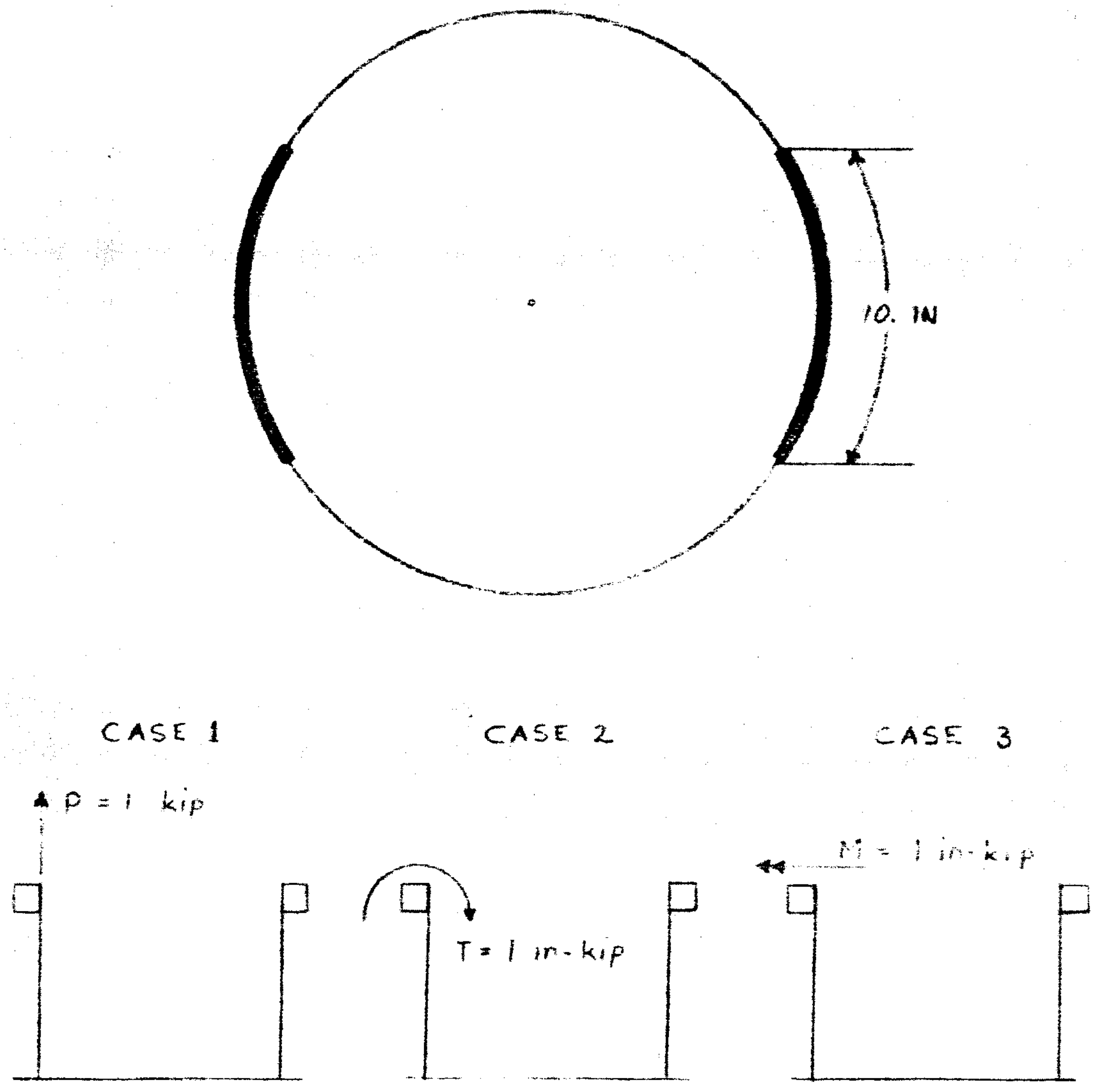
STA.	F_Z	T	M	D_X
1	117	-277	2796	-1.09
2	-136	-1148	7436	-1.13
3	-2243	-3027	52582	-1.32
4	-1477	-2228	52595	-1.33
5	709	-192	7470	-1.15
6	117	-277	2796	-1.09
7	-136	-1148	7436	-1.13
8	-2243	-3027	52582	-1.32
9	-1477	-2228	52595	-1.33
10	709	-192	7470	-1.15
11	117	-277	2796	-1.09
12	-136	-1148	7436	-1.13
13	-2243	-3027	52582	-1.32
14	-1477	-2228	52595	-1.33
15	709	-192	7470	-1.15
16	117	-277	2796	-1.09
17	-136	-1148	7436	-1.13
18	-2243	-3027	52582	-1.32
19	-1477	-2228	52595	-1.33
20	709	-192	7470	-1.15

Example 2

Details of geometry and loading for the three cases of Example 2 are shown in figures 3 and 4. Basically the same procedure was followed for Example 2 that was followed for Example 1. First the ring cross-section was analyzed to get the principal moments of inertia. I_x was 0.2681 $in.^4$ and I_z was 0.2068 $in.^4$. A rectangular cross-section having these moments of inertia was determined to have a width of 1.215 inches and a height of 1.384 inches. The J for such a rectangle was found to be 0.4109 $in.^4$. R, the radius to the ring elastic axis, was 9.1675 inches. The ring was located outside the shell so that C was negative. The value of C was found to be -0.6075 inches. From the above values the parameters were calculated. GJ/EI was 0.58 and C/R was -0.066. This time the parameter GJ/EI was within the range of the results in Appendix 1 as was the negative C/R. However, in order to demonstrate directly the capability of the developed program, a ring and tie solution were run as in Example 1.

Again unit loads were utilized in the tie solution. A distributed unit force, unit torque and unit moment were applied to a 9-degree arc. The results from this solution were rotated and superimposed several times to obtain the results for a 67.5-degree loaded arc. These results were then rotated 180 degrees and added to the unrotated results to obtain the results for two diametrically opposite loaded arcs as specified in Reference 4. The actual load arcs given in Reference 4 were determined to be 66.93 degrees so an error of 0.57 degrees was incurred in each loaded arc. It was felt that this small error would produce a negligible effect on the final answers so no correction was made.

Results of this analysis are given in table form on pages 9, 10 and 11.



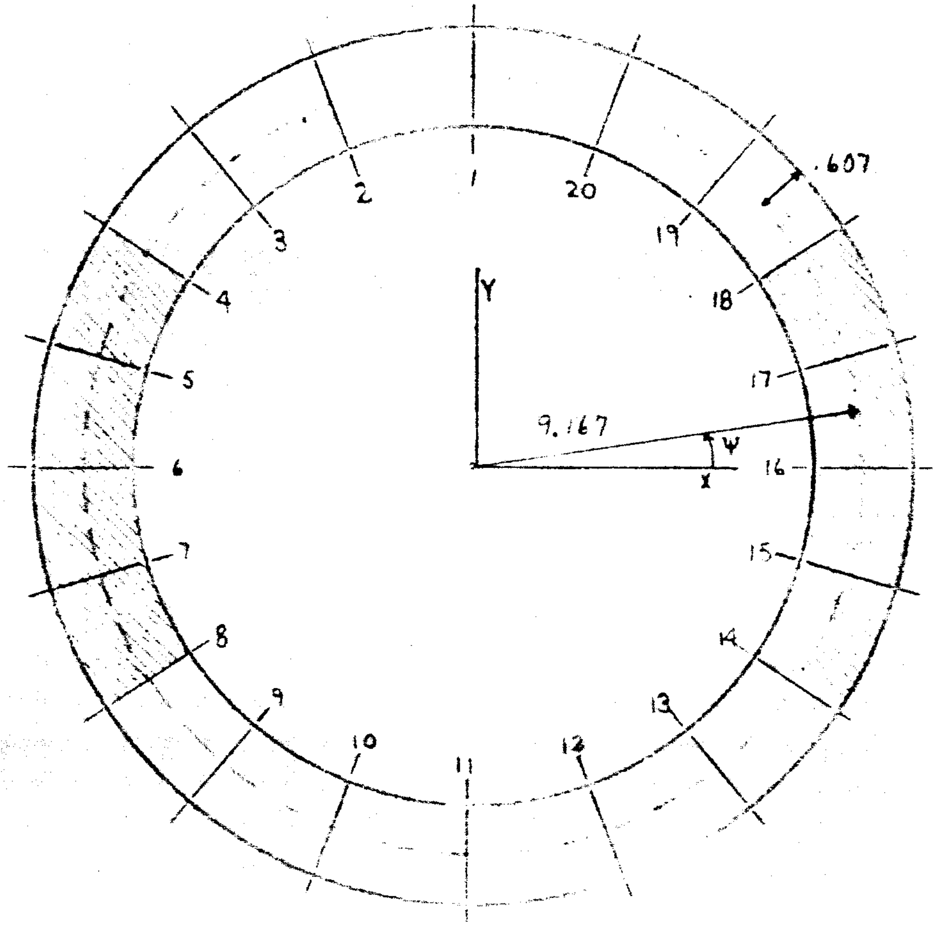
I_x = 0.2681 in^4

I_z = 0.2068 in^4

J = 0.4109 in^4

ρ_{EA} = 9.1675 in

Figure 3. Ring Properties and Loading, Example 2



STA	Ψ
[illegible]	90
2	109
3	128
4	146.5329
5	163

STA	Ψ
6	180
7	197
8	213.4671
9	232
10	251

STA	Ψ
11	270
12	289
13	308
14	326.5329
15	343

STA	Ψ
16	0
17	17
18	33.4671
19	52
20	71

Figure 4. Station Numbering System, Example 2

TABLE 2

RING SHELL EXAMPLE 2, CASE 1 LOADING

INTERNAL LOADS AND DEFLECTIONS

STA	F_Z	T	M	$D_Z \times 10^3$
1	21	32	148	.138
2	-1	-32	171	.151
3	-18	-102	213	.187
4	-53	-130	240	.227
5	-90	-93	267	.258
6	-83	-30	279	.270
7	-59	38	267	.258
8	-42	100	240	.227
9	-23	135	213	.187
10	33	95	171	.151
11	21	32	148	.138
12	-1	-32	171	.151
13	-18	-102	213	.187
14	-53	-130	240	.227
15	-90	-93	267	.258
16	-83	-30	279	.270
17	-59	38	267	.258
18	-42	[illegible]	240	.227
19	-23	135	213	.187
20	33	[illegible]	171	[illegible]

TABLE 3

RING SHELL EXAMPLE 2, CASE 2 LOADING

INTERNAL LOADS AND DEFLECTIONS

STA	F_Z	T	M	$D_Z \times 10^3$
1	35	53	247	.421
2	-1	-53	285	.442
3	-30	-170	355	.490
4	-43	-190	398	.553
5	-40	-90	441	.601
6	-27	14	459	.618
7	-14	112	441	.601
8	16	217	398	.553
9	15	257	355	.490
10	55	159	285	.442
11	35	53	247	.421
12	-14	-53	285	.442
13	-30	-170	355	.490
14	-43	-190	398	.553
15	-40	-90	441	.601
16	-27	14	459	.618
17	-14	112	441	.601
18	16	217	398	.553
19	15	257	355	.490
20	55	159	285	.442

TABLE 4

RING SHELL EXAMPLE 2, CASE 3 LOADING

INTERNAL LOADS AND DEFLECTIONS

STA	F_Z	T	M	$D_Z \times 10^3$
1	35	614	-188	.48
2	33	594	290	-.68
3	27	468	750	-1.36
4	60	277	981	-1.25
5	110	78	891	-.42
6	99	-77	621	.61
7	68	-84	15	1.85
8	61	12	-556	2.63
9	34	197	-888	2.74
10	36	525	-663	1.38
11	35	614	-188	.48
12	33	594	290	-.68
13	27	468	750	-1.36
14	60	277	981	-1.25
15	110	78	891	-.42
16	99	-77	621	.61
17	68	-84	15	1.85
18	61	12	-556	2.63
19	34	197	-888	2.74
20	36	525	-663	1.38