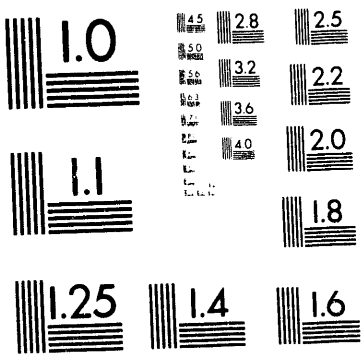
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1 of 2

BASE ISOLATION: FRESH INSIGHT

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Program Director: Dr. Mahendra P. Singh.

ABSTRACT

The objective of the research is a further development of the engineering concept of seismic isolation. Neglecting the transient stage of seismic loading results in a widespread misjudgement: the force of resistance associated with velocity is mostly conceived as a source of damping vibrations, though it is an active force at the same time, during an earthquake type excitation. For very pliant systems such as base isolated structures with relatively low bearing stiffness and with artificially added heavy damping mechanism, the so called "damping" force may occur even the main pushing force at an earthquake. Thus, one of the two basic pillars of the common seismic isolation philosophy, namely, the doctrine of usefulness and necessity of a strong damping mechanism, is turning out to be a self-deception, sometimes even jeopardizing the safety of structures and discrediting the very idea of seismic isolation. There is a way out: ***breaking with damping dependancy***.

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I. REPORT

SECTION 1

MODERN CONCEPT OF SEISMIC ISOLATION

It will be shown in this section that despite a wide veriety of practical implementations, the common concept of seismic isolation is resting primarily on two pillars: flexible mounting and energy dissipation [1], and that the last one does does not necessarily contribute to a better isolation.

A global view of the History of base isolation application, except that of the newest ideas on antifriction and non-destructive softening systems, is given by James M.Kelly [2]. Therefore, there is no need to duplicate this information here. Instead, it seems more productive to concentrate on fresh or well forgotten perspectives concerning seismic isolation technique.

Seismic isolation, or base isolation is a particular case of the vibration isolation technique extended upon essentially non-rigid structures which are to be protected against possible earthquakes. Concept of seismic isolation is based on the premise that the fundamental period of the superstructure as a rigid body rocking on isolators (isolated period) is several times greater than the period of the fixed-base structure. The more the difference, the better the isolation, and vice versa. By decreasing the actual ratio of the base-isolated period to the fixed-base period, we will enter the area where the positive effect of the seismic isolation is very small if any.

Such was the case with the Foothill Community Law & Justice Center at the June 28, 1992 Landers Earthquake. Despite of the fact that the building was mounted on isolators, due to specific properties of those isolators which, for activating their most beneficial prformance, required the quake to be not just strong but still accompanied with large lateral displacements, the system, failing to reach the targeted value of the isolated period, behaved like an ordinary one with the recorded maximum roof acceleration of 0.19g at the 0.11g acceleration of the base [3].

The matter is that the shearing systems of seismic isolation similar to that of FCLJC, obtain their full mitigating capacity mostly when the earth shaking is strong enough and when supposedly protected object has already suffered a certain, possibly significant structural damage. This is the price for developing the "effective stiffness", as well as for the overestimated "positive" contribution of heavy damping.

Besides separating the frequency of the superstructure and that of the isolated system, to make the earthquake protection successful, one more level of separation should be provided: between the fundamental frequency of the structure on isolators and the most damaging frequency range of the shaking ground. Still in 1975 Ray W. Clough and Joseph Pensien [4] had demonstrated that a base isolated structure, treated as a rigid body on a spring and a viscous damper, experiences two principally different stages of steady state response while successively undergoing harmonic excitation with varying relative frequencies $\beta = \bar{w} / w$ where the isolated frequency w is supposed to be fixed, and the ground frequency $\bar{w}$ grows up starting from zero. Thus, when $0 < \beta < \sqrt{2}$, there is no isolation effect at all. In the range of $\beta > \sqrt{2}$ the damper's contribution is negative.

However, the monograph [4] is not probably the most read book by the base isolation researchers and engineers. Of the total amount of 53 papers included into the "Earthquake Spectra" 6(2)1990 and Proceedings ATC-17-1, Vol.1 and devoted to the seismic isolation, which contain 532 references altogether, only one [5] alludes to the monograph [4], and that one, unfortunately, misrepresents the damping coefficient of viscous model by alleging that the energy loss is dependent upon the system fundamental frequency instead of the frequency of excitation (which is actually true).

J. Kelly [6] admits that "damping can be viewed as a contaminant of the isolation process". This utterly articulated opinion of the researcher who is considered to be the "father" of modern seismic base isolation did not prevent, however, from publication the SEONC Requirements [7] which encouraged implementation of overdamped systems. Those Requirements with some amendments were included in the UBC-91 [8] as an Appendix, and now, using the same terminology, they "contaminate" the whole field of seismic isolation engineering.

As soon as the damping has nothing to do with isolation process, why do we need damping?

It is taken for granted that the flexible mounting by itself cannot provide a favorable regime of structural performance in the range of low ground periods merely because most of the existing types of isolators do not provide enough flexibility. Damping is just intended to shield this particular range. When allowable displacements of a structure are to be less than the ground ones, only severe damping can seemingly help. Otherwise, the superstructure should use its own mitigating mechanism of ductility which means that the goal of seismic isolation has not been achieved (strictly speaking, it looks like nobody believes that this could be avoided: parameter R_{wi} in the Regulations [8] is just the quantitive measure of the expected seismic isolation ineffectiveness).

But damping mechanism of any kind under kinematic excitation is simultaneously a driving one. Normally, we recognize the velocity-associated force of resistance solely as a source of restricting ("damping") periresonant structural responses but we disregard its another quality: to be one of the two pushing mechanisms transforming the earth movement into the forces applied to the structures (the second pushing mechanism is stiffness). For relatively pliant systems like base isolated structures with low bearing stiffness and strong damping mechanism, the "damping" force can occur even the main "pushing" one during an earthquake. Its negative, pushing effect is immediate, while its positive, dissipating capacity needs more time to fully develop.

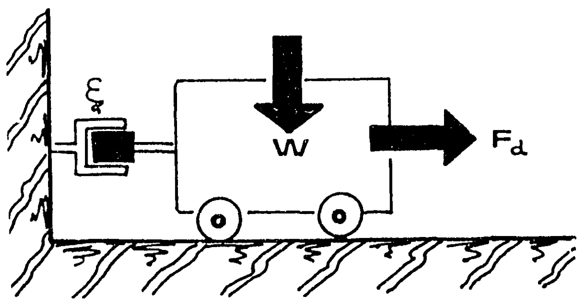


Figure 1-1. Mass-damper system without restoring mechanism.

As an example, consider a mass supported on rollers (Figure 1-1). The mass is connected to the ground through a viscous damper in absence of any spring force. If the mass is disturbed from its initial position by imparting the instant velocity $\dot{v}_{max} = gZ/w$ (effective peak ground velocity per UBC-91), the velocity-related resistance F_d being proportioned to the weight W could be written as follows:

$$F_d/W = 2\xi w\dot{v}_{max}/g = 2\xi Z \qquad (1.01)$$

The same results will be received for a hysteretic damper:

$$F_d/W = 2\xi k v_{max}/mg = 2\xi Z \qquad (1.02)$$

Assuming equivalent viscous damping ratio $\xi = 0.4$ as in the case of Super Plastic Rubber [9] and $Z = 0.4$, obtain:

$$F_d/W = 2 \times 0.4 \times 0.4 = 0.32$$

For near-fault location this value should be essentially increased, and this will account for one pulse only, without a magnifying contribution of the spring mechanism of isolators. It is obvious that heavily damped seismic isolators are not a remedy: they inevitably generate powerful pulses accompanied with violent jerks in the superstructure [10].

How could it happen that we overlooked the negative effect of damping?

Routinely, we do not take into account that the kinematic information from the shaking ground is not transmitted to the top of the structure instantly but in a transient process of running waves propagation. We simply disregard that real seismic loads are applied not in the points of lumped mass concentration but in the planes of contact between the structure and the soil. In case of base isolated systems, the stage when the running wave just covers the height of the isolator and the superstructure still remains undisturbed, is of primary importance. By this moment, the initial pushing force ("negative quality") associated with the velocity of lateral vibration and with the magnitude of the damping characteristic of the isolator has already developed, whereas the damping in the traditional sense of the word ("positive quality") has not. This fenomenon is not obvious if we use the kind of analysis which is usually employed in earthquake engineering due to its lack of sufficient resolving power.

In spite of the fact that the first attempts to isolate buildings from potentially shaky ground were made probably thousands years ago, the modern concept of seismic isolation (flexible mounting + damping) is forein for earthquake engineering: it has not been inherited, it has been borrowed from mechanical engineering. Though the concept is working perfectly in all sorts of vehicles, in seismic isolation everything is not so smooth because the conditions in both cases are quite different. In a car, for instance, the working stresses in auto parts are far below their ultimate bearing capacity, therefore some overloads associated with heavy damping are of no practical importance. Another matter is a building structure: during a strong earthquake it is intended to perform at the near-to-collapse level and any extras can become crucial for its safety.

SECTION 2

FRESH APPROACH

This section will present a new concept of damping-independent seismic isolation engaging a nondestructive tuning-out procedure through the use of multi-curvature geometry of the pedestal plate of a sliding isolator.

There is an alternative to the contradictory damping mechanism of base isolators. It can be found in the utmost lessening the damping and substituting its positive, mitigating quality with any sort of tuning-out mechanism which satisfies the following requirements:

a) Let the earth move its way.
b) Prevent resonant amplifications.
c) Restore the structure in its pre-earthquake position on the foundation.

It is not the building, it is the earth that should be vibrating if the building is supported on the ideal isolation system. Any attempt to reduce a relative displacement of the superstructure with respect to the base will inevitably result in additional transmission of earthquake energy into the building.

An example of seismic isolation which meets those requirements was described in [11, 12]. A new concept embodied in Shock Evader or, which is the same, in the Antifriction and Multi-Step Base Isolation (AF&MS BI) unit incorporates the merits of the traditional flexible mounting but without its drawback - a compulsory damping mechanism. The Shock Evader consists (Figure 2-1) of a ball transfer unit (1) supporting

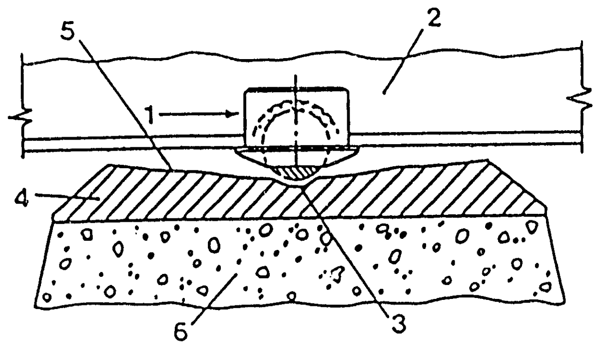


Figure 2-1. Shock Evader^{tm}.

a superstructure (2) and resting on a depression (3) of a pedestal plate (4). The depression is shaped in compliance with the configuration of the contacting surface of the ball and is centered at the lowest point of the pedestal plate (4) having a concave upper surface (5) and resting on a foundation (6). The depth of the depression at given radius of the ball is governed by the weight of the superstructure and by the design wind load. The force of gravity will keep the superstructure in a steady position on the pedestal plate both at any wind and minor earthquakes. When magnitude of the earth movement exceedes a certain threshold, the ball gets out of the depression and any transfer of horizontal movement to the superstructure considerably decreases.

To confine the base shear by an acceptable level, the upper surface of the pedestal plate is shaped as a combination of spherical surfaces with successively increasing radii of curvature which are continuously transforming into each other. The maximum vertical grade of every component surface is pre-determined in compliance with the sliding friction coefficient of the ball transfer unit and with allowable base shear. Such design provides multi-step non-destructive softening the system thus protecting it against resonant amplification.

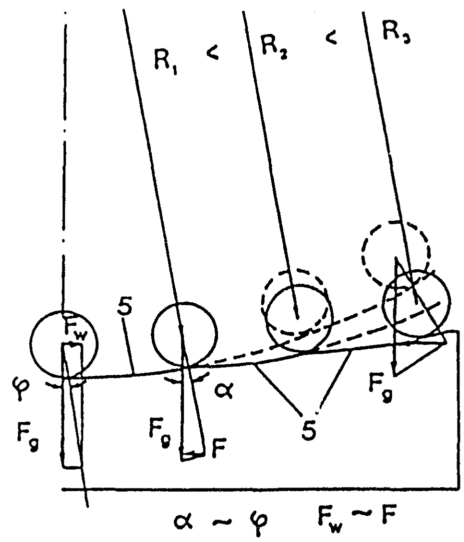


Figure 2-2. Fragment of a multi-curved pedestal plate with balls in critical positions.

Pushing mechanism of a "sliding pendulum" isolator consists of two major components: the force of velocity-related resistance (friction force) and the force of rigidity which depends on the vertical curvature of the sliding surface. While designing a seismic isolator, its friction characteristic is of primary importance. It controls the corresponding radius of cuvature R to satisfy the following controversial criteria:

a) To be as big as possible to provide a better frequencies separation.

b) To be as small as to create the necessary steepness of the sliding slope in order to secure returning the superstructure to its initial position.

Simple analysis reveals that sliding pendulum deflected at distance d will return exactly to its "zero point" without any overshoot if the friction coefficial equals to the following expression:

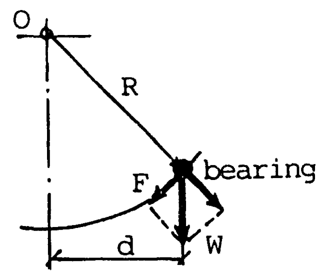


Figure 2-3. Force diagram.

$$f_* = \frac{1 - \sqrt{1 - \left(\frac{d}{R}\right)^2}}{\arc\sin\left(\frac{d}{R}\right)} \qquad (2.01)$$

For example: when R = 100 cm and d = 5 cm, per Equation (1.03) $f_* = 0.025$.

One of the main components of the AF&MS BI, the Ball Transfer Unit, is widely used in stationary and mobile transport. It has a proven history of heavy duty and extreme conditions performance.

The Ball Transfer Unit is not the only choice for using in the Shock Evader. It can be substituted with the Consumable Candle Bearing (patented now) which is depicted in Figure 2-4 (positions 2 and 3).

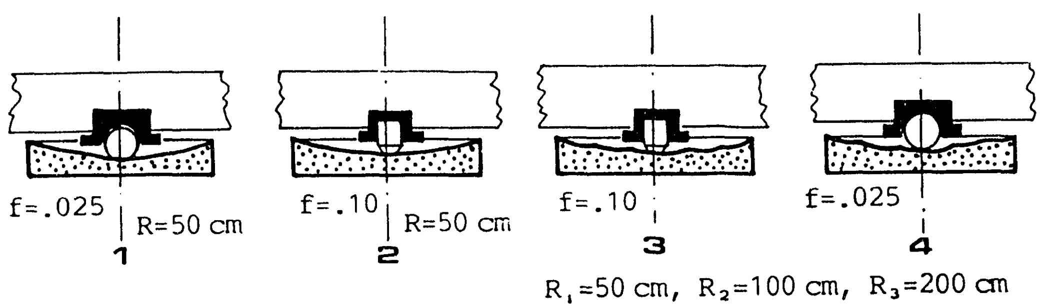


Figure 2-4. Some types of gravitational pendulum isolators: 1 and 4 - with ball bearings, 2 and 3 - with teflon candle bearings.

Systems 1 and 2 have mono-curvature sliding surfaces while those of 3 and 4 are of multi-curvature profile. Friction coefficient of ball transfer units is at least two times less than that of consumable candle bearings, however the last have advantage in bearing capacity.

Figure 2-5. Two pedestal plates (1) D = 40 cm and two bearing units: (2) - ball transfer unit and (3) - teflon candle transfer unit at EERC, UC Berkeley testing facility (August, 1992).

The satic load-deflection curves for different embodiments of the Shock Evader can be easily obtained without any specific tests: this technology makes it possible to create isolators with preset properties by merely changing their working surface configuration. Another advantage of the Shock Evader in comparison with any type of shear bearings (elastomeric, for example) is the absence of alternating, eccentrically applied vertical base reactions which can excite damaging flextural stress waves.

Figure 2-6 represents an inside view of the Shock Evader^{tm} which has been continually exposed in action since May, 1992 on the earthquake simulating platform at the California Museum of Science and Industry (Los Angeles). You can see three pedestal plates there (lower part), as well as corresponding to them three ball transfer units (upper part).

Figure 2-6. Shock Evader^{tm}: inside view

Photo in Figure 2-7 shows the Shock Evader^{tm} positioned on the platform which is shaking in a regime of real earthquake. Nevertheless, a steel pipe, a wooden post, and a jumbo glass of water, all stocked on the top of each other and supported by the Shock Evader, remain standing freely and surprisingly safely.

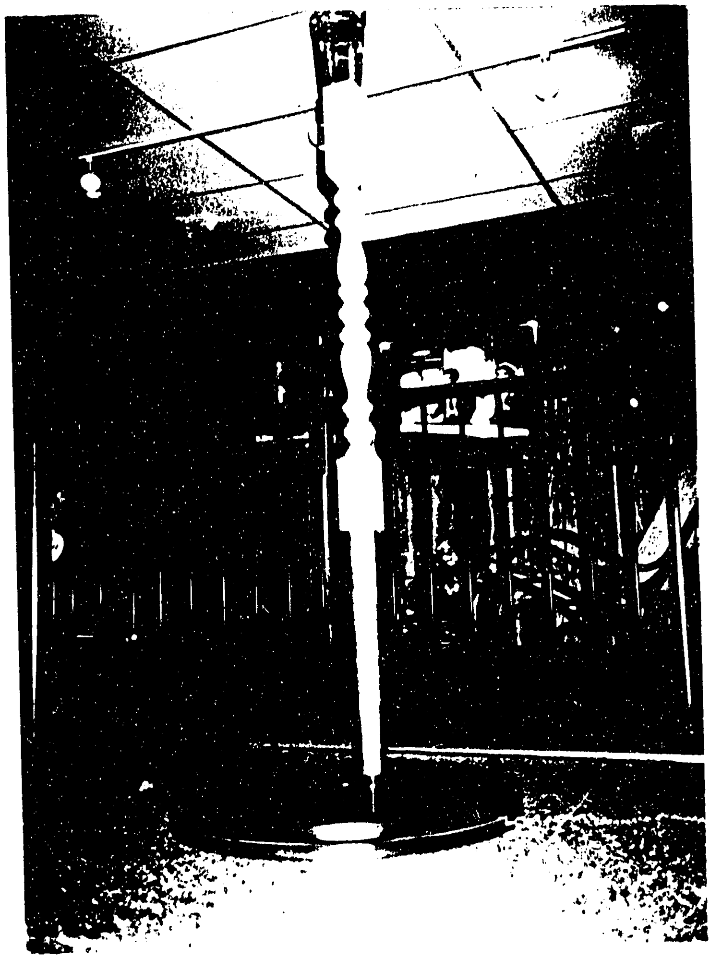


Figure 2-7. Shock Evader^{tm} in action during an earthquake simulation

A similar subject was captured by the KABC in the program "Why Didn't I Think of That?" which was first aired nation-wide from Los Angeles on April 10, 1993.

SECTION 3

ANALYTICAL MODELS

Analytical models and solution algorythms will be described in this section both for the fresh concept and for some old ones.

Validation of the new approach is to be performed on a generic 1-D structural models which can be adequately represented by a multi-degree-of-freedom shearing system that is linear for the superstructure but non-linear for the isolators [14].

The most convenient way to describe the corresponding equations of dynamic equilibrium is to do it in terms of relative displacements (story drifts) because those displacements are direct and ingenuous criteria of the earthquake imposed internal forces:

$$[M]\cdot\{\ddot{v}\} + [C]\cdot\{\dot{v}\} + [K]\cdot\{v\} = -[M_{11}]\cdot\ddot{u}_g \qquad (3.01)$$

where, for a three-degree-of-freedom system:

$$[M] = [M_{11}\ M_{12}\ M_{13}]$$

$$M_{11} = \begin{bmatrix} 0 & 0 & m_2 \\ 0 & m_1 & m_2 \\ m_o & m_1 & m_2 \end{bmatrix}$$

$$M_{12} = \begin{bmatrix} 0 & 0 & m_2 \\ 0 & m_1 & m_2 \\ 0 & m_1 & m_2 \end{bmatrix}$$

$$M_{13} = \begin{bmatrix} 0 & 0 & m_2 \\ 0 & 0 & m_2 \\ 0 & 0 & m_2 \end{bmatrix}$$

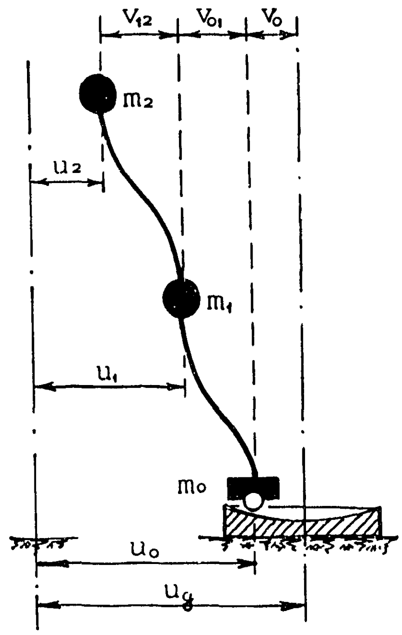


Figure 3-1. One-dimentional model of building seismically isolated with Shock Evader.

Total mass:

$$M = m_o + m_1 + m_2$$

Story drifts: $v_o = u_o - u_g$ $v_{01} = u_1 - u_o$ $v_{12} = u_2 - u_1$

Vectors-derivatives of relative displacements:

$$\{\ddot{v}\} = \begin{Bmatrix} \ddot{v}_o \\ \ddot{v}_{01} \\ \ddot{v}_{12} \end{Bmatrix} \qquad \{\dot{v}\} = \begin{Bmatrix} \dot{v}_o \\ \dot{v}_{01} \\ \dot{v}_{12} \end{Bmatrix} \qquad \{v\} = \begin{Bmatrix} v_o \\ v_{01} \\ v_{12} \end{Bmatrix}$$

Velocity related resistance matrix and stiffness matrix:

$$[C] = \begin{bmatrix} 0 & 0 & C_{12} \\ 0 & C_{01} & 0 \\ fgM|\dot{v}_o|^{-1} & 0 & 0 \end{bmatrix} \qquad [K] = \begin{bmatrix} 0 & 0 & K_{12} \\ 0 & K_{01} & 0 \\ \frac{g}{R}M & 0 & 0 \end{bmatrix}$$

Basic properties of sliding systems can be obtained from the analysis of lateral excitation of structures on four types of isolators depicted in Figure 2-4 which incorporate different shapes of working surfaces of pedestal plates and/or different mechanisms of transfer units. Ball transfer unit is associated with a small, and teflon candle with a greater friction there. All variety of known makes of sliding bearings can be mathematically described by the same relationships as the seismic isolators in Figure 2-4.

For sliding isolators the rigidity equals:

$$K_o = (g/R)M \qquad (3.02)$$

where R represents a vertical radius of the pedestal plate at the spot of load transfer.

The "damping" coefficient for sliding isolators is:

$$C_o = fgM[\dot{v}_o]^{-1} \qquad (3.03)$$

where f is the friction coefficient which is assumed to be invariant both relative to the travel speed and pressure though accounting for those parameters as well as for some other ones is possible [15, 16, 17, 18].

While choosing the type of deformation as a criterion for isolators classification, it seems more correct to match *sliding isolators* with *shearing* ones rather than to call the last ones *elastomeric*, for example, which is common. So, for

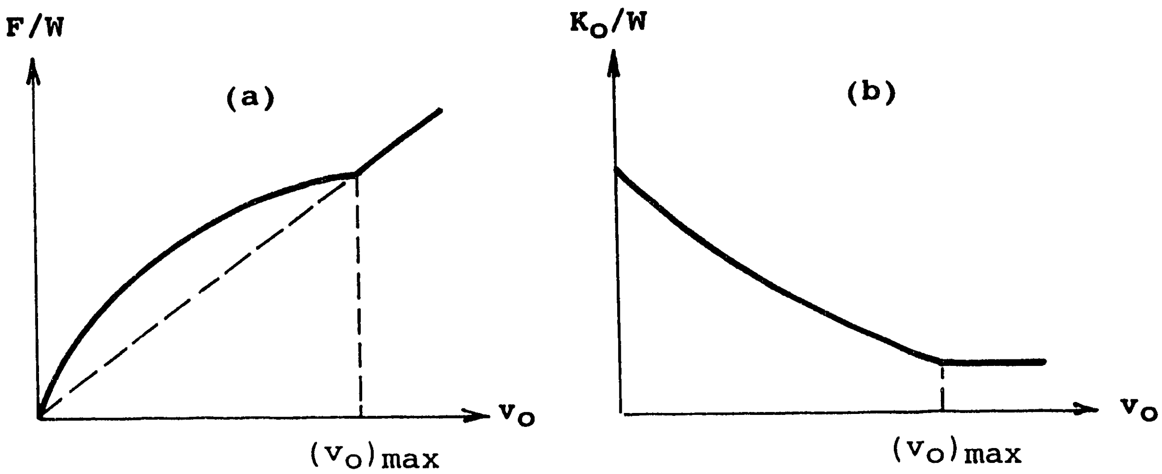


Figure 3-2. Force **(a)** and rigidity **(b)** vs drift in isolator

a shearing isolator the lateral force and equivalent rigidity, both related to the weight W, can be expressed in the interval $0 - (v_o)_{max}$ as follows:

$$F/W = (A/g)\ v_o \exp(-B\sqrt{v_o}) \qquad (3.04)$$

and

$$K_o/W = (A/g) \exp(-B\sqrt{v_o}) \qquad (3.05)$$

In all computational experiments of this report it was assumed that

$$A = 69{,}7; \quad B = 0.3; \quad v_o = [cm]$$

Thus,

$$K_o = 69.7 \exp(-0.3\sqrt{v_o})M \qquad (3.06)$$

when $0 < v_o < (v_o)_{max} = 37.5$ cm

and

$$K_o = 69.7 \exp\{-0.3\sqrt{(v_o)_{max}}\}M \qquad (3.07)$$

when $v_o > (v_o)_{max} = 37.5$ cm

Damping coefficient for a viscous type of shearing isolators:

$$c_o = 2\xi_o w\, m_o \qquad (3.08)$$

Dealing with non-harmonic process, instead of instantaneous frequency of excitation w use its effective value:

$$w_{eff} = \frac{(\dot{u}_g)_{peak}}{(u_g)_{peak}} \qquad (3.09)$$

where $(u_g)_{peak}$ and $(\dot{u}_g)_{peak}$ are the peak ground displacements and velocities preceeding the current instant of time.

Damping coefficient for a hysteretic type of shearing isolators:

$$c_o = 2\,\xi_o k_o[v_o/\dot{v}_o] \qquad (3.10)$$

where v_o and $\dot{v}_o$ are the relative displacements and velocities of the floor just above the isolators.

Interstory rigidity for all systems:

$$k = \alpha m \qquad (3.11)$$

In computations for the current report it was assumed:

$$\alpha = 1500$$

Damping coefficient for all systems:

$$c = \beta m \qquad (3.12)$$

Assumed in computations:

$$\beta = 1.233$$

Geometry of the Shock Evader^{tm}, investigated in this report, is depicted in Figure 3-3.

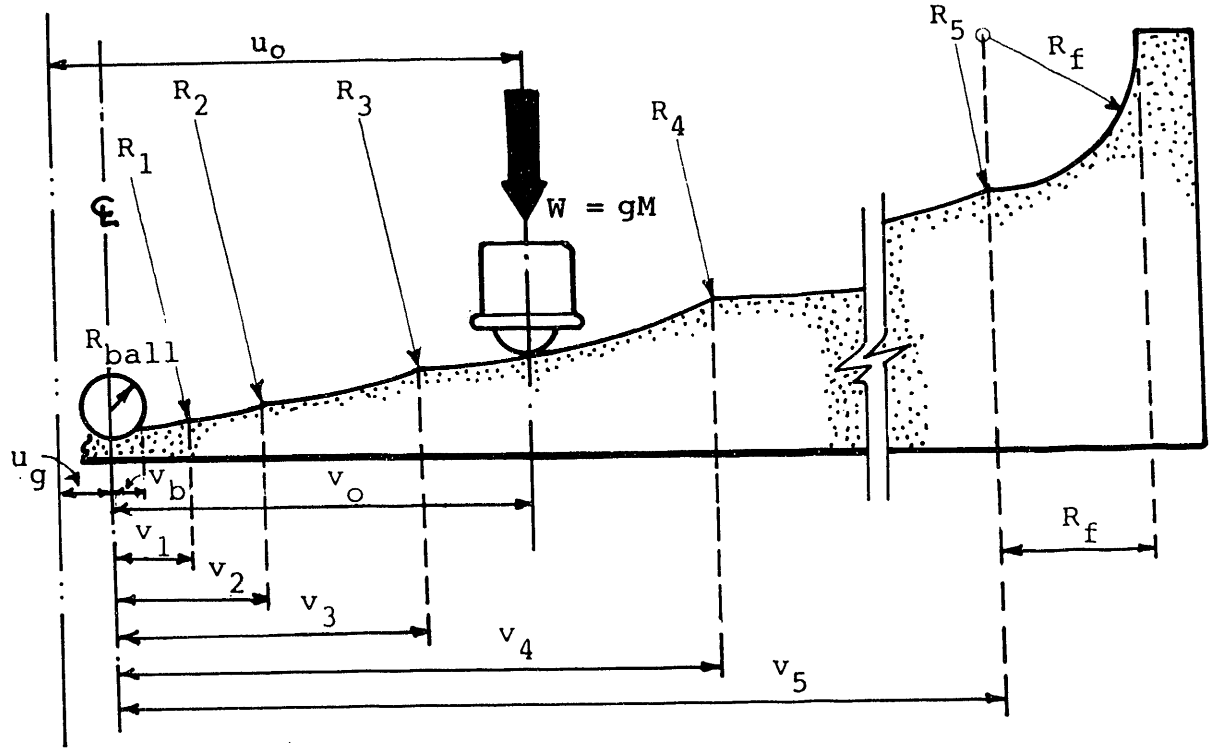


Figure 3-3. Shock Evader: cross-section.

Here: $r = R_{ball} < R_1 < R_2 < R_3 < R_4 < R_5 >> R_f$

When

$0 < v_o < v_{ball}$	$R = R_{ball}$
$v_b < v_o < v_1$	$R = R_1$
$v_1 < v_o < v_2$	$R = R_2$
$v_2 < v_o < v_3$	$R = R_3$
$v_3 < v_o < v_4$	$R = R_4$
$v_4 < v_o < v_5$	$R = R_5$
$v_5 < v_o < (v_5 + R_f)$	$R = R_f$

Assume: $R_b = 0.16\ M^{0.4}$; $R_1 = 50$; $R_2 = 100$;

$R_3 = 200$; $R_4 = 400$; $R_5 = 800$; $R_f = 10$.

$v_b = nfR_{ball}$; $v_1 = 2.5$; $v_2 = 5$; $v_3 = 10$; $v_4 = 20$;

$v_5 = 40$; $v_5 + R_f = 50$.

Relative displacement of secondary systems (equipment):

$$v_{ss} = u_{ss} - u_{fl}$$

Equation of motion for secondary systems:

$$m_{ss}\ddot{u}_{ss} + c_{ss}\dot{v}_{ss} + k_{ss}v_{ss} =$$

$$= - m_{ss}\ddot{u}_{fl} \qquad (3.13)$$

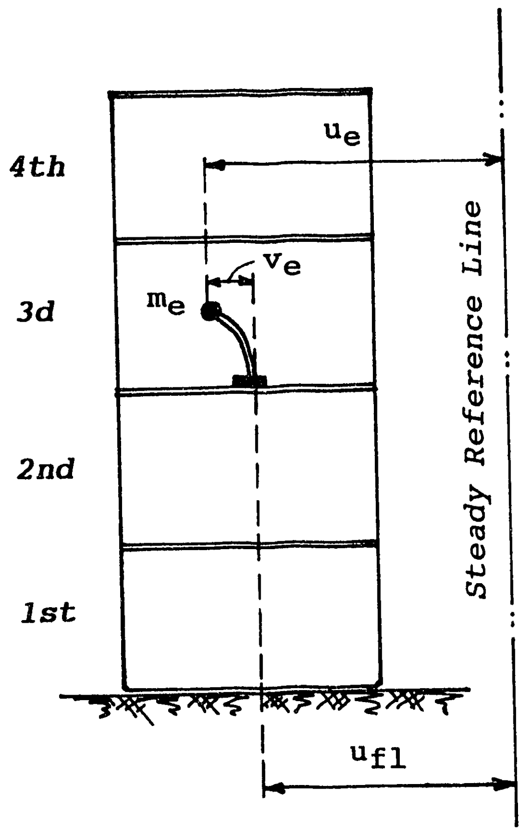


Figure 3-4. Secondary system model

Absolute floor acceleration $\ddot{u}_{fl}$ is to be found from the equations of motion of the building and applied to the equipment (mass m_{ss}, damping coefficient $c_{ss} = 2\xi\sqrt{k_{ss}m_{ss}}$, damping ratio $\xi = 0.02$, equipment rigidity $k_{ss} = 4\pi^2\ m_{ss}/T_{ss}^2$, equipment natural period T_{ss}).

Earthquake input can be executed in two ways:

1. Real time-history.
2. Imitational regime Cone[tm] [19] per the following formula for one-dimentional horizontal vibration:

$$u_g = at \sin 2\pi \log_b[(b-1)t/bT_o+1] \qquad (3.14)$$

where

$$a = \frac{(\dot{u}_g)max}{\sqrt{1 + (2\pi/\ln b)^2}} \qquad (3.15)$$

$$b = \frac{t_*}{t_* - T_* + T_o} \qquad (3.16)$$

t_* is a duration of the ground shaking, T_o is the initial and T_* is the final (the largest) instantaneous periods.

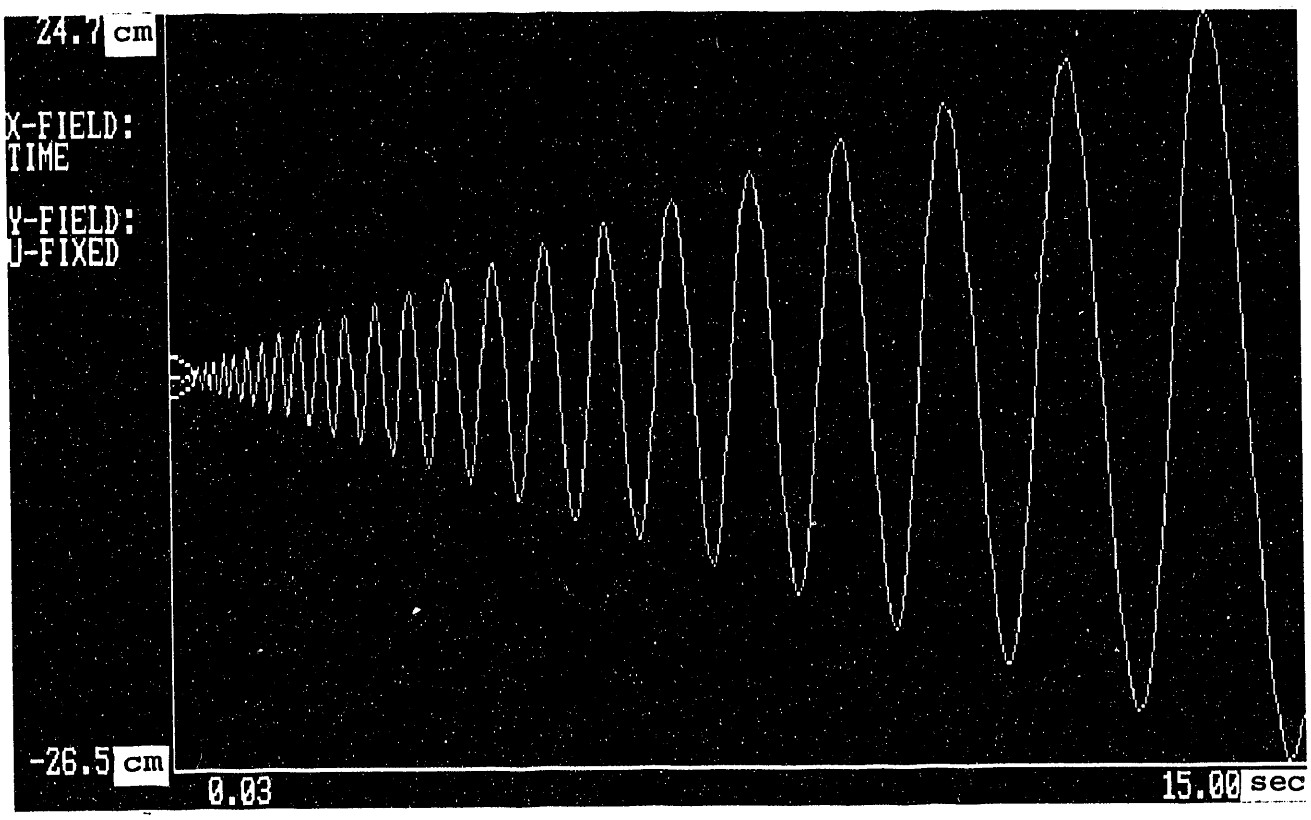


Figure 3-5. Imitational regime Cone^{tm}.

Application of "Cone" does not leave any chance for missing a single hazardous frequency: all natural periods of vibration between T_o and T_* (in this research it was assumed that $T_o = 0.03$ sec and $T_* = 2.0$ sec) are rung up in the state of transient resonance. Besides, you have no need to filter the "wrong" frequencies [20, 21], and any moment of time here is associated with the definate instantaneous period of excitation which is a real advantage while interpreting various responses vs time.
In all computational experiments of the current report the duration of ground shaking was taken the same: $t_* = 15$ sec but the maximum velocity was of three different levels: 20, 40 and 80 cm/sec^2.

SECTION 4

COMPUTER ANALYSIS

In this section a computational verification of the new approach will be undertaken with illustrations including both the building structures and the secondary systems (contents). Numerical solutions for some sample systems incorporating the Shock Evader will demonstrate advantages of the new antifriction approach in comparison with the damping-dependent one.

On basis of the global mathematical model including the superstructure, isolation system and mechanism of the ground input, the Step-by-Step method [20] as the only completely general approach to analysis of nonlinear responses is employed. It avoids any modal superposition [22], and it is described in details in the SIPP Manual (Part II of the current report).

The following format for computational experiments that has been accepted in the research is probably the the most visual and compact one:

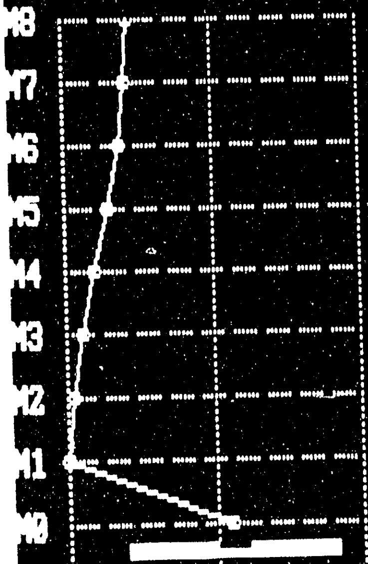
1) Six different systems are compared simultaneously in every experiment, namely: **Fixed** ("zero" isolation), **AF&MS** (Shock Evader^{tm} or AF&MS BI without a central depression), **AF&MS/CD** (Shock Evader^{tm} or AF&MS BI with a central depression), **Sliding** (visualized here as a gravitational pedulum system but actually representing any sliding model with a permanent rigidity), **Shear-vis** (Shearing type isolation incorporating a viscous damping mechanism) and **Shear-hys** (Shearing type isolation with a hysteretic damping mechanism).

2) Three versions of story numbers can be viewed simultaneously in any experiment: **one**-storied, **four**-storied and **eight**-storied structure with the same interstory heights and rigidities.

3) The Standard Case was chosen, including the Standard Isolation Systems and the Standard Input.

Isolation: Fixed sys.
Ground displacement
Ug =+7.69E+00cm

TIME t = 9.03sec; SNAPSHOT FOR REL.V1 =-7.804E+01cm

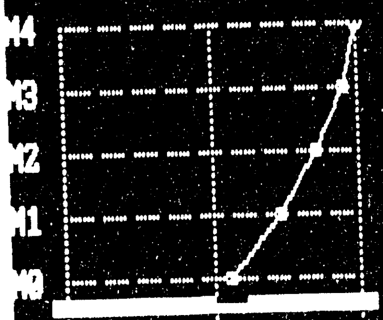


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
-39.284	+1.775	-2685	15000	22.5	399.3	-402.8
-41.058	+3.624	-2782	15000	22.5	815.3	-417.3
-44.682	+5.395	-2662	15000	22.5	1214.0	-399.3
-50.077	+6.389	-1483	15000	22.5	1437.5	-222.4
-56.466	+6.188	+320	15000	22.5	1392.2	+48.1
-62.654	+4.920	+1919	15000	22.5	1107.1	+287.9
-67.574	+2.775	+3237	15000	22.5	624.3	+485.5
-70.349	-78.041	+4135	15000	0.0	0.0	+620.3
+7.692	+0.000	-192	15000	0.0	0.0	-28.8

-7.03E+01cm 0cm +7.03E+01cm <-- Absolute coordinates

Isolation: Fixed sys.
Ground displacement
Ug =+3.83E+00cm

TIME t = 4.34sec; SNAPSHOT FOR REL.V1 =+1.181E+01cm

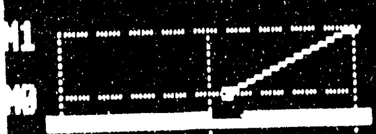


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+34.240	+3.197	-4771	15000	22.5	719.4	-715.6
+31.043	+6.532	-4967	15000	22.5	1469.6	-745.1
+24.511	+8.871	-3524	15000	22.5	1995.9	-528.5
+15.641	+11.814	-1519	15000	18.8	2217.2	-227.8
+3.827	+0.000	-364	15000	0.0	0.0	-54.6

-3.42E+01cm 0cm +3.42E+01cm <-- Absolute coordinates

Isolation: Fixed sys.
Ground displacement
Ug =+9.60E-01cm

TIME t = 1.26sec; SNAPSHOT FOR REL.V1 =+6.707E+00cm

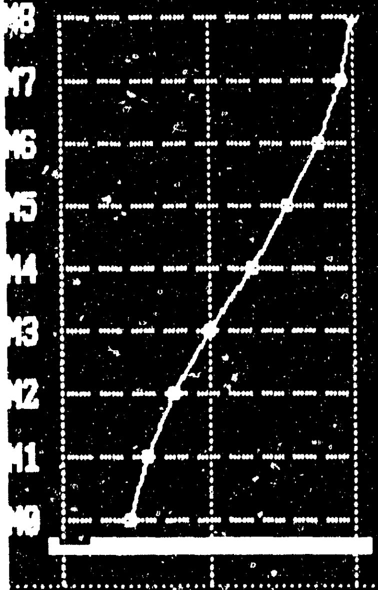


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+7.667	+6.707	-10069	15000	22.5	1509.2	-1510.4
+0.960	+0.000	-840	15000	0.0	0.0	-126.0

-7.67E+00cm 0cm +7.67E+00cm <-- Absolute coordinates

Isolation: AF&MS sys.
Ground displacement
Ug =-3.15E+00cm

TIME t = 3.96sec; SNAPSHOT FOR REL.V4 =+9.630E-01cm

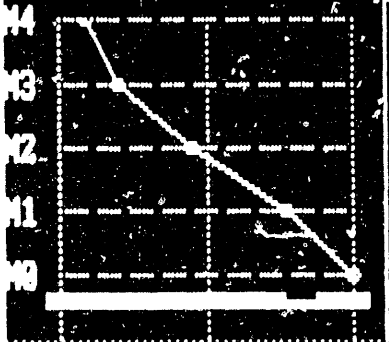


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	+3.397		-400	15000			-60.0
		+0.264			22.5	59.5	
M7	+3.133		-393	15000			-58.9
		+0.530			22.5	119.3	
M6	+2.602		-299	15000			-44.8
		+0.731			22.5	164.4	
M5	+1.872		-224	15000			-33.6
		+0.878			22.5	197.5	
M4	+0.994		-129	15000			-19.4
		+0.963			22.5	216.7	
M3	+0.031		+174	15000			+26.2
		+0.848			22.5	190.7	
M2	-0.817		+340	15000			+50.9
		+0.620			22.5	139.6	
M1	-1.437		+296	15000			+44.4
		+0.422			22.5	95.1	
M0	-1.860		+299	15000			+44.9
		+1.295			1.3	17.1	

-3.40E+00cm 0cm +3.40E+00cm <-- Absolute coordinates

Isolation: AF&MS sys.
Ground displacement
Ug =+5.23E-01cm

TIME t = 2.28sec; SNAPSHOT FOR REL.V2 =-5.290E-01cm

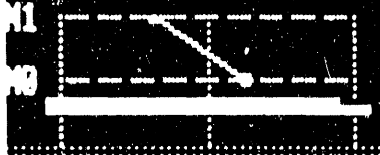


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M4	-0.666		+267	15000			+40.1
		-0.177			22.5	39.8	
M3	-0.489		+339	15000			+50.9
		-0.403			22.5	90.8	
M2	-0.086		+187	15000			+28.0
		-0.529			22.5	119.0	
M1	+0.443		-236	15000			-35.4
		-0.371			22.5	83.4	
M0	+0.814		-449	15000			-67.3
		+0.291			0.7	2.1	

-8.14E-01cm 0cm +8.14E-01cm <-- Absolute coordinates

Isolation: AF&MS sys.
Ground displacement
Ug =+2.68E-01cm

TIME t = .855sec; SNAPSHOT FOR REL.V1 =-1.637E-01cm

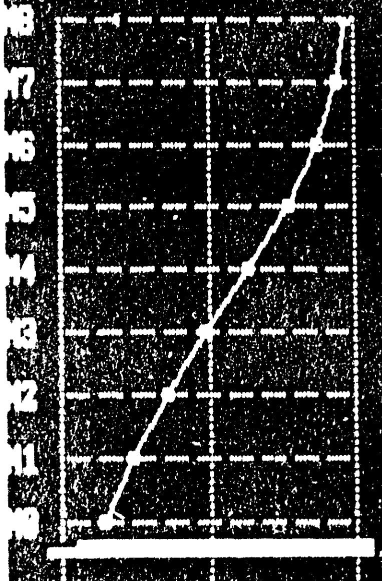


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M1	-0.097		+246	15000			+36.9
		-0.164			22.5	36.8	
M0	+0.067		-193	15000			-28.9
		-0.201			0.3	0.6	

-2.68E-01cm 0cm +2.68E-01cm <-- Absolute coordinates

Isolation: AF&MS/CD
Ground displacement
Ug =-3.28E+00cm

TIME t = 3.87sec; SNAPSHOT FOR REL.V4 =+9.649E-01cm

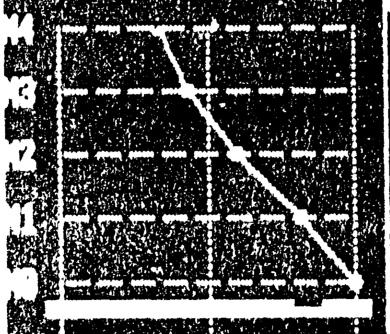


	u cm	Δu cm	u'' cm/s^2	m kg	K kN/cm	V=K*Δu kN	F=m*u'' kN
M8	+3.102		-347	15000			-52.0
		+0.228			22.5	51.3	
M7	+2.874		-344	15000			-51.6
		+0.462			22.5	103.9	
M6	+2.412		-256	15000			-38.4
		+0.632			22.5	142.1	
M5	+1.780		-364	15000			-54.6
		+0.872			22.5	196.3	
M4	+0.908		-136	15000			-20.5
		+0.965			22.5	217.1	
M3	-0.057		+127	15000			+19.1
		+0.878			22.5	197.7	
M2	-0.935		+134	15000			+20.2
		+0.789			22.5	177.6	
M1	-1.725		+239	15000			+35.9
		+0.631			22.5	141.9	
M0	-2.355		+644	15000			+96.6
		+0.926			1.3	12.3	

-3.28E+00cm 0cm +3.28E+00cm <-- Absolute coordinates

Isolation: AF&MS/CD
Ground displacement
Ug =+9.08E-01cm

TIME t = 2.295sec; SNAPSHOT FOR REL.V2 =-5.986E-01cm



	u cm	Δu cm	u'' cm/s^2	m kg	K kN/cm	V=K*Δu kN	F=m*u'' kN
M4	-0.445		+408	15000			+61.3
		-0.270			22.5	60.8	
M3	-0.175		+254	15000			+38.1
		-0.439			22.5	98.9	
M2	+0.265		+236	15000			+35.3
		-0.599			22.5	134.7	
M1	+0.863		-156	15000			-23.4
		-0.496			22.5	111.5	
M0	+1.359		-773	15000			-116.0
		+0.450			5.2	23.2	

-1.36E+00cm 0cm +1.36E+00cm <-- Absolute coordinates

Isolation: AF&MS/CD
Ground displacement
Ug =-7.17E-01cm

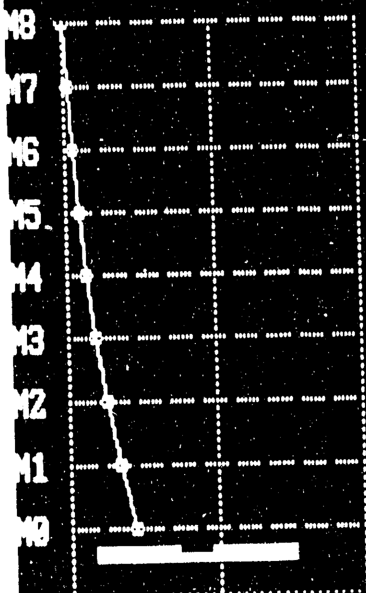
TIME t = .806sec; SNAPSHOT FOR REL.V1 =+2.452E-01cm

	u cm	Δu cm	u'' cm/s^2	m kg	K kN/cm	V=K*Δu kN	F=m*u'' kN
M1	+0.278		-368	15000			-55.3
		+0.245			22.5	55.2	
M0	+0.033		+305	15000			+45.7
		+0.750			0.3	2.2	

-7.17E-01cm 0cm +7.17E-01cm <-- Absolute coordinates

Isolation: Sliding s.
Ground displacement
Ug =-1.14E+01cm

TIME t = 14.6sec; SNAPSHOT FOR REL.V1 =-7.747E+00cm

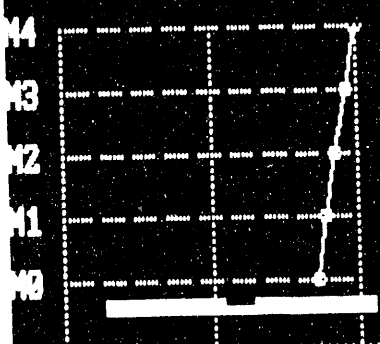


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
-74.605	-1.367	+2026	15000	22.5	307.5	+304.0
-73.238	-2.240	+1339	15000	22.5	504.1	+200.8
-70.998	-2.938	+1069	15000	22.5	661.0	+160.4
-68.060	-3.636	+1026	15000	22.5	818.1	+153.9
-64.424	-3.950	+434	15000	22.5	888.8	+65.0
-60.474	-4.775	+1263	15000	22.5	1074.4	+189.5
-55.699	-6.561	+2697	15000	22.5	1476.3	+404.6
-49.137	-7.747	+1766	15000	22.5	1743.0	+264.9
-41.391	-30.000	-6292	15000	2.6	794.6	-943.8

-7.46E+01cm 0cm +7.46E+01cm <-- Absolute coordinates

Isolation: Sliding s.
Ground displacement
Ug =+1.02E+01cm

TIME t = 12.0sec; SNAPSHOT FOR REL.V3 =+4.765E+00cm

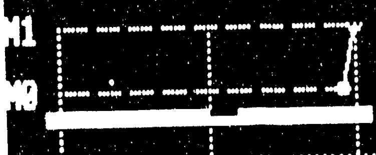


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+54.832	+3.594	-5430	15000	22.5	808.6	-814.5
+51.238	+4.765	-1713	15000	22.5	1072.0	-257.0
+46.473	+3.507	+1887	15000	22.5	789.0	+283.1
+42.967	+2.787	+1080	15000	22.5	627.0	+162.0
+40.180	+30.000	+1227	15000	1.5	441.5	+184.0

-5.48E+01cm 0cm +5.48E+01cm <-- Absolute coordinates

Isolation: Sliding s.
Ground displacement
Ug =+3.91E+00cm

TIME t = 10.6sec; SNAPSHOT FOR REL.V1 =+2.723E+00cm

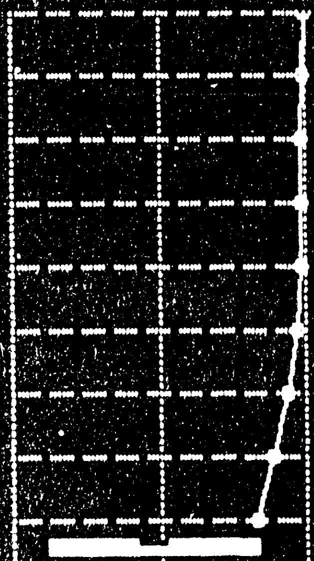


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+36.636	+2.723	-4086	15000	22.5	612.6	-612.8
+33.913	+30.000	+2894	15000	0.6	176.6	+434.1

-3.66E+01cm 0cm +3.66E+01cm <-- Absolute coordinates

Isolation: Shear-vis. TIME t = 14.3sec; SNAPSHOT FOR REL.V1 =+7.966E+00cm

Ground displacement
Ug =-3.26E+00cm

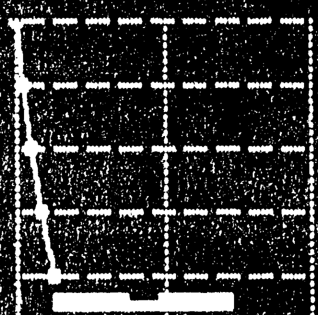


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	+70.014		-984	15000			-147.6
		+0.646			22.5	145.4	
M7	+69.368		+45	15000			+6.7
		+0.610			22.5	137.3	
M6	+68.757		+572	15000			+85.8
		+0.242			22.5	54.4	
M5	+68.516		-307	15000			-46.0
		+0.466			22.5	104.9	
M4	+68.049		-2224	15000			-333.7
		+1.948			22.5	438.4	
M3	+66.101		-3540	15000			-531.0
		+4.271			22.5	961.1	
M2	+61.829		-4307	15000			-646.0
		+7.125			22.5	1603.1	
M1	+54.704		-1206	15000			-180.9
		+7.966			22.5	1792.4	
M0	+46.738		+6921	15000			+1038.1
		+50.000			1.5	749.4	

-7.00E+01cm 0cm +7.00E+01cm <-- Absolute coordinates

Isolation: Shear-vis. TIME t = 14.9sec; SNAPSHOT FOR REL.V1 =-7.320E+00cm

Ground displacement
Ug =-1.23E+01cm

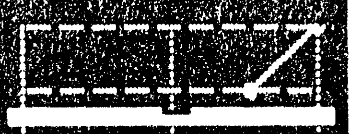


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M4	-82.830		+4023	15000			+603.4
		-2.658			22.5	598.0	
M3	-80.173		+3179	15000			+476.8
		-4.817			22.5	1083.8	
M2	-75.356		+1442	15000			+216.2
		-5.775			22.5	1299.5	
M1	-69.580		+2337	15000			+350.5
		-7.320			22.5	1647.1	
M0	-62.260		-8164	15000			-1224.6
		-50.000			0.8	416.3	

-8.28E+01cm 0cm +8.28E+01cm <-- Absolute coordinates

Isolation: Shear-vis. TIME t = 1.09sec; SNAPSHOT FOR REL.V1 =+1.385E+00cm

Ground displacement
Ug =+1.34E-01cm

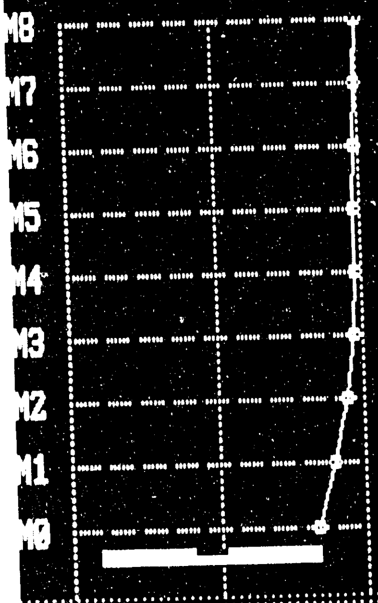


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M1	+3.098		-2075	15000			-311.3
		+1.385			22.5	311.6	
M0	+1.714		-208	15000			-31.3
		+1.579			1.4	22.7	

-3.10E+00cm 0cm +3.10E+00cm <-- Absolute coordinates

Isolation: Shear-hys.
Ground displacement
Ug =-4.88E+00cm

TIME t = 14.4sec; SNAPSHOT FOR REL.V1 =+8.762E+00cm

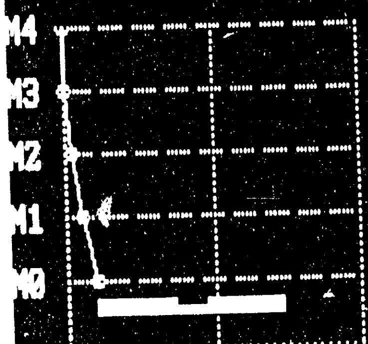


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+67.779	+0.902	-1343	15000	22.5	202.9	-201.4
+66.877	+0.976	-134	15000	22.5	219.5	-20.0
+65.902	+0.391	+871	15000	22.5	88.0	+130.6
+65.511	+0.220	+281	15000	22.5	49.6	+42.2
+65.291	+1.263	-1525	15000	22.5	284.1	-228.8
+64.028	+3.381	-3219	15000	22.5	760.7	-482.8
+60.647	+6.768	-5160	15000	22.5	1522.8	-774.1
+53.879	+8.762	-2915	15000	22.5	1971.5	-437.2
+45.117	+50.000	+8108	15000	1.5	749.4	+1216.2

-6.78E+01cm 0cm +6.78E+01cm <-- Absolute coordinates

Isolation: Shear-hys.
Ground displacement
Ug =-1.29E+01cm

TIME t = 14.9sec; SNAPSHOT FOR REL.V1 =-7.722E+00cm

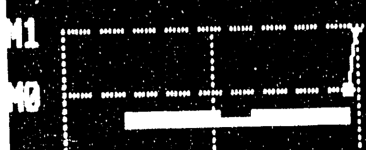


u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
-79.131	+0.209	-458	15000	22.5	46.9	-68.7
-79.339	-2.659	+4405	15000	22.5	598.3	+660.8
-76.680	-6.087	+5170	15000	22.5	1369.5	+775.5
-70.593	-7.722	+2467	15000	22.5	1737.4	+370.1
-62.871	-50.000	-8765	15000	0.8	416.3	-1314.8

-7.93E+01cm 0cm +7.93E+01cm <-- Absolute coordinates

Isolation: Shear-hys.
Ground displacement
Ug =+1.10E+01cm

TIME t = 13.9sec; SNAPSHOT FOR REL.V1 =+4.760E+00cm



u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
+65.729	+4.760	-7147	15000	22.5	1070.9	-1072.0
+60.970	+50.000	+6007	15000	0.3	166.5	+901.1

-6.57E+01cm 0cm +6.57E+01cm <-- Absolute coordinates

Figure 4-6. Shear-hysteretic system: Standard Case.

Characteristics of **Standard Isolation Systems:**

AF&MS BI and AF&MS BI/CD
Friction coefficient $f = 0.025$
Central depression ratio $N = 2$
Initial radius of vertical curvature VRAD1 = 100 cm.

Sliding
Friction coefficient $f_{sl} = 0.05$
Radius of vertical curvature VRAD = 50 cm (inversely proportional to the friction coefficient: to make the restoring condition equivalent to those of both previous sliding systems).

Shear-viscous and Shear-hysteretic
Damping ratio $\xi = 0.2$.

Certain limitations are imposed on relative displacements (drift) of the isolators which assumed to be restricted into R_{conf} = 50 cm boundary by using some sort of confiners: *dead rigid* like the enclosing cylinders in the FPS [23] or chain leash in the shear type isolators [24], and *reasonably rigid* like those achieved with the help of the final radius of vertical curvature in the AF&MS BI and AF&MS BI/CD.

Characteristics of **Standard Input:**

Imitational regime Cone^{tm}
Duration $t_* = 15$ sec

Smallest instantaneous period $T_o = 0.03$ sec

Largest instantaneous period $T_* = 2$ sec

Maximum peak ground velocity UG'MAX = 40 cm/sec.

4) Two sorts of deviations from the Standard Case are investigated: deviation of input intensity and deviation of parameters associated with velocity-related resistance ("damping" parameters).

Deviation of input intensity:

The Cone^{tm} regimes with UG'MAX = 20 and 80 cm/sec have been tried which represent the *Substandard* and *Superstandard intensities*.

Deviation of "damping" parameters:

Friction coefficients $f = 0.01$ and 0.05.

Initial radii of vertical curvature corresponding to the above coefficients VRAD1 = 200 and 100 cm.

Friction coefficients for Sliding systems f_{sl} = 0.04 and 0.1.

Radius of vertical curvature for Sliding systems VRAD = 50 cm remains the same for all values of f_{sl}.

Damping ratio for both types of Shearing isolators ξ = 0.1 and 0.4.

The values of parameters listed above pertain accordingly to *the Substandard* and *Superstandard damping*.

5) Limit displacement for interstory drifts was introduced: when drift reaches the 50 cm threshold, the structure is considered to lose its horizontal and vertical load bearing capacity (collapse).

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	5.755	5.548	5.256	4.878	4.331	3.556	2.542	1.328
AF&MS sys.	10.85	.5742	.6090	.6125	.6458	.5833	.5107	.5070	.3373
AF&MS/CD	10.56	.5851	.7007	.6372	.5577	.6036	.6190	.4747	.3407
Sliding s.	17.05	2.126	1.915	1.665	1.376	1.193	1.023	.7337	.6087
Shear-vis.	44.56	2.549	2.435	2.292	2.316	2.235	2.101	1.713	.9983
Shear-hys.	50.00	4.493	3.360	3.359	3.277	3.289	2.992	2.419	1.645

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	5.548	4.788	3.535	1.895	0	0	0	0
AF&MS sys.	9.932	.3151	.4215	.3479	.2612	0	0	0	0
AF&MS/CD	10.87	.3959	.5046	.4950	.3094	0	0	0	0
Sliding s.	14.59	.9317	.8775	.6624	.4634	0	0	0	0
Shear-vis.	38.67	1.469	1.445	1.350	.8558	0	0	0	0
Shear-hys.	50	3.403	3.462	2.801	1.518	0	0	0	0

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	3.353	0	0	0	0	0	0	0
AF&MS sys.	10.39	.1579	0	0	0	0	0	0	0
AF&MS/CD	10.41	.1988	0	0	0	0	0	0	0
Sliding s.	14.14	.3001	0	0	0	0	0	0	0
Shear-vis.	14.98	.7762	0	0	0	0	0	0	0
Shear-hys.	50	2.857	0	0	0	0	0	0	0

Figure 4-7. Substandard Quake responses.

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	190.8	11.25	9.528	10.31	10.01	8.753	7.835	4.914
AF&MS sys.	34.02	.9255	1.313	1.586	1.690	1.532	1.294	1.016	.6768
AF&MS/CD	33.97	.9482	1.366	1.573	1.785	1.613	1.338	1.084	.7283
Sliding s.	30.00	11.58	697.2	11.63	10.94	11.49	15.36	9.165	4.789
Shear-vis.	50.00	20.47	10.00	13.12	197.6	12.39	7.653	6.653	5.257
Shear-hys.	50.00	130.9	10.13	10.62	10.98	11.51	7.875	6.528	5.354

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	373.9	9.849	7.842	5.061	0	0	0	0
AF&MS sys.	30.75	.5207	.7052	.6527	.4967	0	0	0	0
AF&MS/CD	30.81	.5300	.7194	.6781	.5240	0	0	0	0
Sliding s.	30.00	14.14	6.724	6.659	5.523	0	0	0	0
Shear-vis.	50.00	9.675	8.023	8.625	8.169	0	0	0	0
Shear-hys.	50.00	8.916	7.769	8.484	7.541	0	0	0	0

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	980.6	0	0	0	0	0	0	0
AF&MS sys.	31.63	.1746	0	0	0	0	0	0	0
AF&MS/CD	31.70	.1985	0	0	0	0	0	0	0
Sliding s.	30.00	6.852	0	0	0	0	0	0	0
Shear-vis.	50.00	5.334	0	0	0	0	0	0	0
Shear-hys.	50.00	6.426	0	0	0	0	0	0	0

Figure 4-8. Superstandard Quake responses.

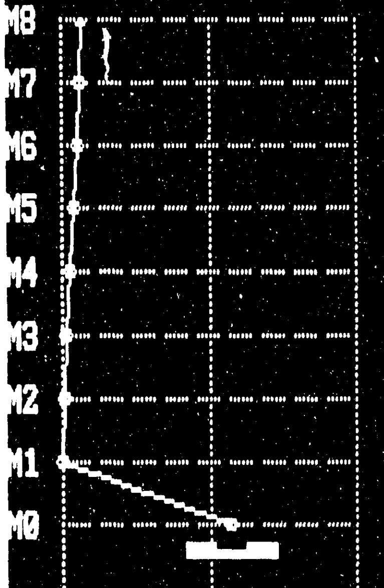
6) Possibility to compare the shearing forces, developed on different levels of a multi-story building, with those of a rigid body of the same mass, rocking on the isolators, is provided.

7) Time-histories and response spectra for secondary systems (building contents) are also available for any story and any type of isolation system.

Data presented in Figures 4-1 through 4-6 prove that anti-friction approach incorporated in the seismic isolation system Shock Evader^{tm} (AF&MS BI and AF&MS BI/CD) yields essentially better mitigating effect than that of a conven-

Isolation: Fixed sys.
Ground displacement
Ug =+2.45E+01cm

TIME t = 13.8sec; SNAPSHOT FOR REL.V1 =-1.909E+02cm

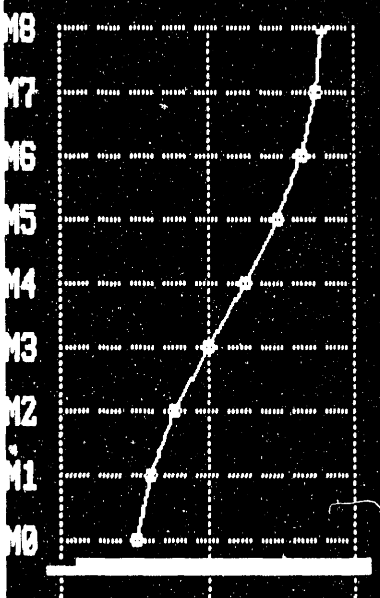


	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	-143.9		-2457	15000			-368.6
		+1.6			22.5	368.6	
M7	-145.5		-2107	15000			-316.1
		+3.0			22.5	684.7	
M6	-148.6		-1450	15000			-217.5
		+4.0			22.5	902.3	
M5	-152.6		-566	15000			-84.9
		+4.4			22.5	988.4	
M4	-157.0		+426	15000			+64.0
		+4.2			22.5	953.0	
M3	-161.2		+1401	15000			+210.2
		+3.2			22.5	713.1	
M2	-164.4		+2143	15000			+321.5
		+2.0			22.5	444.0	
M1	-166.4		+2610	15000			+391.5
		-190.9			0.0	0.0	
M0	+24.5		-247	15000			-37.1
		+0.0			0.0	0.0	

-1.66E+02cm 0cm +1.66E+02cm <-- Absolute coordinates

Isolation: AF&MS sys.
Ground displacement
Ug =-6.82E+00cm

TIME t = 3.98sec; SNAPSHOT FOR REL.V4 =+1.690E+00cm



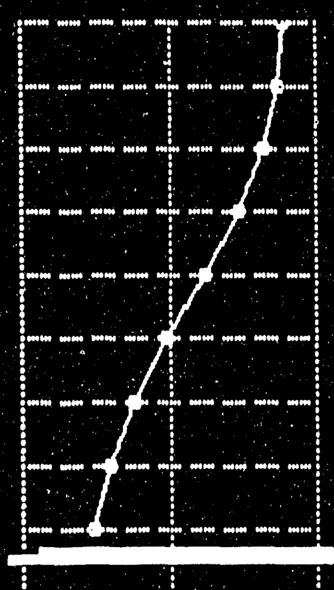
	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	+5.303		-420	15000			-63.1
		+0.283			22.5	63.8	
M7	+5.020		-553	15000			-82.9
		+0.652			22.5	146.8	
M6	+4.368		-727	15000			-109.0
		+1.133			22.5	255.0	
M5	+3.234		-597	15000			-89.5
		+1.532			22.5	344.7	
M4	+1.703		-239	15000			-35.8
		+1.690			22.5	380.4	
M3	+0.012		+205	15000			+30.7
		+1.549			22.5	348.6	
M2	-1.537		+627	15000			+94.1
		+1.130			22.5	254.3	
M1	-2.667		+630	15000			+94.5
		+0.712			22.5	160.2	
M0	-3.379		+550	15000			+82.4
		+3.442			1.3	45.6	

-6.82E+00cm 0cm +6.82E+00cm <-- Absolute coordinates

Figure 4-9. Fixed and AF&MS BI systems subjected to a Superstandard Earthquake.

Isolation: AF&MS/CD
Ground displacement
Ug =-6.73E+00cm

TIME t = 3.98sec; SNAPSHOT FOR REL.V4 =+1.785E+00cm

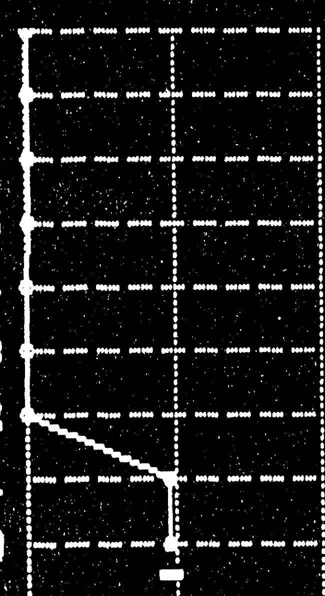


	u cm	v cm	u'' cm/s^2	m kg	K kI/s^2	V=K*v kN	F=m*u'' kN
M8	+5.295		-458	15000			-68.7
		+0.309			22.5	69.6	
M7	+4.986		-496	15000			-74.4
		+0.639			22.5	143.8	
M6	+4.346		-723	15000			-108.4
		+1.116			22.5	251.1	
M5	+3.230		-744	15000			-111.6
		+1.613			22.5	362.9	
M4	+1.618		-258	15000			-38.6
		+1.785			22.5	401.7	
M3	-0.168		+412	15000			+61.8
		+1.506			22.5	338.8	
M2	-1.674		+635	15000			+95.3
		+1.079			22.5	242.7	
M1	-2.753		+574	15000			+86.1
		+0.701			22.5	157.6	
M0	-3.453		+547	15000			+82.1
		+3.273			1.3	43.3	

-6.73E+00cm 0cm +6.73E+00cm <-- Absolute coordinates

Isolation: Sliding s.
Ground displacement
Ug =-2.37E+01cm

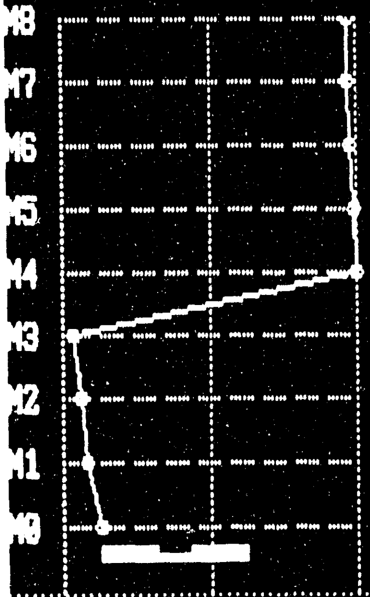
TIME t = 14.9sec; SNAPSHOT FOR REL.V2 =-6.972E+02cm



	u cm	v cm	u'' cm/s^2	m kg	K kI/s^2	V=K*v kN	F=m*u'' kN
M8	-715.4		-1125	15000			-168.7
		+0.7			22.5	165.6	
M7	-716.1		-702	15000			-105.3
		+1.2			22.5	268.5	
M6	-717.3		-239	15000			-35.9
		+2.3			22.5	518.8	
M5	-719.6		+200	15000			+30.0
		+1.4			22.5	320.6	
M4	-721.1		+552	15000			+82.8
		+1.0			22.5	214.8	
M3	-722.0		+698	15000			+104.7
		+0.5			22.5	108.0	
M2	-722.5		+625	15000			+93.8
		-697.2			0.0	0.0	
M1	-25.3		+241	15000			+36.1
		-0.2			22.5	44.0	
M0	-25.1		+434	15000			+65.1
		-1.4			2.6	36.3	

-7.23E+02cm 0cm +7.23E+02cm <-- Absolute coordinates

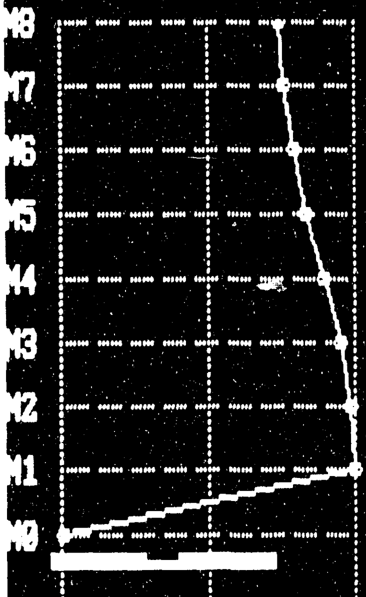
Isolation: Shear-vis. TIME t = 14.7sec; SNAPSHOT FOR REL.V4 =+1.976E+02cm
Ground displacement
Ug =-2.56E+01cm



Level	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	+96.5		+1571	15000			+235.6
		-1.0			22.5	215.4	
M7	+97.5		+1352	15000			+202.8
		-1.9			22.5	419.8	
M6	+99.3		-183	15000			-27.5
		-1.8			22.5	403.6	
M5	+101.1		-1052	15000			-157.8
		-1.4			22.5	322.6	
M4	+102.5		-1688	15000			-253.1
		+197.6			0.0	0.0	
M3	-95.1		+5358	15000			+803.8
		-4.8			22.5	1089.3	
M2	-90.2		+678	15000			+101.7
		-4.0			22.5	908.3	
M1	-86.2		-486	15000			-72.9
		-10.6			21.2	2246.2	
M0	-75.6		-554	15000			-83.0
		-50.0			1.5	749.4	

-1.03E+02cm 0cm +1.03E+02cm <-- Absolute coordinates

Isolation: Shear-hys. TIME t = 14.6sec; SNAPSHOT FOR REL.V1 =+1.309E+02cm
Ground displacement
Ug =-2.08E+01cm



Level	u cm	v cm	u'' cm/s^2	m kg	K kT/s^2	V=K*v kN	F=m*u'' kN
M8	+32.0		+3125	15000			+468.8
		-2.1			22.5	469.1	
M7	+34.1		+3145	15000			+471.8
		-4.2			22.5	941.3	
M6	+38.3		+2881	15000			+432.1
		-6.1			22.5	1376.1	
M5	+44.4		+1462	15000			+219.4
		-8.3			22.5	1859.4	
M4	+52.7		-1273	15000			-190.9
		-6.9			22.5	1550.4	
M3	+59.5		-3263	15000			-489.5
		-4.3			22.5	967.3	
M2	+63.8		-3333	15000			-500.0
		-1.8			22.5	413.6	
M1	+65.7		-2745	15000			-411.7
		+130.9			0.0	0.0	
M0	-65.2		+4434	15000			+665.2
		-44.4			1.5	665.1	

-6.57E+01cm 0cm +6.57E+01cm <-- Absolute coordinates

[illegible]

tional sliding or shearing isolation systems. All three investigated structures survive a Standard Earthquake performing undoubtedly elastically if mounted on Shock Evaders^{tm}.

Tables in Figures 4-7 and 4-8 together with Figures 4-1 through 4-6 demonstrate that buildings on Shock Evaders^{tm} can easily live through each of the three levels of earthquake intensity while the 8-story structures on other types of isolators as well as the fixed ones will obviously collapse at a Superstandard Earthquake (Figures 4-9, 4-10, 4-11).

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	78.04	10.03	9.706	8.976	8.144	6.882	5.027	2.816
AF&MS sys.	15.92	.3077	.4071	.5422	.5942	.5852	.5240	.3663	.2061
AF&MS/CD	16.00	.3143	.4068	.5515	.6178	.6010	.5392	.3691	.2093
Sliding s.	30.00	8.142	7.277	7.007	7.077	6.767	6.563	5.216	3.170
Shear-vis.	50.00	8.715	7.669	5.031	5.789	5.293	4.813	4.580	3.004
Shear-hys.	50.00	8.762	7.371	5.013	5.822	5.050	4.815	4.573	3.022

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	11.81	9.295	7.161	3.994	0	0	0	0
AF&MS sys.	15.97	.1798	.2631	.2346	.1768	0	0	0	0
AF&MS/CD	16.10	.1876	.2701	.2439	.1863	0	0	0	0
Sliding s.	30.00	4.514	4.294	4.635	3.947	0	0	0	0
Shear-vis.	50.00	7.952	6.140	6.069	3.830	0	0	0	0
Shear-hys.	50.00	7.721	6.526	6.478	4.898	0	0	0	0

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	6.707	0	0	0	0	0	0	0
AF&MS sys.	15.93	0.068	0	0	0	0	0	0	0
AF&MS/CD	15.85	0.073	0	0	0	0	0	0	0
Sliding s.	30.00	3.402	0	0	0	0	0	0	0
Shear-vis.	50	3.695	0	0	0	0	0	0	0
Shear-hys.	50.00	4.759	0	0	0	0	0	0	0

Figure 4-12. Interstory drifts at Substandard Damping.

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	78.04	10.03	9.706	8.976	8.144	6.882	5.027	2.816
AF&MS sys.	18.35	.6300	.7928	.8771	.9630	.8864	.8616	.6988	.4296
AF&MS/CD	18.24	.6500	.7998	.9110	.9648	.9471	.7936	.8535	.6157
Sliding s.	30.00	7.746	6.773	6.718	6.100	6.138	5.737	4.516	2.600
Shear-vis.	50.00	7.966	7.442	5.151	5.247	5.125	4.508	4.311	2.854
Shear-hys.	50.00	8.762	7.371	5.013	5.822	5.050	4.815	4.573	3.022

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	11.81	9.295	7.161	3.994	0	0	0	0
AF&MS sys.	17.81	.4206	.5289	.5023	.3638	0	0	0	0
AF&MS/CD	17.92	.5600	.5985	.5678	.4857	0	0	0	0
Sliding s.	30.00	4.620	4.029	4.764	3.725	0	0	0	0
Shear-vis.	50.00	7.320	6.350	4.914	3.638	0	0	0	0
Shear-hys.	50.00	7.721	6.526	6.478	4.898	0	0	0	0

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	6.707	0	0	0	0	0	0	0
AF&MS sys.	17.82	.1636	0	0	0	0	0	0	0
AF&MS/CD	17.88	.2452	0	0	0	0	0	0	0
Sliding s.	30.00	2.722	0	0	0	0	0	0	0
Shear-vis.	40.29	1.384	0	0	0	0	0	0	0
Shear-hys.	50.00	4.759	0	0	0	0	0	0	0

Figure 4-13. Interstory drifts at Standard Damping.

Figures 4-12, 4-13 and 4-14 represent the results of experiments with damping deviation. It is obvious that for low friction isolators Shock Evader the damping acts as a deteriorating factor. For Sliding systems the damping in the range of investigation (f = 0.04 through 0.10) is a positive quality: due to lack of softening mechanism, it remains the only defender when swaying builds up. Damping in shear-viscous systems provides some relief but not always for one-story buildings where results depend on interrelation between design parameters. Shear-hysteretic systems do not reveal a slightest sensitivity to damping deviations.

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	78.04	10.03	9.706	8.976	8.144	6.882	5.027	2.816
AF&MS sys.	15.08	.8508	1.008	1.134	1.088	1.113	1.021	1.014	.6747
AF&MS/CD	15.84	1.262	1.413	1.274	1.115	1.207	1.238	.9495	.6814
Sliding s.	30.00	5.371	5.169	4.197	3.502	2.794	2.721	2.370	1.457
Shear-vis.	50.00	6.789	6.863	5.575	4.670	4.852	4.366	4.008	2.768
Shear-hys.	50.00	8.699	7.221	5.029	5.782	4.957	4.838	4.569	3.027

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	11.81	9.295	7.161	3.994	0	0	0	0
AF&MS sys.	15.17	.6235	.8430	.6959	.5224	0	0	0	0
AF&MS/CD	16.17	.7918	1.009	.9900	.6189	0	0	0	0
Sliding s.	29.19	1.863	1.755	1.324	.9269	0	0	0	0
Shear-vis.	49.30	1.727	1.723	1.587	1.398	0	0	0	0
Shear-hys.	50.00	7.721	6.526	6.478	4.898	0	0	0	0

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	6.707	0	0	0	0	0	0	0
AF&MS sys.	14.59	.3159	0	0	0	0	0	0	0
AF&MS/CD	14.92	.3977	0	0	0	0	0	0	0
Sliding s.	28.28	.6002	0	0	0	0	0	0	0
Shear-vis.	20.86	4.522	0	0	0	0	0	0	0
Shear-hys.	50.00	4.759	0	0	0	0	0	0	0

Figure 4-14. Interstory drifts at Superstandard Damping.

Generally speaking, none of the damping-dependent systems of seismic isolation can render protection effectiveness even close to that of the antifriction and multi-step softening technology incorporated in the Shock Evaders.

In Figure 4-15 the results of experiment with the rigid body of a mass equal to the total mass of the 8-story building, Standard Earthquake, are shown. The experiment was to evaluate the governing concept of the current Regulations

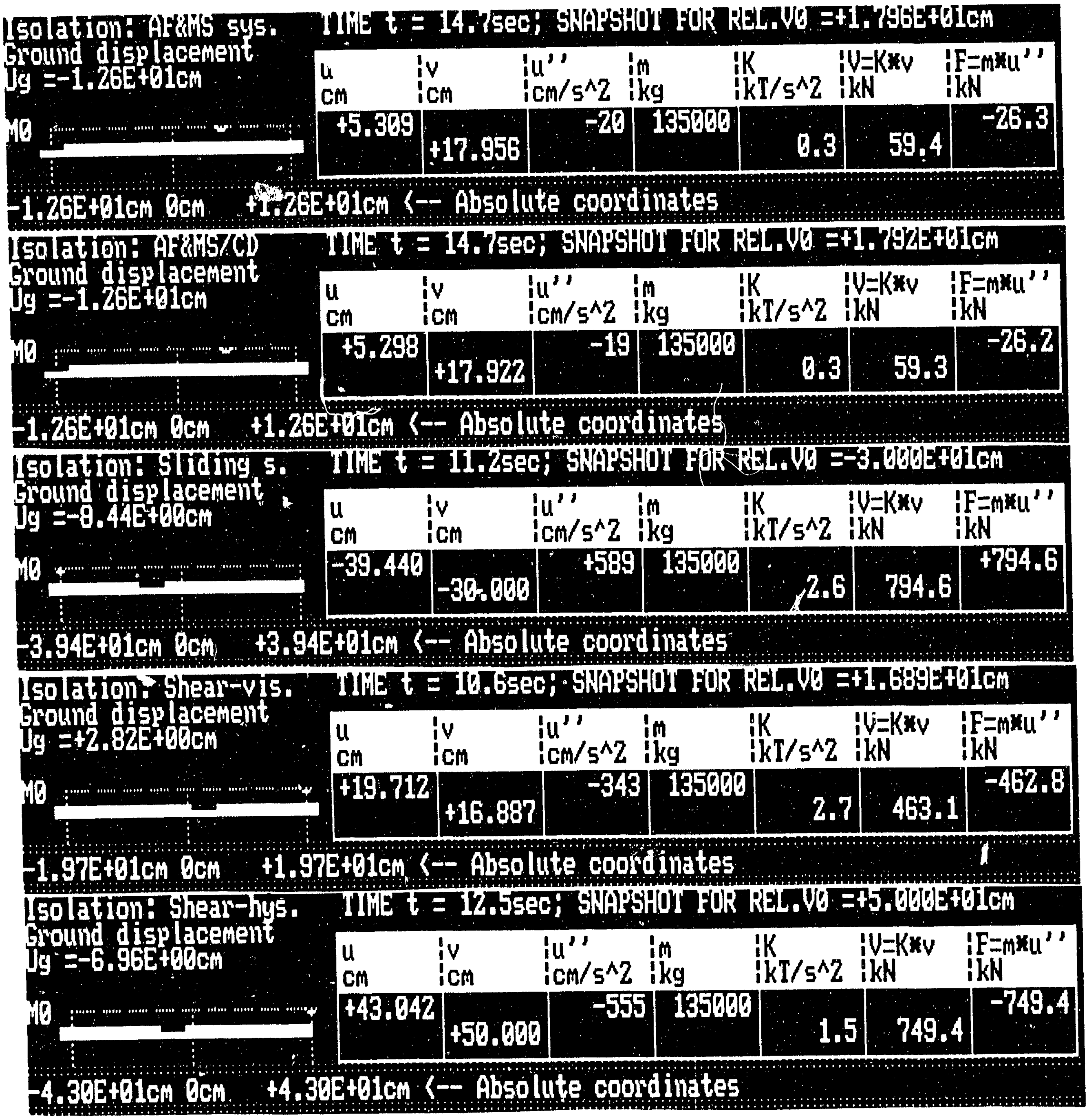


Figure 4-15. Condensed 8-story structure responses to a Standard Earthquake.

[8] , according to which an n-story building can be mentally "compressed" into a solid body of the same mass, and the maximum shearing force of this body, rocking on isolators, may be considered a reasonable approximation to the real maximum shearing force in the original structure. If you compare the corresponding values from Figure 4-15, on the one hand, and from Figures 4-2 through 4-6, on the other, namely, shearing forces V in the isolated structures:

59 and 217
59 and 217
795 and 1743
463 and 1792
749 and 1972

you can see that the concept is dead wrong and that there is absolutely no ground to share the optimism, though restrained, of the report [25].

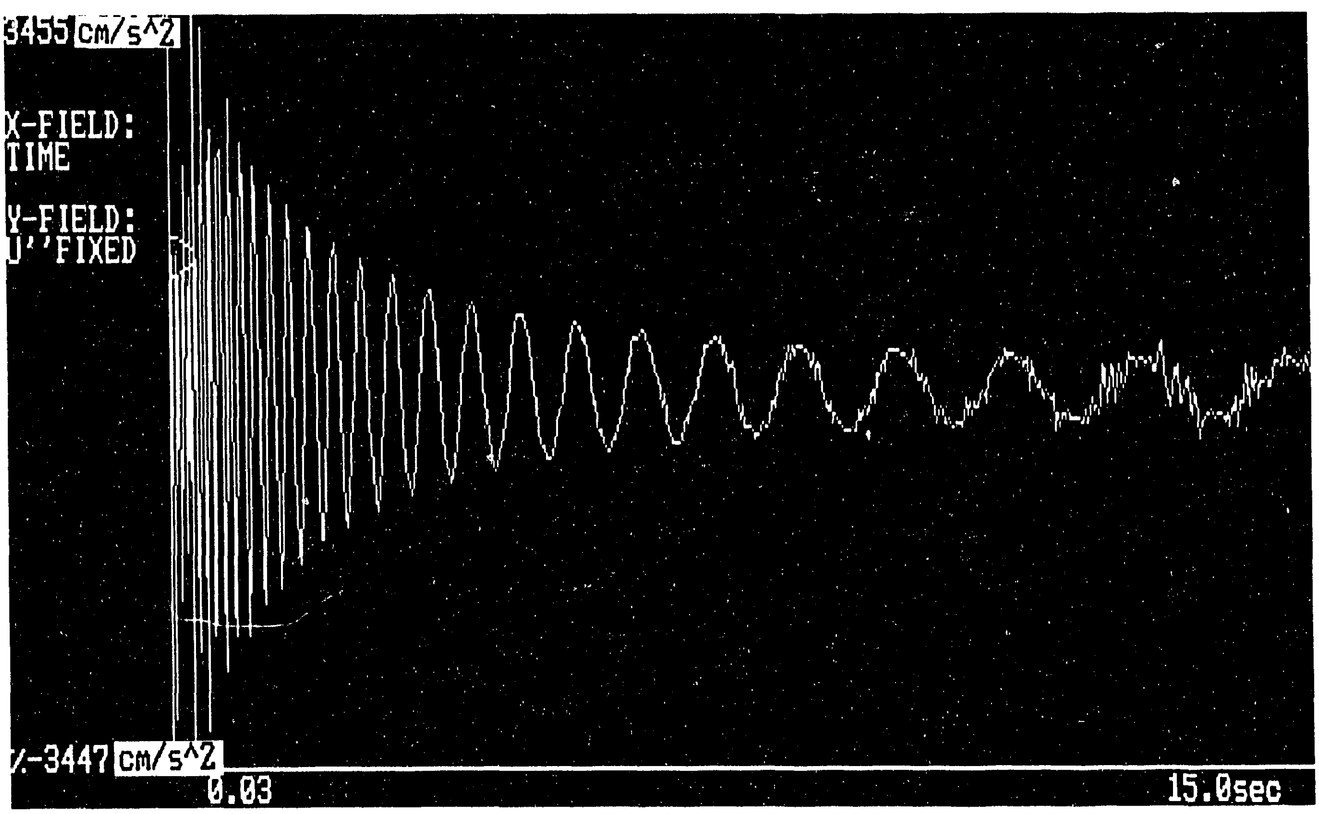


Figure 4-16. Acceleration time-history: ***Fixed system***, 0-floor, one-story museum building, Superstandard Quake.

Secondary systems in general [26, 27, 28] and those supported on seismically isolated structures [29, 30] under some circumstances are of the primary concern. Although floor response spectra can be readily generated by the program SIPP

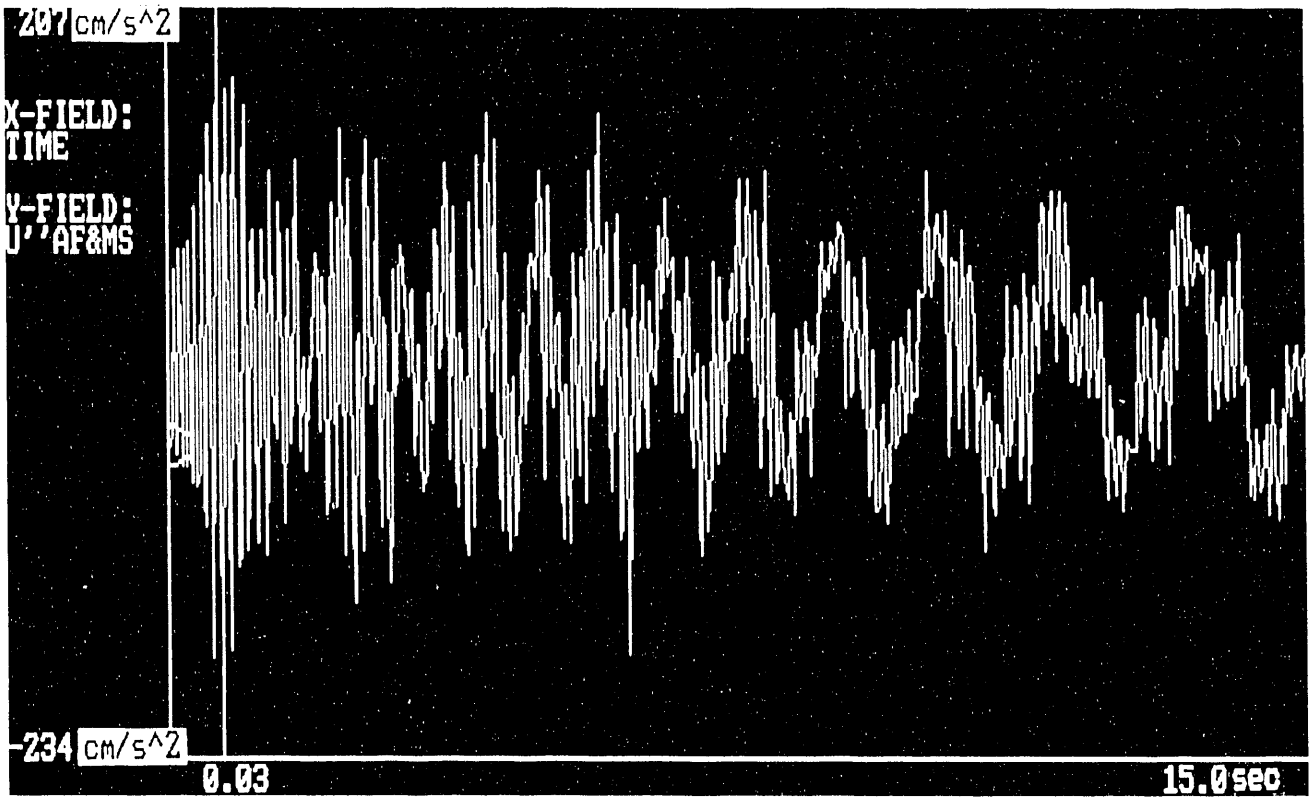


Figure 4-17. Acceleration time-history: ***AF&MS BI system***, 0-floor, one-story museum building, Superstandard Quake.

(see Part II of the current report), for most of the practically rigid equipment or museum artifacts the corresponding floors time-histories are good enough to draw an appropriate judgement. Figures 4-16 through 4-19 are just representing the 0-floor acceleration time-histories of a one-story museum building, for six categories of isolation systems under investigation, which are subjected to a Superstandard Earthquake. Only buildings resting on Shock Evaders^{tm} (AF&MS BI and AF&MS BI/CD) are apparently on the safe side (maximum accelerations do not exceed 0.21g and 0.24g accordingly).

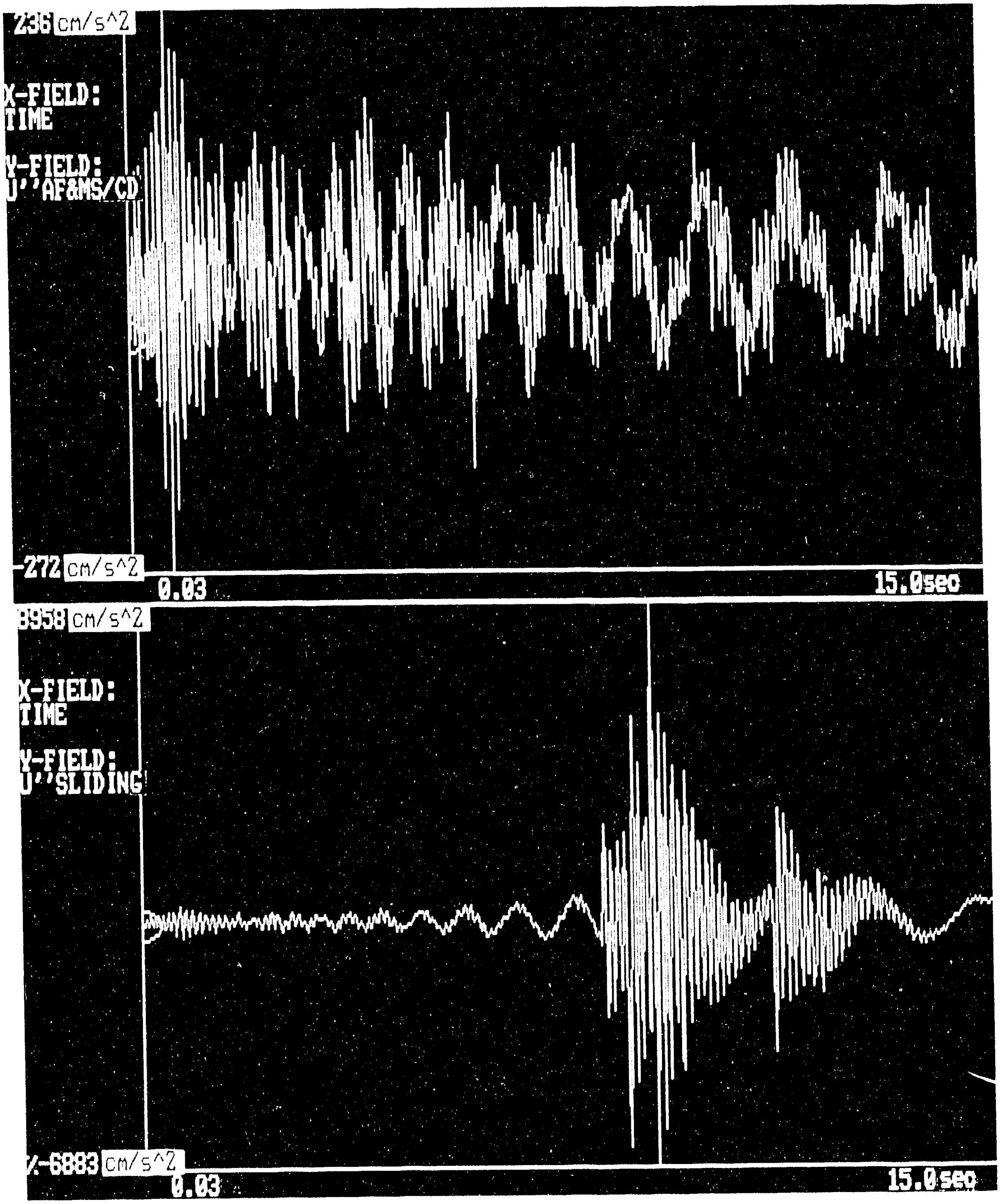
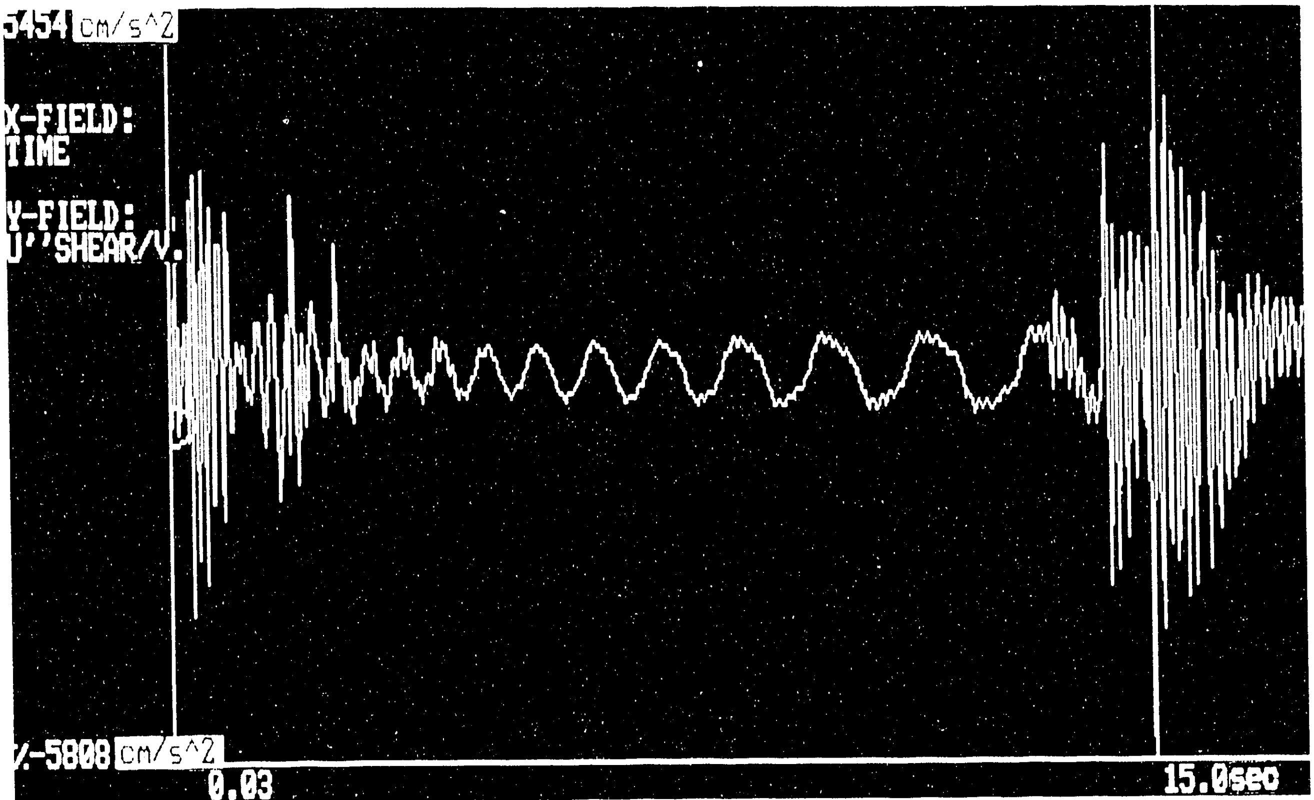


Figure 4-18. Acceleration time-histories: *AF&MS BI/CD system* (top) and *Sliding system* (bottom), 0-floor, one-story museum building, Superstandard Quake.



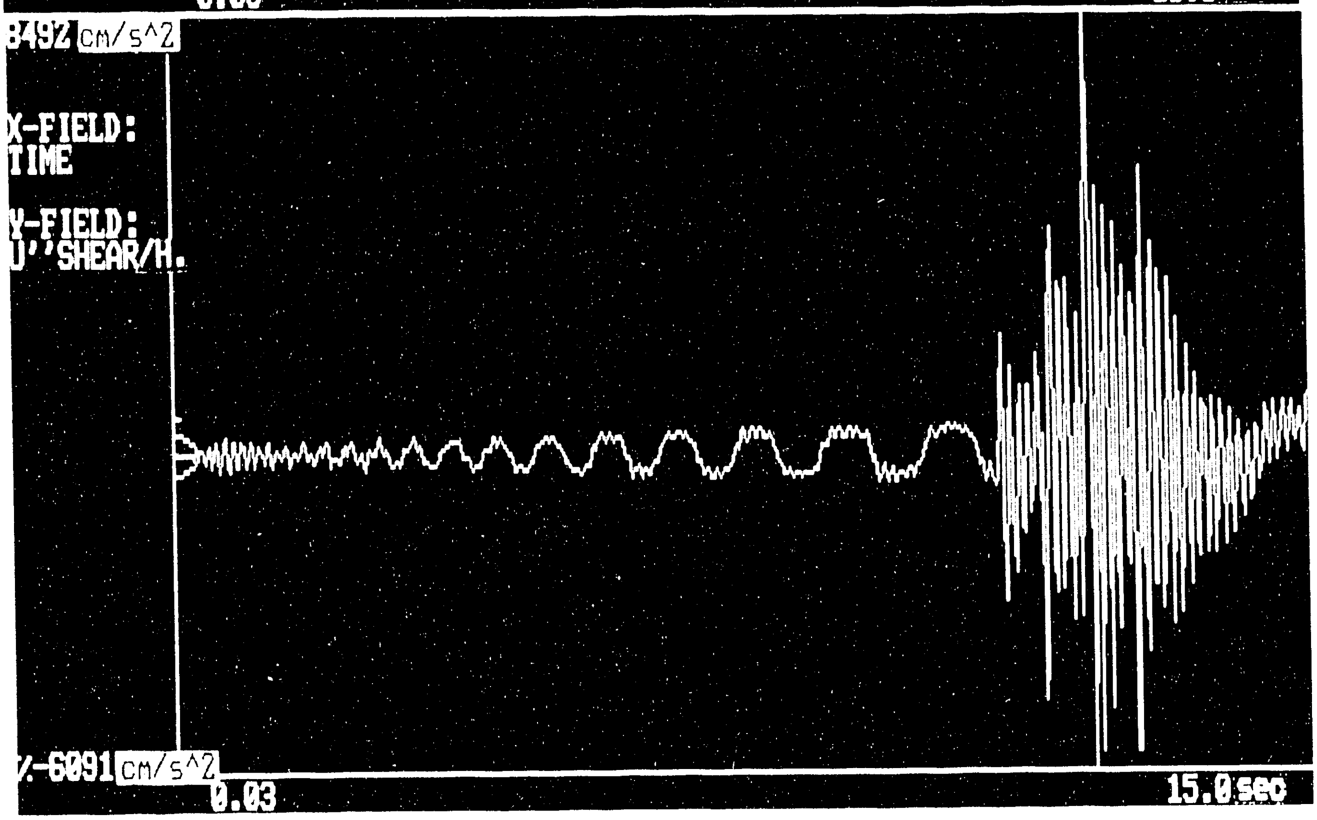


Figure 4-19. Acceleration time-histories: *Shear-viscous system* (top) and *Shear-hysteretic system* (bottom), 0-floor, one-story museum building, Superstandard Quake.

All the rest cannot promise anything except the desperately large accelerations: 9.13g, 5.56g, 8.66g (that of the Fixed system equals only 3.52g).

The next experiment is devoted to the common superstition [31] stating that the peak displacement of the isolation system is the most important parameter for design of an isolated structure. Figure 4-20 presents an evidence to the

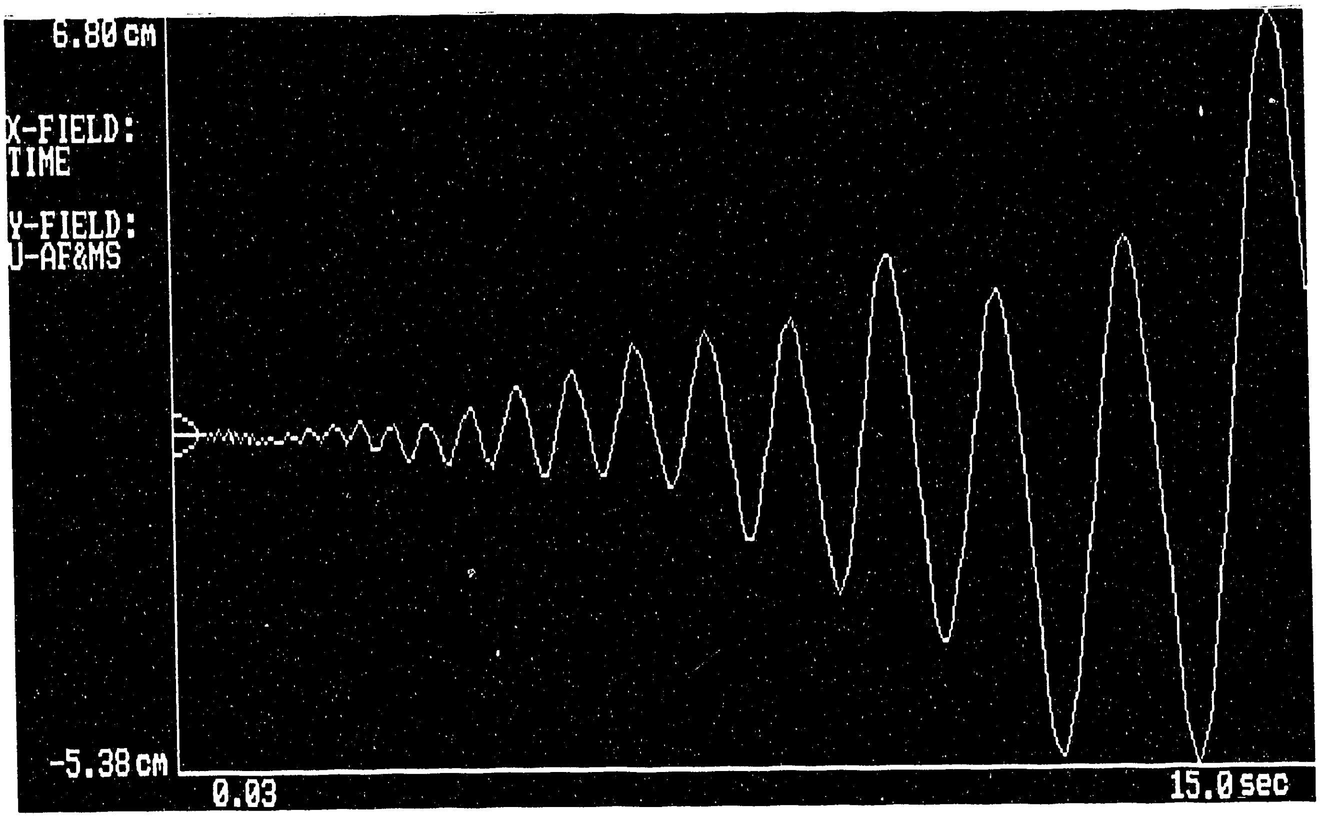


Figure 4-20. Displacement time-history: ***AF&MS BI system***, 0-floor, one-story museum building, Superstandard Quake.

contrary: if you compare it with the Figure 4-17, you will see that despite the peak displacements steadily build up, the peak accelerations continuously go down leaving behind a big question about the displacements' contribution.

SECTION 5

THE REGULATIONS: WRONG WAY. SEVERE DAMAGE GUARANTEED

The recently adopted design provisions for base-isolated buildings, the Regulations [8] are not mandatory. However, they are the only guidance for the code officials, and this guidance is extremely misleading.

After years of base isolation euphoria, it is high time to get to the bottom, and the bottom line is the Regulations [8].

An innocent client has good reasons to expect some formula in those Regulations which will enable a designer to reduce the demand on structural elements providing the structure is to be put on seismic isolators, and this would be the best proof of the consultant's sincerity about widely proclaimed "miraculous" mitigating effects of the new technology.

Unfortunately, there is nothing of the kind there. The design base shear and contributing to it inertial forces per Regulations will probably be much bigger than those per UBC, Chapter 23, Part III [32] which deals with conventional, non-isolated structures. The picture in Figure 5-1 is just visualizing the fact.

Thus, at the time when a wide stream of seismic isolation propaganda is continually brainwashing potential clients and building officials by creating dead-false expectations of extremely large margins of safety, we are selling a variety of over-designed and over-priced boxes on so called "isolators" in full compliance with said Regulations.

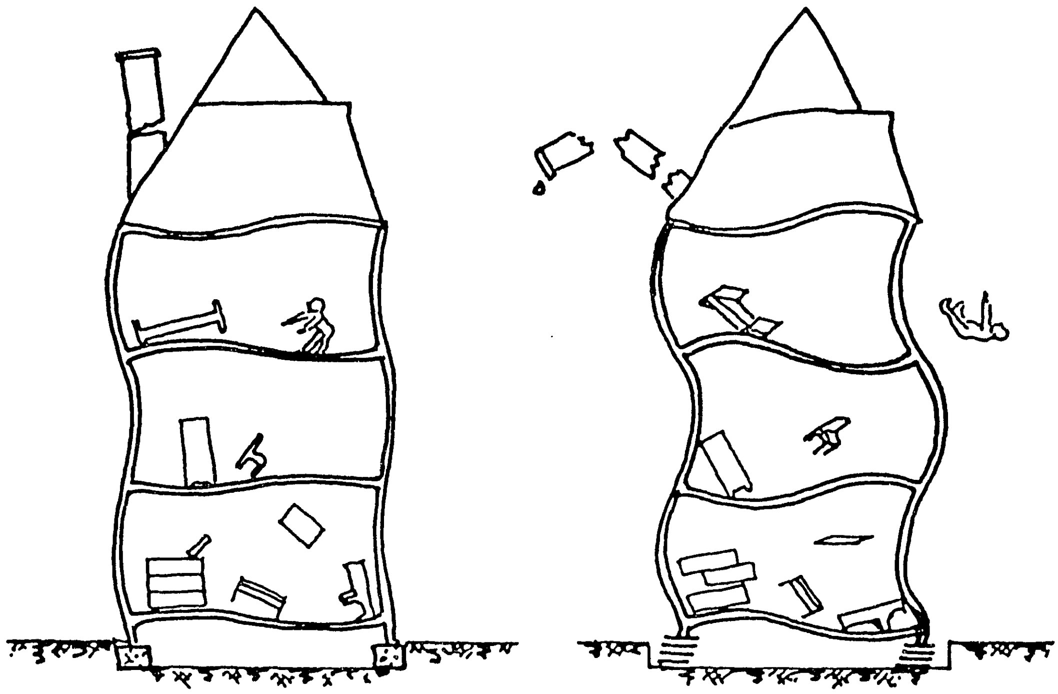
But is this over-conservatism necessarily warranted? - Not at all [3]. What seems to be rather conservative under statically applied loads can happen to be surprisingly vulnerable and easily give in when dynamics is on.

Then, what is really wrong in the Regulations?

The review that follows contains a brief list of the most obvious shortcomings.

1. There is no definition as to what is a base-isolated structure, which makes it impossible to address the Regulations properly.

The very concept of base isolation rests on the assumption that the fundamental period of the superstructure rocking as a rigid body on isolators (isolated period) is several times



Conventional Structure per UBC **Seismically Isolated Structure per Regulations**

Figure 5-1. Comparison of design forces of inertia.

greater than the period of the fixed-base structure. Not specifying the period shift ratio, we cannot separate the ***truly isolated*** structures from those ***simply resting on isolators*** and, therefore, to apply duly any regulations. The best candidate to the last kind of structures will be the retrofitted City Hall of Oakland, 18 stories high, with the expected fundamental period, just before the isolators yield, of 1.6-1.7 sec, and that at the effective displacement, of 2.85 sec [33].

2. The pronounced goal of the new technology is nothing more than "to provide results equivalent to those obtained by the use of conventional structural systems".

This requirement imposing minimum obligations is apparently intended to protect dear engineers rather than those damned structures (who cares?).

3. There is neither criterium for effectiveness evaluation of the new technology in comparison with non-isolated structures nor for comparison of different embodiments of base isolation.

The document, in general, is a collection of recipes, without any indication ***when*** and ***what for***, concerning feasibility of base isolation alternative.

*4. The definition of the major design parameter **design displacement** is void: "Design displacement is the design-basis earthquake lateral displacement ...". What is displaced and relative to what?*

Anyway, according to the demonstration on page 46 of this report, an increase of displacement can result in decrease of inertia forces, which casts doubt on adequacy of the displacement's contribution into the relationship (74-6) for shear force V_s [8].

5. The Regulations and the main body of the UBC are incompatible.

Their formulas for base shear

$$V = ZICW/R_w = 1.25\ SZIW/T^{2/3}R_w \qquad (5.01)$$

and

$$V_s = K_{max}D/R_{wi} = 10\ K_{max}ZNS_iT_i/BR_{wi} \qquad (5.02)$$

contain S and S_i, R_w and R_{wi} which stipulate different values of the identical parameters under the same conditions. Besides, the formula for V_s contains the fault proximity coefficient N which is absent in the formula for V, though both isolated and non-isolated structures might be sensitive to the distance from the active fault.

In order to couple those formulas, let us consider a particular building: the Foothill Communities Law and Justice Center (FCLJC) in Rancho Cucamonga, for instance, which is the first base-isolated building in the United States, well instrumented and serving as a model. In this case we have the following design parameters:

$$I = 1; \quad N = 1$$

$S = 1.2$ and $S_i = 1.4$ (Soil profile type S_2)

$R_w = 8$ and $R_{wi} = 2.2$ (Steel concentric-braced frame)

$$B = 1.2; \quad T = 0.72 \text{ sec}; \quad T_i = 2 \text{ sec}$$

$$K_{max} = K_{min} = 4\pi^2 W/gT_i^2 = 0.0255\ W$$

Establishing *Effectiveness Factor* (E.F.) as the ratio:

$$E.F. = V/V_s \qquad (5.03)$$

and using the relationships (5.01) and (5.02), obtain:

$$E.F. = 0.86 < 1$$

This means that according to the Regulations the seismic isolation of the FCLJC is ineffective (?!).

6. The formula (5.02) creates a false impression as though the relationship between the isolated and non-isolated periods, as well as dynamic properties of the superstructure, are of no importance for the value of the design base shear.

It has been shown in the previous Section (pages 41 and 42) that there is absolutely no ground for attributing the shear forces from a SDF system, and the formula (5.02) is just the case, to a MDF system, even if the total masses of both systems are the same.

7. The factor B yields an erroneous conception of damping in isolators as a mechanism inevitably lessening the base shear.

To create base isolators damping-dependent or damping-free? This is the ***Mother of All Questions*** concerning the seismic isolation engineering. As it was proved in Section 4 (pages 39 and 40) of the current report, none of the existing isolation technologies can protect the superstructure better than the low damping ones.

8. The dynamic response procedure is utterly devaluated by its principal guidelines.

It forbids the major design parameters, namely D and V_s, to be less than 80 to 90 percent of the values corresponding to the static response procedure which, in its turn, should provide results equivalent to those of conventional systems. As soon as the external loads imposed on isolated structures are essentially the same or greater than those imposed on non-isolated ones, what is good in fussing about with such "mitigating" technology? [34].

Response spectrum analysis, though being a part of Dynamic analysis, has the same drawbacks as Static one because it also deals with SDF systems.

Time-history analysis does not specify ***how to use damping characteristics*** in the equations of motion which provokes unwarranted voluntarism in computations (see page 8, remark on reference [5]). Another example of bare voluntarism is introduction of R_{wi} factor: the message contained in it should be a result of particular computer analysis rather than being administered a priori.

9. Testing procedure provides little credit to the project.

Substitution of a real (instataneous) stiffness with an effective one has no justification: it can cause vain expectations of ever "good" behaviour of an isolation system when displacements are small and frequencies are high, which is not always true (see, for instance, Figure 4-19, top).

Knowing an effective damping ratio of the isolation system is not enough for accurate computations: it is still necessary to know the relevant ***form of damping***. Otherwise, a huge uncertainty may arise. As an example, Figure 5-2 presents two acceleration time-histories, one for a linear viscous and one for a hysteretic form of damping, both having ***the same damping ratio***.

We cannot tell beforehand ***how*** the velocity related force of resistance will depend on loading rates. Therefore, ***all*** isolators have to be tested dynamically, besides, the frequency of test loading should correspond not to the isolated period but to the instantaneous frequency of excitation.

The most aggravating shortcoming, however, is the absence of any performance test requirements in the Regulations. Even the National Institute of Standards and Technology, into the very bold dreams [35], does not dare to mention a slightest possibility of performance testing in the future. It is especially discouraging due to the fact that ***none*** of the isolators, incorporated into any existing structures or those under construction, ***have ever been tested full-scale kinematically up to the contemporary design levels.***

A consequence of this extremely loose and inadequate testing procedure can be demonstrated on the retrofit project of the

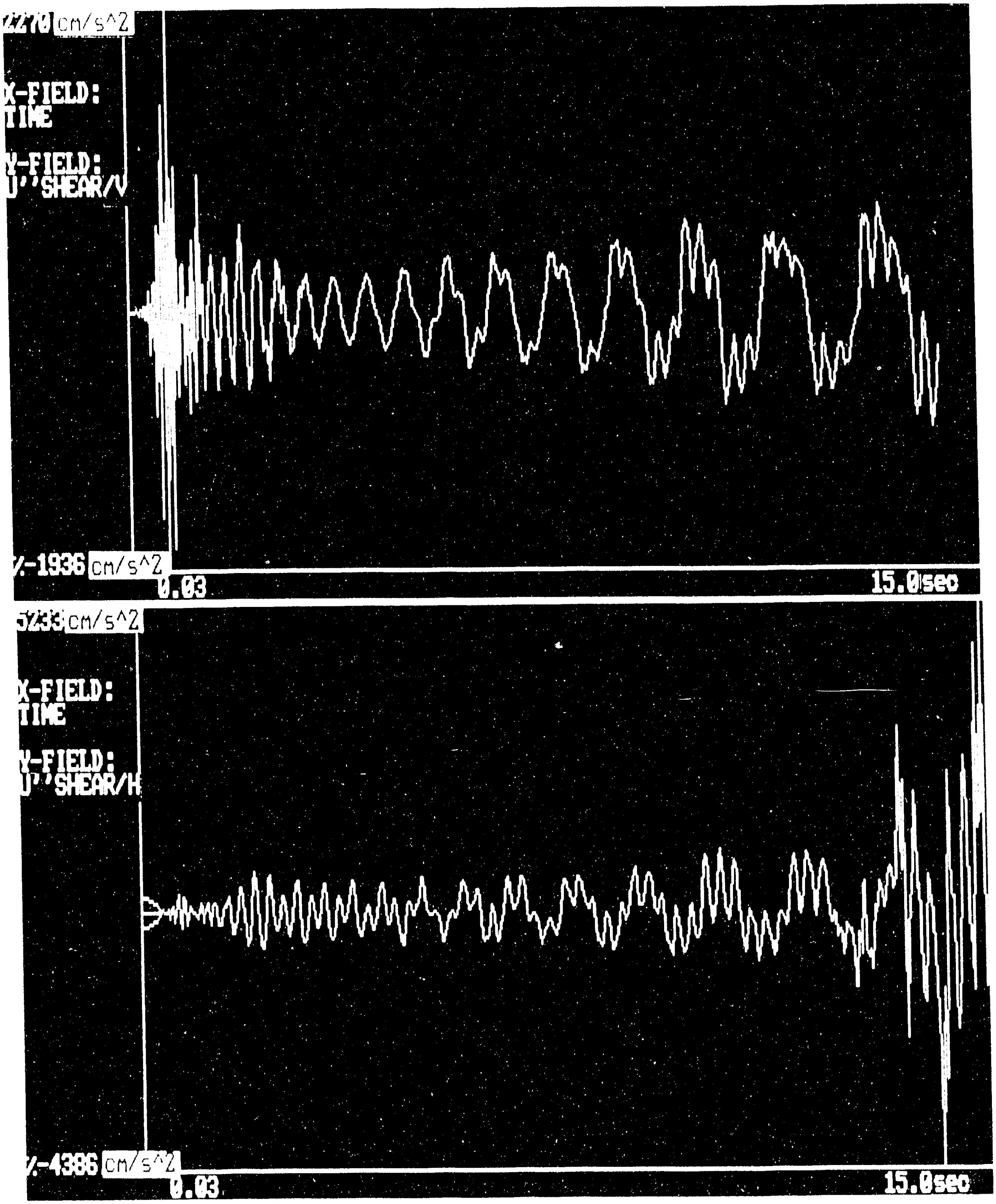


Figure 5-[illegible]. Acceleration time-history plots: *Shear-viscous* (top) and *Shear-hysteretic* (bottom) *systems*, 3d floor, 4-story building, Standard Earthquake, Superstandard damping

Ninth Circuit U.S. Court of Appeals building (San Francisco)[36]. The isolation technology applied in the project is Friction Pendulum System (FPS) which employs a convex-faced bearing intended to slide upon a matching concave surface of a support. The spherically-surfaced pedestal, as an element of seismic isolation, was patented in the U.S. yet in 1927 [37]. The new feature of FPS is the bearing itself consisting of a double sliding hemisphere of a small radius, which is rotary supporting a hemispherical socket connected to a superstructure (sliding mechanism #1), and is rotary supported by a spherically-shaped pedestal plate of a much greater radius (sliding mechanism #2). For satisfactory performance, the friction force of the sliding mechanism #1 should be dynamically balanced by that of the mechanism #2. Otherwise, the reaction centering ability of the device will be lost, the effective area of the weight support will get shifted to a boundary of the slider, the thin layer of the bearing material will turn out to be momentarily eaten, and the metal of the hemisphere will plough up the metal of the pedestal plate, which means a ***failure of the isolator***.

This can and will happen under considerable vertical loads: an enormous stress concentration at the crown of the hemisphere will inevitably lock the sliding mechanism #1, and the report on the corresponding experimental research, promised in [38], will, hopefully, document this phenomenon. Nevertheless, the isolators FPS have successfully passed through the Regulations [8] testing procedure, and the Court of Appeals building obtained a chance to go down in history.

SECTION 6

CONCLUSIONS & RECOMMENDATIONS

1. Damping mechanism of seismic isolators is simultaneously a driving one. Its negative, pushing effect is immidiate, while its positive, dissipating effect needs time to develop. However, a mere lessening the damping potential is none of a remedy: it should be followed by the appropriate changes in the isolators mechanism of rigidity in order to be a success.

2. Analytical investigation proves: damping-free approach works. None of the damping-dependent systems of seismic isolation can render protection effectiveness even close to that of the antifriction and multi-step softening technology incorporated in the Shock Evader. This is true both for structural elements and content, and at any magnitude of earth shaking. Now, the viability of the new approach have to be investigated experimentally.

3. Abundance of details in the Regulations [8] does not substitute for the lack of sense. The formulas there do not provide an adequate insight into the phenomenon of seismic isolation and create faulse ideas about interrelations between design parameters. Practically, the Regulations permit indiscriminate use of isolation technology and are, therefore, a real and imminent threat to the building safety. The work should be done anew.

SECTION 7

REFERENCES

[1] Buckle, I.G. and Mayes, R.L., 1990, *"Seismic Isolation: History, Application, and Performance - A World View"*, ***Earthquake Spectra***, 6(2): 161-201.

[2] Kelly, J.M., 1993, *"State-of-the-Art and State-of-the-Practice in Base Isolation"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1: 9-28.

[3] Kelly, J., Aiken, I., and Clark, P., 1991, *"Response of Base-Isolated Structures in Recent California Earthquakes"*, Proc. ***SMIP 91***, Sacramento, CA, 12-1 - 12-10.

[4] Clough, R.W. and Penzien, J., 1975, *"Dynamics of Structures"*, ***McGraw-Hill, Inc.***, New York, N.Y.

[5] Button, Martin R., 1993, *"Story Shear Distributions in Seismically Isolated Structures"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1: 307-318.

[6] Kelly, J.M., 1991, *"Dynamic and Failure Characteristics of Bridgestone Isolation Bearings"*, ***Report No UCB/EERC-91/04***, Univ. of Calif., Berkley, CA.

[7] Griffith, M.C., Aiken, I.D., and Kelly J.M., 1990, *"Comparison of Earthquake Simulator Test Results with SEAONC Tentative Seismic Isolation Design Requirements"*, ***Earthquake Spectra***, 6(2): 403-417.

[8] UBC, Appendix Chapter 23, Division III: *Earthquake Regulations for Seismic Isolated Structures*, ***ICBO***, 1991.

[9] Kojima, H. and Fukahori, Y., 1990, *"Rubber World"*, Vol.35, No 202.

[10] Kelly, J., 1990, *"Base Isolation: Linear Theory and Design"*, ***Earthquake Spectra***, 6(2): 223-244.

[11] Shustov, V., 1991, *"New Approach to Seismic Base Isolation"*, Proc. ***6th CCEE***, Toronto, Canada.

[12] Shustov, V., 1992, *"Base Isolation: Fresh Insight"*, Proc, ***10th WCEE***, Madrid, Spain, pp. 1983-1986.

[13] Shustov, V., 1991, *"Multi-Step Base isolator"*, ***U.S. Patent 5,056,280.***

[14] Shustov, V., 1993, *"Seismic Isolation: Antifriction Approach"*, Proc. ***6th Intl. Conf. SDEE-93***, Bath, UK, pp. 529-536.

[15] Mokha, A., Constantinou, M.C. and Reinhorn, A.M., 1988, *"Teflon Bearings in Aseismic Base Isolation: Experimental Studies and Mathematical Modeling"*, ***Report No NCEER-88-0038***, NCEER, Buffalo, NY.

[16] Mokha, A., Constantinou, M.C. and Reinhorn, A.M., 1991, *"Further Results on the Frictional Properties of Teflon Bearings"*, ***J. Structural Engng.***, ASCE, 117(2): 622-626.

[17] Campbell, T.I., Pucchio, J.B., Roeder, C.W. and Stanton, J.F., 1991, *"Frictional Characteristics of PTFE Used in Slide Surfaces of Bridge Bearings"*, Proc. ***3rd WCJB***, Vol.2, 847-870.

[18] Constantinou, M.C., Khartoum, A., Reinhorn, A.M. and Bradford, P., 1991, *"Experimental and Theoretical Stady of a Sliding Isolation System for Bridges"*, ***Report No NCEER-91-0027***, NCEER, Buffalo, NY.

[19] Shustov, V., 1976, *"Method of Earthquake Imitation"*, ***Invention No 552,581, USSR***, Intl. Cl. G01V1/00.

[20] Clough, R.W. and Penzien, J., 1993, *"Dynamics of Structures"*, Second Edition, ***McGraw-Hill, Inc.***, New York, N.Y.

[21] Hudson, D.E., 1979, *"Reading and Interpreting Strong Motion Accelerograms"*, ***EERI***, Berkley, CA.

[22] Nagarajaiah, S., Reinhorn, A.M. and Constantinou, M.C. 1991, *"3D-BASIS, Nonlinear Dynamic Analysis of Three-Dimensional Base Isolated Structures: Part II"*, ***Report NCEER-91-0005***, NCEER, Buffalo, N.Y.

[23] Zayas, Victor A., Low, Stanley S., Mahin, Stephen A., 1987, *"The FPS Earthquake Resisting System"*, ***Report UCB/EERC-87/01***, UC Berkley, CA.

[24] Anderson, T.L., 1990, *"Seismic Isolation Design and Construction Practice"*, Proc. ***4th NCEE***, Vol.3, pp.519-528.

[25] Winter, C.W. and Constantinou, M.C., 1993, *"Evaluation of Static and Response Spectrum Analysis Proceedures of SEAOC/UBC for Seismic Isolated Structures"*, ***Report NCEER-93-0004***, NCEER, Buffalo, N.Y.

[26] Biggs J.M., 1971, *"Seismic Response Spectra for Equipment Design in Nuclear Power Plants"*, Proc. ***1st SMIRT Conf.***

[27] Singh, M.P., 1975, *"Generation of Floor Response Spectra"*, ***J. Engrg. Mech. Div.***, ASCE, 101(5):593-607.

[28] Singh, M.P., 1988, *"Seismic Design of Secondary Systems"*, ***Probab. Engng. Mech.***, 3(3):151-158.

[29] Kelly, J.M., 1982, *"The Influence of Base Isolation on the Seismic Response of Light Secondary Equipment"*, ***Report No UCB/EERC-81/17***, EERC, UC Berkley, CA.

[30] Kelly, J.M., and Tsai, H.C., 1985, *"Seismic Response of Light Internal Equipment in Base-Isolated Structures"*, ***Earthquake Engng. Struct. Dyn.***, 13(6):711-732.

[31] Lashkari, Bahman and Kircher, Charles A., 1993, *"Evaluation of SEAOC/UBC Analysis Procedures. Part I: Stiff Superstructure"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1:149-160.

[32] Uniform Building Code, 1991, Chapter 23, Part III - *Earthquake Design, **ICBO***.

[33] Honeck, William, Walters, Mason, Sattary, Vahid and Rodler, Paul, 1993, *"The Seismic Isolation of the Oakland City Hall"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1:221-232.

[34] Shustov, V., 1993, *"What ATC Does Not Want You to Know at the ATC-17-1 Seminar"*, ***Communication***, San Francisco, CA.

[35] Shenton III, Harry W., 1993, *"Draft Guideline for Testing and Evaluation of Seismic Isolation Systems"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Fracisco, CA, 1:349-354.

[36] Amin, Navin, Mokha, Anoop, Fatehi, Hamid, 1993, *"Seismic Isolation Retrofit of the U.S. Court of Appeals Building"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1:185-196.

[37] Porter, A.A., 1927, *"Foundation for Earthquakeproof Buildings", **U.S. Patent 1,651,411.***

[38] Zayas, Victor, Piepenbrock, Theodore, Al-Hussaini, Tahmeed, 1993, *"Summary of Testing of the Friction Pendulum Seismic Isolation System"*, Proc. ***ATC-17-1 Seminar*** on Seismic Isolation, Energy Dissipation, and Active Control, San Francisco, CA, 1:377-388.

II. SEISMIC ISOLATION PROBE PROGRAMS MANUAL

1. SEISMIC ISOLATION PROBE PROGRAMS (SIPP) DATABASE

All data files are of random access type and fall into one of the two categories: Folder Type Files and Fake Type Files; each Fake Type File is represented by a single record in Folder Type File. Though the total number of files is 33, most of them are linked together to create a single data block. Practically, you will be dealing with a few main files: BUILDING DATA FOLDER, EARTHQUAKE DATA FOLDER folder files and BUILDING DATA OUTPUT, SEC. SYSTEM OUTPUT, FLOOR DATA OUTPUT and EARTHQUAKE DATA OUTPUT fake files. Note, that SEC. SYSTEM FOLDER and FLOOR DATA FOLDER files are extensions of BUILDING DATA FOLDER file because the output of each experiment goes into the three main blocks of seismograms and accelerograms: for superstructure (BUILDING DATA OUTPUT), for secondary system (SEC. SYSTEM OUTPUT) and for the floor where the secondary system is placed (FLOOR DATA OUTPUT). Shown below is the file layouts schedule listed in order of the output of FLIST and LPRALL FNA commands.

1.1 BUILDING DATA FOLDER (BDF)

```
BUILDING DATA    *FOLDER                      File# 1  Type:folder Prg# 0
        -  EXPERIMENT #  - Experiment number, also a DBF record number; set up automatically
        -  EXPER. REMARKS - Remarks
* File# 2  Type:folder Prg# 0
        -  UG' MAX - Peak velocity of ground displacement, [cm/sec]
        -  MIN.PERIOD - Initial period of ground displacement, [sec]
        -  MAX.PERIOD - Max. period of ground displacement, [sec]
        -  TOTAL TIME - Total earthquake time, [sec]
        -  CALC./FILE - Flag, see section 2.1
        -  RIGIDITY - Rigidity of superstrusture, [kg/sec^2]
        -  DAMPING - Damping coefficient of superstructure, [kg/sec]
* File# 3  Type:folder Prg# 0
        -  MASS-0 - Concentrated basement mass (0-level), [kg]
        -  MASS-1 - Same, for the 1st floor
        -  MASS-2 - Same, for the 2nd floor
        -  MASS-3 - Same, for the 3rd floor
        -  MASS-4 - Same, for the 4th floor
        -  MASS-5 - Same, for the 5th floor
        -  MASS-6 - Same, for the 6th floor
        -  MASS-7 - Same, for the 7th floor
        -  MASS-8 - Same, for the 8th floor
* File# 14  Type:folder Prg# 0
        -  EXP.#  - Experiment number
        -  NATURAL FRICTION - Friction coefficient for AF&MS System
        -  COEF.-N - Coefficient "N", see (15) in section 2.3
        -  AF&MS-REMARKS - Remarks
* File# 15  Type:folder Prg# 0
        -  VRAD1 - First (smallest) vertical radius of AF&MS System, [cm]
        -  VRAD2 - 2nd vertical radius
        -  VRAD3 - 3rd vertical radius
        -  VRAD4 - 4th vertical radius
        -  VRAD5 - 5th vertical radius
        -  VRAD6 - 6th vertical radius
        -  VRAD7 - 7th vertical radius
        -  VRAD8 - 8th vertical radius
        -  VRAD9 - 9th vertical radius
        -  VRAD10 - 10th vertical radius
* File# 16  Type:folder Prg# 0
        -  HRAD1 - First (smallest) vertical radius of AF&MS System, [cm]
        -  HRAD2 - 2nd horizontal radius
        -  HRAD3 - 3rd horizontal radius
        -  HRAD4 - 4th horizontal radius
        -  HRAD5 - 5th horizontal radius
        -  HRAD6 - 6th horizontal radius
        -  HRAD7 - 7th horizontal radius
        -  HRAD8 - 8th horizontal radius
        -  HRAD9 - 9th horizontal radius
        -  HRAD10 - 10th horizontal radius
* File# 17  Type:folder Prg# 0
        -  EXP.#  - Experiment number
        -  NATURAL FRICTION - Friction coefficient for Sliding System
        -  RADIUS - Vertical Radius of Sliding System, [cm]
        -  SLIDING-REMARKS - Remarks
* File# 18  Type:folder Prg# 0
```

- EXP.# - Experiment number
- DAMPING RATIO - Damping ratio for Shear-viscous and Shear-hysteretic systems
- COEF.-A - Coefficient "A", see {17} of section 2.3
- COEF.-B - Coefficient "B", see {17} of section 2.3
- SHEAR-REMARKS - Remarks

* File# 19 Type:folder Prg# 0
- EXP.# - Experiment number
- MASS - Secondary system mass, [kg]
- DAMPING RATIO - Damping ratio for the secondary system
- FLOOR# - Floor number, where the secondary system is placed
- SEC.SYS.-REMARKS - Remarks

* File# 20 Type:folder Prg# 0
- EXP.# - Experiment number
- FLOOR-REMARKS - Remarks

1.2 BUILDING DATA OUTPUT

BUILDING DATA *OUTPUT File# 4 Type:fake Prg# 4
- SYSTEM - Type of seismic isolator
- ABS.U0 - Peak of absolute displacement for the basement, [cm]
- ABS.U1 - Same, for the 1st floor
- ABS.U2 - Same, for the 2nd floor
- ABS.U3 - Same, for the 3rd floor
- ABS.U4 - Same, for the 4th floor
- ABS.U5 - Same, for the 5th floor
- ABS.U6 - Same, for the 6th floor
- ABS.U7 - Same, for the 7th floor
- ABS.U8 - Same, for the 8th floor

* File# 5 Type:fake Prg# 0
- TIME-U0 - Time corresponding to peak of abs. displacement for the basement, [sec]
- TIME-U1 - Same, for the 1st floor
- TIME-U2 - Same, for the 2nd floor
- TIME-U3 - Same, for the 3rd floor
- TIME-U4 - Same, for the 4th floor
- TIME-U5 - Same, for the 5th floor
- TIME-U6 - Same, for the 6th floor
- TIME-U7 - Same, for the 7th floor
- TIME-U8 - Same, for the 8th floor

* File# 6 Type:fake Prg# 0
- SYSTEM - Type of seismic isolator
- REL.V0 - Peak of relative displacement for the basement, [cm]
- REL.V1 - Same, for the 1st floor
- REL.V2 - Same, for the 2nd floor
- REL.V3 - Same, for the 3rd floor
- REL.V4 - Same, for the 4th floor
- REL.V5 - Same, for the 5th floor
- REL.V6 - Same, for the 6th floor
- REL.V7 - Same, for the 7th floor
- REL.V8 - Same, for the 8th floor

* File# 7 Type:fake Prg# 0
- TIME-V0 - Time corresponding to peak of rel. displacement for the basement, [sec]
- TIME-V1 - Same, for the 1st floor
- TIME-V2 - Same, for the 2nd floor
- TIME-V3 - Same, for the 3rd floor
- TIME-V4 - Same, for the 4th floor
- TIME-V5 - Same, for the 5th floor
- TIME-V6 - Same, for the 6th floor
- TIME-V7 - Same, for the 7th floor
- TIME-V8 - Same, for the 8th floor

* File# 8 Type:fake Prg# 0
- SYSTEM - Type of seismic isolator
- U0'' - Peak of absolute acceleration for the basement, [cm/sec^2]
- U1'' - Same, for the 1st floor
- U2'' - Same, for the 2nd floor
- U3'' - Same, for the 3rd floor
- U4'' - Same, for the 4th floor
- U5'' - Same, for the 5th floor
- U6'' - Same, for the 6th floor
- U7'' - Same, for the 7th floor

- U8'' - Same, for the 8th floor

* File# 9 Type:fake Prg# 0
  - U0''TIME - Time corresponding to peak of abs. acceleration for the basement, [sec]
  - U1''TIME - Same, for the 1st floor
  - U2''TIME - Same, for the 2nd floor
  - U3''TIME - Same, for the 3rd floor
  - U4''TIME - Same, for the 4th floor
  - U5''TIME - Same, for the 5th floor
  - U6''TIME - Same, for the 6th floor
  - U7''TIME - Same, for the 7th floor
  - U8''TIME - Same, for the 8th floor
* File# 10 Type:fake Prg# 0
  - V - Momentary values of relative displacements for all superstructure floors, corresponding to peak value of relative displacement for the basement in file #6. Numeric data converted in the string 9[floors] * 4[bytes]=36 characters long
  - V - Same, for the 1st floor
  - V - Same, for the 2nd floor
  - V - Same, for the 3rd floor
  - V - Same, for the 4th floor
  - V - Same, for the 5th floor
  - V - Same, for the 6th floor
  - V - Same, for the 7th floor
  - V - Same, for the 8th floor
* File# 11 Type:fake Prg# 0
  - V1 - Momentary values of relative velocities for all superstructure floors, corresponding to peak value of relative displacement for the basement in file #6. Numeric data converted in the string 9[floors] * 4[bytes]=36 characters long
  - V1 - Same, for the 1st floor
  - V1 - Same, for the 2nd floor
  - V1 - Same, for the 3rd floor
  - V1 - Same, for the 4th floor
  - V1 - Same, for the 5th floor
  - V1 - Same, for the 6th floor
  - V1 - Same, for the 7th floor
  - V1 - Same, for the 8th floor
* File# 12 Type:fake Prg# 0
  - U - Momentary values of absolute displacements for all superstructure floors, corresponding to peak value of relative displacement for the basement in file #6. Numeric data converted in the string 9[floors] * 4[bytes]=36 characters long
  - U - Same, for the 1st floor
  - U - Same, for the 2nd floor
  - U - Same, for the 3rd floor
  - U - Same, for the 4th floor
  - U - Same, for the 5th floor
  - U - Same, for the 6th floor
  - U - Same, for the 7th floor
  - U - Same, for the 8th floor
* File# 13 Type:fake Prg# 0
  - U2-UG - Momentary values of absolute accelerations for all superstructure floors, corresponding to peak value of relative displacement for the basement in file #6, plus value of ground absolute displacement. Numeric data converted in the string 9[floors] * 4[bytes] + 4[bytes]=40 characters long
  - U2-UG - Same, for the 1st floor
  - U2-UG - Same, for the 2nd floor
  - U2-UG - Same, for the 3rd floor
  - U2-UG - Same, for the 4th floor
  - U2-UG - Same, for the 5th floor
  - U2-UG - Same, for the 6th floor
  - U2-UG - Same, for the 7th floor
  - U2-UG - Same, for the 8th floor

1.3 SEC. SYSTEM DATA FOLDER

See description in section 1.1 (above).

SEC. SYSTEM DATA*FOLDER File# 19 Type:folder Prg# 0

- EXP.#
- MASS
- DAMPING RATIO
- FLOOR#

- SEC.SYS.-REMARKS

* File# 20 Type:folder Prg# 0
  - EXP.#
  - FLOOR-REMARKS

1.4 SEC. SYSTEM DATA OUTPUT

SEC. SYS. DATA *OUTPUT File# 21 Type:fake Prg# 21
- PERIOD-T - Current period, [sec]
- U-FIXED - Peak of absolute displacement for Fixed System, [cm]
- U-AF&MS - Same, for AF&MS System
- U-AF&MS/CD - Same, for AF&MS/CD System
- U-SLIDING - Same, for Sliding System
- U-SHEAR/V. - Same, for Shear-viscous System
- U-SHEAR/H. - Same, for Shear-hysteretic System

* File# 22 Type:fake Prg# 0
  - TU-FIXED - Time corresponding to peak of abs. displacement for Fixed System, [sec]
  - TU-AF&MS - Same, for AF&MS System
  - TU-AF&MS/CD - Same, for AF&MS/CD System
  - TU-SLIDING - Same, for Sliding System
  - TU-SHEAR/V. - Same, for Shear-viscous System
  - TU-SHEAR/H. - Same, for Shear-hysteretic System
* File# 23 Type:fake Prg# 0
  - PERIOD-T - Current period, [sec]
  - V-FIXED - Peak of relative displacement for Fixed System, [cm]
  - V-AF&MS - Same, for AF&MS System
  - V-AF&MS/CD - Same, for AF&MS/CD System
  - V-SLIDING - Same, for Sliding System
  - V-SHEAR/V. - Same, for Shear-viscous System
  - V-SHEAR/H. - Same, for Shear-hysteretic System
* File# 24 Type:fake Prg# 0
  - TV-FIXED - Time corresponding to peak of rel. displacement for Fixed System, [sec]
  - TV-AF&MS - Same, for AF&MS System
  - TV-AF&MS/CD - Same, for AF&MS/CD System
  - TV-SLIDING - Same, for Sliding System
  - TV-SHEAR/V. - Same, for Shear-viscous System
  - TV-SHEAR/H. - Same, for Shear-hysteretic System
* File# 25 Type:fake Prg# 0
  - PERIOD-T - Current period, [sec]
  - U''FIXED - Peak of absolute acceleration for Fixed System, [cm/sec^2]
  - U''AF&MS - Same, for AF&MS System
  - U''AF&MS/CD - Same, for AF&MS/CD System
  - U''SLIDING - Same, for Sliding System
  - U''SHEAR/V. - Same, for Shear-viscous System
  - U''SHEAR/H. - Same, for Shear-hysteretic System
* File# 26 Type:fake Prg# 0
  - TU''FIXED - Time corresponding to peak of abs. acceleration for Fixed System, [sec]
  - TU''AF&MS - Same, for AF&MS System
  - TU''AF&MS/CD - Same, for AF&MS/CD System
  - TU''SLIDING - Same, for Sliding System
  - TU''SHEAR/V. - Same, for Shear-viscous System
  - TU''SHEAR/H. - Same, for Shear-hysteretic System

1.5 FLOOR DATA FOLDER

See description in section 1.1 (above).

FLOOR DATA *FOLDER File# 20 Type:folder Prg# 0
- EXP.#
- FLOOR-REMARKS

1.6 FLOOR DATA OUTPUT

FLOOR DATA *OUTPUT File# 27 Type:fake Prg# 0
- TIME - Current time, [sec]
- U-FIXED - Current absolute displacement for Fixed System, for secondary system level, (level is FLOOR# from file #19), [cm]

- U-AF&MS - Same, for AF&MS System
- U-AF&MS/CD - Same, for AF&MS/CD System
- U-SLIDING - Same, for Sliding System
- U-SHEAR/V. - Same, for Shear-viscous System
- U-SHEAR/H. - Same, for Shear-hysteretic System

* File# 28 Type:fake Prg# 0

- TIME - Current time, [sec]
- U''FIXED - Current absolute acceleration for Fixed System, for secondary system level, [cm/sec^2]
- U''AF&MS - Same, for AF&MS System
- U''AF&MS/CD - Same, for AF&MS/CD System
- U''SLIDING - Same, for Sliding System
- U''SHEAR/V. - Same, for Shear-viscous System
- U''SHEAR/H. - Same, for Shear-hysteretic System

* File# 29 Type:fake Prg# 0

- TIME - Current time, [sec]
- V-FIXED - Current relative displacement for Fixed System, for secondary system level, [cm]
- V-AF&MS - Same, for AF&MS System
- V-AF&MS/CD - Same, for AF&MS/CD System
- V-SLIDING - Same, for Sliding System
- V-SHEAR/V. - Same, for Shear-viscous System
- V-SHEAR/H. - Same, for Shear-hysteretic System

1.7 EARTHQUAKE DATA FOLDER

EARTHQUAKE DATA *FOLDER File# 32 Type:folder Prg# 0

- EQ.NAME - Earthquake name
- EQ.LOCAL TIME - Earthquake local time, [hr/min/sec]
- STATION NAME - Station name
- FILE NAME - file name, see section 5.1

* File# 31 Type:folder Prg# 0

- ACCEL. ID - Accelerogram identification number
- STATION - Station number
- EQ.HYPOCENTER - Earthquake hypocenter (latitude, longitude & depth)
- MAGNITUDE - Earthquake magnitude, [ml]

* File# 33 Type:folder Prg# 0

- TRANS.NAT.PERIOD - Transducer natural period, [sec]
- DAMPING - Damping, in fraction of critical
- SENSITIVITY - Sensitivity, [cm/g]
- LENGTH - Length, [sec]
- U-MAX - Peak of absolute displacement, [cm]
- TU-MAX - Corresponding time, [sec]
- U'-MAX - Peak of absolute velocity, [cm/sec]
- TU'-MAX - Corresponding time, [sec]
- U''-MAX - Peak of absolute acceleration, [cm/sec^2]
- TU''-MAX - Corresponding time, [sec]

1.8 EARTHQUAKE DATA OUTPUT

EARTHQUAKE DATA *OUTPUT File# 30 Type:fake Prg# 30

- TIME - Current time, [sec]
- ABS.DISPLACEMENT - Current value of absolute displacement, [cm]
- ABS.ACCELERATION - Current value of absolute acceleration, [cm/sec^2]

2. SUPERSTRUCTURE DATA I/O

2.1 SUPERSTRUCTURE DATA INPUT

All information about superstructure and seismic isolators is represented by ten FNA files chained together. The file named BUILDING DATA FOLDER (BDF) is the Main FNA File (first in the chain) and consists of two data fields: EXPERIMENT NUMBER and EXPERIMENT REMARKS. Other nine files called FNA Extension Files. Second file in chain carries earthquake parameters (max. period, total time, etc.) plus rigidity and damping coefficient for superstructure. The rest of chained files carry an information about four fifferent types of seismic isolators: AF&MS BI, Sliding, Shear-viscous and Shear-hysteretic.

EXAMPLE:

Run FNA.BAT file or click FNA icon if you are using Widows.
Optional: press <2> to check, if you currently are in the right directory. If not, input directory name.
Press <1> to run FNA.
Using <UP> and <DOWN> cursors, select BDF file (highlight file name and press <ENTER>).
Press <F2> and select RCHANGE or RADD command (to change existing record or add new record), or type proper command on the Command Input Level (bottom of the screen). Current record number appears on the lower left screen corner. To change record, press <BAR> and select [NEXT], [PREVIOUS], etc. from the menu at the screen bottom, or use RLIST command (see FNA Manual about RCHANGE, RADD and RLIST commands). To change current file, use <LEFT> and <RIGHT> cursors, if you are RLISTing records, or press <EXTENSION> if you are in RCHANGE (RADD) command level. Listed below is one of the BDF records with comments below each of the chained files.

BUILDING DATA FOLDER
record # 2 of 4

EXPERIMENT # - 2
EXPER. REMARKS - f=.02 for AF&MS,1st floor seismogram
Data field EXPER. REMARKS is used to distinguish between different BDF records.
UG' MAX - 40 CM/S
MIN.PERIOD - .03 S
MAX.PERIOD - 2 S
TOTAL TIME - 15 S
CALC./FILE - 0
RIGIDITY - 1500
DAMPING - 1.233
Data field CALC./FILE is an integer and must be equal to zero, if earthquake parameters (absolute displacement Ug=F (TIME) and absolute acceleration U''g=F (TIME)) are calculated according to the formula for Imitation Mode (see (1) in section 2.3), and CALC./FILE is equal to the record number of EARTHQUAKE DATA FOLDER file, if earthquake parameters are inputed from accellerogram and seismogram corresponding to this EDF record.
Data fields UG'MAX, MIN.PERIOD, MAX.PERIOD and TOTAL TIME are encountered only for the Imitation Mode. Data fields MIN.PERIOD and MAX.PERIOD are used as limits for spectra-calculations for the secondary system (see section 3).
MASS-0 - 15000 KG
MASS-1 - 15000 KG
MASS-2 - 15000 KG
MASS-3 - 15000 KG
MASS-4 - 0 KG
MASS-5 - 0 KG
MASS-6 - 0 KG
MASS-7 - 0 KG
MASS-8 - 0 KG
At least one of the mass has to be more than zero. Max. number of levels in superstructure is set to nine, from MASS-0 (basement) to the MASS-8 (eighth floor).
EXP.# - 2
NATURAL FRICTION- .02
COEF.-N - 2
AF&MS-REMARKS -f=.2, 1st floor
COEF.-N is a coefficient in formula (15) of section 2.3. This formula is used to account for the central depression in AF&MS BI isolators.
VRAD1 - 100 CM
VRAD2 - 200 CM
VRAD3 - 400 CM
VRAD4 - 800 CM
VRAD5 - 1600 CM
VRAD6 - 10 CM
VRAD7 - 0 CM

VRAD8 - 0 CM
VRAD9 - 0 CM
VRAD10 - 0 CM
Max. number of vertical radiuses for AF&MS BI systems is set to 10, each VRADx corresponds to it's own horizontal radius HRADx (see below). Last HRADx (non-zero value) calculated as previous HRADx plus last vertical radius VRADx.
HRAD1 - 2.5 CM
HRAD2 - 5 CM
HRAD3 - 10 CM
HRAD4 - 20 CM
HRAD5 - 40 CM
HRAD6 - 50 CM
HRAD7 - 0 CM
HRAD8 - 0 CM
HRAD9 - 0 CM
HRAD10 - 0 CM

EXP.# - 2
NATURAL FRICTION- .05
RADIUS - 100 CM
SLIDING-REMARKS -1 st floor seismogram
This file is for the sliding type seismic isolator.
EXP.# - 2
DAMPING RATIO - .2
COEF.-A - 69.7
COEF.-B - .3
SHEAR-REMARKS -1 st floor seismogram
This file is for the both viscous and hysteretic types of seismic isolators, see section 2.3, formulas {16},{17} and {18}.
EXP.# - 2
MASS - 100 KG
DAMPING RATIO - .01
FLOOR# - 1
SEC.SYS.-REMARKS-100kg secondary system on the first floor U,V,U''MAX=F (T)
This file also is used as a SEC. SYSTEM DATA FOLDER file, if it's accessed thru the SEC. SYSTEM OUTPUT file. Setting data field MASS to nonzero value will cause the program to record seismogram and accelerogram for the particular FLOOR#. This record will be used for calculations of secondary system accelarations and displacements. Setting MASS to zero (default value) allow to skip floor seismogram recording.
EXP.# - 2
FLOOR-REMARKS - f=.02, 1st flr. U,V,U''=F (TIME)
This file also is used as a FLOOR DATA FOLDER file, if it's accessed thru the FLOOR DATA OUTPUT file. Data field FLOOR-REMARKS used to distinguish between different BDF records.

2.2 SUPERSTRUCTURE DATA OUTPUT

Just the input of data by itself in described above BDF file can't force data processing. To activate data processing for BDF record, select BUILDING DATA OUTPUT (BDO) by using FLIST or FSEARCH FNA commands. You will be prompted to select one of the BDF records from the screen (records are listed from top to bottom, one record per one line, only EXPERIMENT # and EXPER. REMARKS data fields of BDF file will be shown). Record selection will open new or existing BDO file represented by this record. If this record was never selected before, calculations and output in BDO and FDO (see below) will start automatically; if the output already exists, you will be prompted to regenerate the output. Press <Y> to regenerate and any other button to skip the regeneration. For instance, changing any numerical data in the BDF file should change the output and regeneration will be necessary. The output of BDF record is BDO file with six records. First record is an output for the superstructure without seismic isolator (Fixed System). The rest of the records is an output for the same superstructure with different types of seismic isolators: AF&MS BI isolator (AF&MS System), AF&MS BI isolator with a central depression (AF&MS/CD System), Sliding isolator (Sliding System), Shear-viscous isolator (Shear-viscous System) and Shear-hysteretic isolator (Shear-hysteretic System). If secondary system mass is set to nonzero value, the output will be made also for designated FLOOR# to the FDO file (see section 3). BDO file is combined from ten FNA files linked together. Listed below is an example of the record for Sliding System with the comments.

BUILDING DATA Experiment # 2
record # 4 of 6
SYSTEM - Sliding s.
ABS.U0 - 35.83302 CM
ABS.U1 - 36.64411 CM
ABS.U2 - 37.13083 CM
ABS.U3 - 37.34054 CM

ABS.U4 - 0 CM
ABS.U5 - 0 CM
ABS.U6 - 0 CM
ABS.U7 - 0 CM
ABS.U8 - 0 CM
TIME-U0 - 14.36541 S
TIME-U1 - 14.36729 S
TIME-U2 - 14.37104 S
TIME-U3 - 14.37291 S
TIME-U4 - 0 S
TIME-U5 - 0 S
TIME-U6 - 0 S
TIME-U7 - 0 S
TIME-U8 - 0 S

Listed above are two files included in BDO file: first file keeps peaks of absolute displacements (ABS.Ux) for each floor, second file keeps times (TIME-Ux), corresponding to these displacements. Floors with masses equal to zero are not counted in calculations.

SYSTEM - Sliding s.
REL.V0 - 39.52083 CM
REL.V1 - .9303131 CM
REL.V2 - .731434 CM
REL.V3 - .4643217 CM
REL.V4 - 0 CM
REL.V5 - 0 CM
REL.V6 - 0 CM
REL.V7 - 0 CM
REL.V8 - 0 CM
TIME-V0 - 14.44791 S
TIME-V1 - 14.45353 S
TIME-V2 - 1.689599 S
TIME-V3 - 1.788989 S
TIME-V4 - 0 S
TIME-V5 - 0 S
TIME-V6 - 0 S
TIME-V7 - 0 S
TIME-V8 - 0 S

Listed above are two files included in BDO file: first file keeps peaks of relative displacements (REL.Vx) for each floor, second file keeps times (TIME-Vx), corresponding to these displacements. Floors with masses equal to zero are not counted in calculations.

SYSTEM - Sliding s.
U0'' - 733.7815 CM/S^2
U1'' - 728.2679 CM/S^2
U2'' - 565.0356 CM/S^2
U3'' - 696.7488 CM/S^2
U4'' - 0 CM/S^2
U5'' - 0 CM/S^2
U6'' - 0 CM/S^2
U7'' - 0 CM/S^2
U8'' - 0 CM/S^2
U0''TIME - 1.464565 S
U1''TIME - .8513526 S
U2''TIME - .676957 S
U3''TIME - 1.788989 S
U4''TIME - 0 S
U5''TIME - 0 S
U6''TIME - 0 S
U7''TIME - 0 S
U8''TIME - 0 S

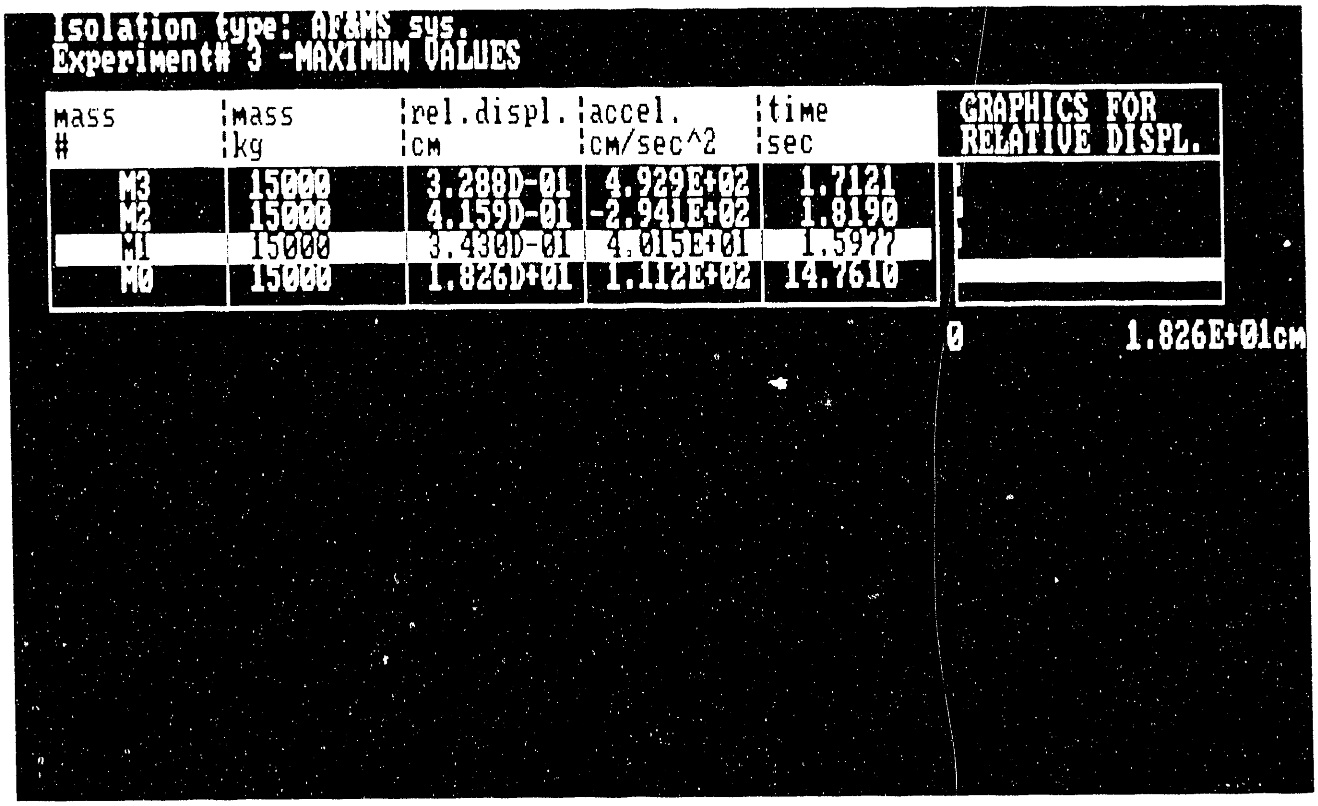
Listed above are two files included in BDO file: first file keeps peaks of absolute accelerations (ABS.Ux'') for each floor, second file keeps times (Ux''TIME), corresponding to these accelerations. Floors with masses equal to zero are not counted in calculations.

Rest of BDO files are not included in the list, because the output for them was saved in the compressed format for single precision variables; each variable occupies 4 bytes and group of nine or ten variables forms a string. It is enough to say now, that each string of the 7th file holds relative displacements of each floor in superstructure for the moment of time corresponding to the peak of relative displacement of x-th floor; 8th file holds relative velocities, 9th file holds absolute displacements and 10th file holds absolute accelerations plus value of ground displacement, respectively. These data are used to depict momentary condition of the system (see section 1.2).

Each step of the calculations will be preceeded by the message on the screen, showing you the name of seismic system currently being in processing (total number of records, or systems, is six). After the sixth message appears and you hear the beep, BDO calculations are completed and you are now in the FNA Command Input Level. Press <F2> and select RLIST, or type it. This command allows you to list all available records:

SYSTEM	REL.V0	REL.V1	REL.V2	REL.V3	REL.V4	REL.V5	REL.V6	REL.V7	REL.V8
Fixed sys.	0	10.48	8.262	4.580	0	0	0	0	0
AF&MS sys.	18.26	.3430	.4158	.3287	0	0	0	0	0
AF&MS/CD	17.79	.3627	.4337	.3491	0	0	0	0	0
Sliding s.	30.00	5.533	3.909	2.484	0	0	0	0	0
Shear-vis.	50	5.034	4.924	4.345	0	0	0	0	0
Shear-his.	50.00	6.252	5.665	4.658	0	0	0	0	0

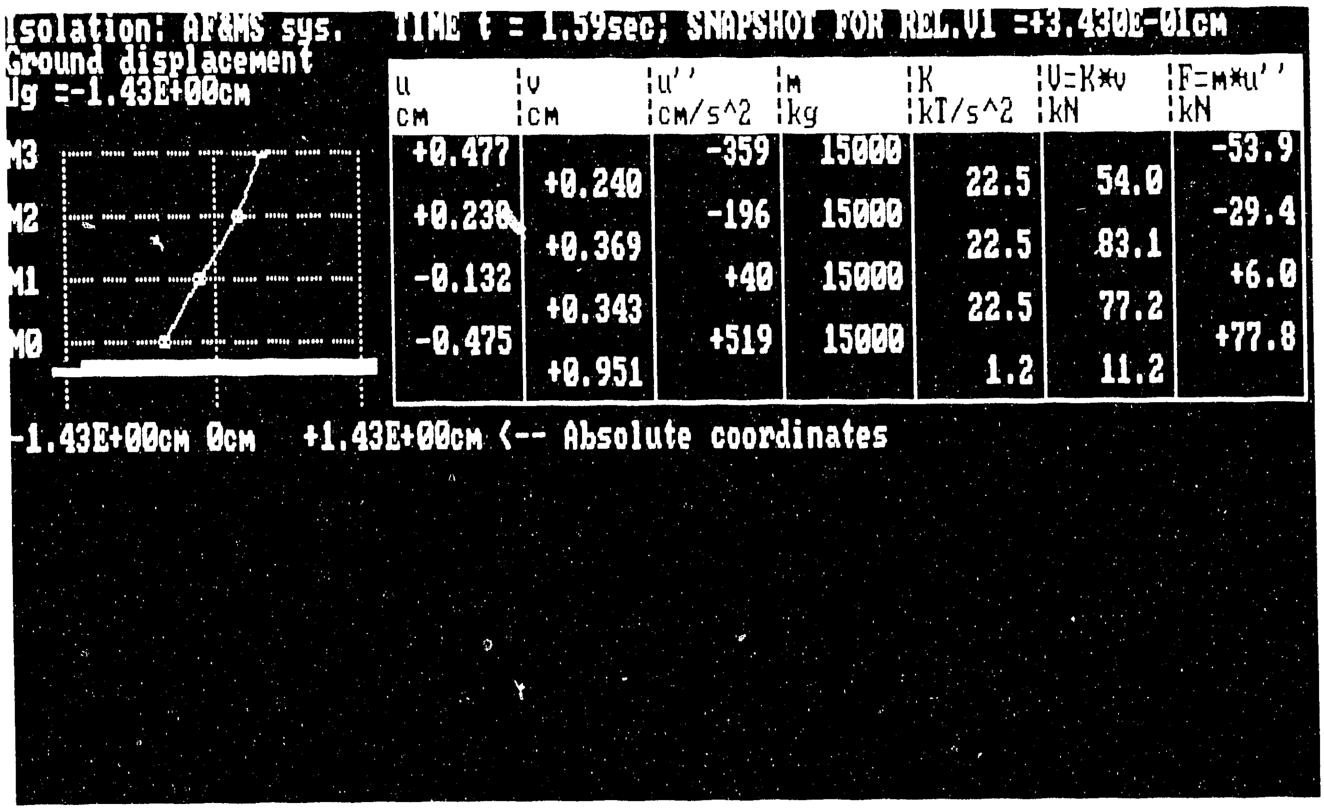
Highlight one of the records using <UP>, <DOWN>, <LEFT> and <RIGHT> cursors and press <ENTER>. Now the display shows: Isolation Type, Maximum Relative Displacement (highest value among all max. relative displacements for this Isolation Type), all superstructure masses with nonzero values and values for the relative displacement, the corresponding moment of time and acceleration for the same moment of time. In the left corner of the screen you could see a graph for relative displacement values in cm.



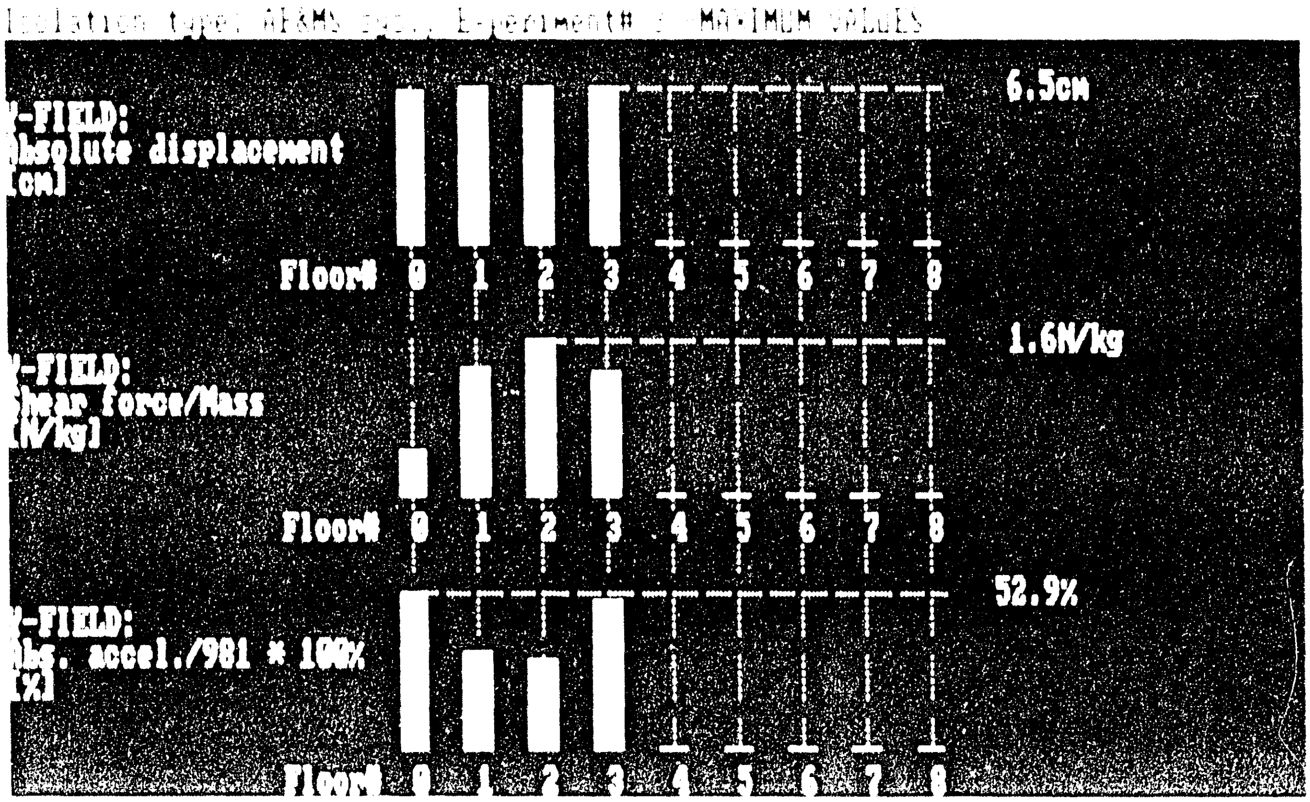
Isolation type: AF&MS sys.
Experiment# 3 -MAXIMUM VALUES

mass #	mass kg	rel.displ. cm	accel. cm/sec^2	time sec
M3	15000	3.288D-01	4.929E+02	1.7121
M2	15000	4.159D-01	-2.941E+02	1.8190
M1	15000	3.430D-01	4.015E+01	1.5977
M0	15000	1.826D+01	1.112E+02	14.7610

Press <BAR> [illegible] snapshots, or press <ENTER> to highlight one of the listed masses (use <UP> and <DOWN> [illegible]). Press <BAR> [illegible] snapshot [illegible] or press <ENTER> for the snapshot of the highlighted mass (see picture [illegible]). All [illegible] data shown are [illegible] the same moment of time. First screen line shows the type of isolation, [illegible] time [illegible] in seconds and max. relative displacement v in cm. Next line on the left shows ground [illegible] and graphs for relative displacements [illegible]. On the right side there is the data [illegible] data related to absolute values (absolute displacement u, absolute acceleration u'', concentrated mass m [illegible]) are [illegible] the [illegible] lines [illegible] the left. Data related to relative values (such as relative displacement v [illegible], stiffness K and shear force V) are shown between the proper [illegible].



Press <ENTER> to display the maximum values for the current seismic system (current record). First line shows the isolation type, experiment number (record number from [illegible] file) and "MAXIMUM VALUES" message, reminding that graphs are based not on momentary data, as in the previous display, but on the maximum values of the current seismic system. Left part of the screen shows [illegible], on the right you see maximum values [illegible].



Isolation type: AF&MS
Experiment#
MAXIMUM VALUES
-FIELD:
bsolute displacement
[cm]
6.5cm
Floor# 0 1 2 3 4 5 6 7 8
-FIELD:
hear force/Mass
[N/kg]
1.6N/kg
Floor# 0 1 2 3 4 5 6 7 8
-FIELD:
bs. accel./981 * 100%
[%]
52.9%
Floor# 0 1 2 3 4 5 6 7 8

2.3 SUPERSTRUCTURE DATA PROCESSING

There are three linked programs that come with BDO file: the purpose of 4.BAS program is data aquisition, 4A.BAS does data processing and 4B.BAS renderes output display. Shown below are main formulas the 4A.BAS program built on.

For imitation type calculations absolute displacements and accelerations are derived from following equations:

```
TDEL=TALL/7999
TDEL2=.5*TDEL^2
TDEL3=.1667*TDEL^3
SB=TALL/(TALL-TMAX+T0)
SA=SUG1M/SQR (1+(6.2832/LOG (SB))^2)
C1=6.2832/LOG (SB)
C2=(SB-1)/(SB*T0)
{1} DEF FNUG (TIME)=SIN (C1*LOG (C2*TIME+1!))*SA*TIME
{2} DEF FNUG1 (TIME)=(FNUG (TIME+TDEL)-FNUG (TIME))/TDEL
DEF FNUG2 (TIME)=(FNUG1 (TIME+TDEL)-FNUG1 (TIME))/TDEL
DEF FNUG3 (TIME)=(FNUG2 (TIME+TDEL)-FNUG2 (TIME))/TDEL
```

Where:
TALL - total earthquake time, [sec]
TDEL - time increment, [sec]
TDEL2 - coefficient for the third member of Tailor formula, [sec^2]
TDEL3 - coefficient for the fourth member of Tailor formula, [sec^3]
T0 - initial period, [sec]
TMAX - maximum period, [sec]
SUG1M - maximum velocity, [cm/sec]
TIME - current time, [sec]
FNUG (TIME) or SUG - current absolute displacement, [cm]
FNUG1 (TIME) or SUG1 - current absolute velocity, [cm/sec]
FNUG2 (TIME) or SUG2 - current absolute acceleration, [cm/sec^2]
FNUG3 (TIME) or SUG3 - current third derivation, [cm/sec^3]

System of equations for superstructure data:

```
{3} SU2 (SMASS)=(-SBT (SMASS)*SV1 (SMASS)-SKA (SMASS)*SV (SMASS))/SM (SMASS)
{4} SU3 (SMASS)=(-SBT (SMASS)*SV2 (SMASS)-SKA (SMASS)*SV1 (SMASS))/SM (SMASS)
..........................................................................................................
.....................

{5} SU2 (P)=(SBT (P+1)*SV1 (P+1)-SBT (P)*SV1 (P)+SKA (P+1)*SV (P+1)-SKA (P)*SV (P))/
SM (P)
{6} SU3 (P)=(SBT (P+1)*SV2 (P+1)-SBT (P)*SV2 (P)+SKA (P+1)*SV1 (P+1)-SKA (P)*SV1 (P))/
SM (P)
..........................................................................................................
.....................

{7} SU2 (0)=(SBT (1)*SV1 (1)-SBT (0)*SV1 (0)+SKA (1)*SV (1)-SKA (0)*SV (0))/SM (0)
{8} SU3 (0)=(SBT (1)*SV2 (1)-SBT (0)*SBT+SKA (1)*SV1 (1)-SKA (0)*SV1 (0))/SM (0)
```

Where:
SMASS - highest floor with nonzero mass value,
P - current floor number,
SBT - coefficient in {8}, value depends on current system type,
SUx (P) - absolute value of x-deriviation for current floor,
{9} SVx (P)=SUx (P)-SUx (P-1) - relative value of x-deriviation for current floor,
{10} SBT (P)=SDAM*SM (P) - damping coefficient, [kg/sec]
{11} SKA (P)=SRIG*SM (P) - rigidity coefficient, [kg/sec^2]
SDAM - superstructure damping coefficient, [1/sec]
SRIG - superstructure rigidity, [1/sec^2]. Restriction on rigidity: if the value of relative displacement exceeds 10cm, then corresponding rigidity coefficient drops to SKA (P)=SRIG*SM (P)*EXP (1-ABS (SV (P))/10) and damping coefficient drops to SBT (P)=SDAM*SM (P)*EXP (1-ABS (SV (P))/10). If the value of relative displacement exceeds 50cm, then SKA (P)=0.
SM (P) - mass for the current floor, [kg]

The values for the basement level of superstructure (the {7} and {8} equations):

For the Fixed System:
SV (0)=0:SV1 (0)=0:SV2 (0)=0:SV3 (0)=0
SU (0)=SUG:SU1 (0)=SUG1:SU2 (0)=SUG2:SU3 (0)=SUG3
This setting allows to skip {7} and {8}

For the AF&MS, AF&MS/CD and Sliding systems:
SBT=0
{12} SKA (0)=981*SM/SR
{13} SBT (0)=981*SF*SM/ABS (SV1 (0))
Where:
SM - summary mass, [kg]
SF - friction coefficient
SR - current vertical radius, [cm]; for the AF&MS/CD System first vertical radius accounted for central depression will be:
{14} SR=.16*SM^.4; corresponding horizontal radius will be:
{15} HR=SF*SF1B*SR, where
SF1B - coefficient "N" for AF&MS System

For the Shear-viscous System:
SBT=0
{16} SBT (0)=2*SDAM3*SM (0)*SV1PK/SVPK
{17} SKA (0)=SM*SKA3*EXP (-SKB3*SQR (SVMAX))
Where:
SDAM3 - damping coefficient for shear systems,
SV1PK - last peak value for relative velocity, [cm/sec]
SVPK - last peak value for relative displacement, [cm]
SKA3 - coefficient "A" for shear systems,
SKB3 - coefficient "B" for shear systems,
SVMAX - equal to the current value of relative displacement, if the value is less than 37.5 cm, and equal to 37.5 cm otherwise
For the Hysteretic System:
SBT=SV1 (0)
{18} SBT (0)=2*SDAM3*SKA (0)*ABS (SV (0)/SV1 (0)
SKA (0)=SM*SKA3*EXP (-SKB3*SQR (SVMAX))
Restriction on the value of relative displacement (basement level): if the value of SV (0) exceeds 0.6*SVR2 for the Sliding System then SV (0)=0.6*SVR2. For all other systems: if the value of SV (0) exceeds maximum horizontal radius SHR (SRADIUS) (see AF&MS System, BDF data) then SV (0)=SHR (SRADIUS).

Tailor formulas are used to update current values for the displacements and velocities:
{19} SU (P)=SU (P)+TDEL*SU1 (P)+TDEL2*SU2 (P)+TDEL3*SU3 (P)
SV (P)=SV (P)+TDEL*SV1 (P)+TDEL2*SV2 (P)+TDEL3*SV3 (P)
{20} SU1 (P)=SU1 (P)+TDEL*SU2 (P)+TDEL2*SU3 (P)
SV1 (P)=SV1 (P)+TDEL*SV2 (P)+TDEL2*SV3 (P)

3. SECONDARY SYSTEM I/O

3.1 SECONDARY SYSTEM INPUT

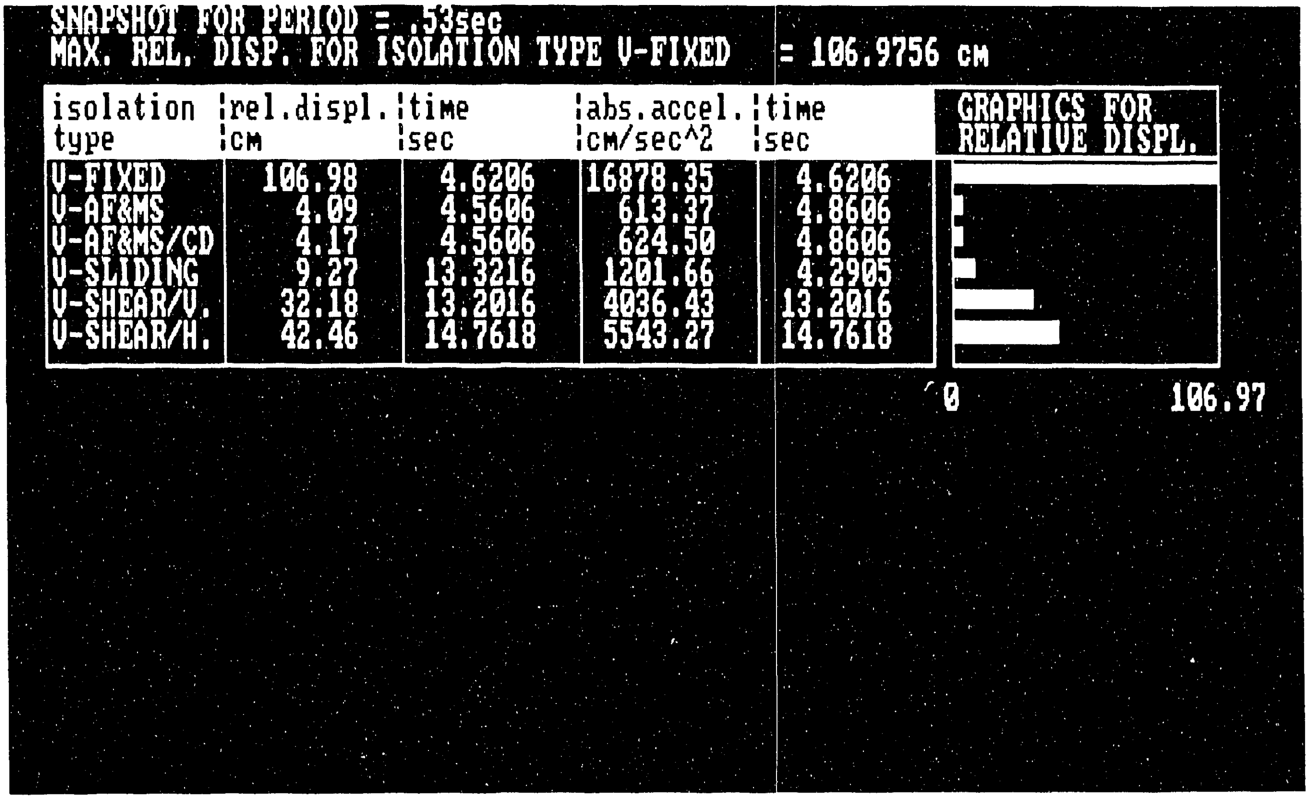
Input for secondary system calculations is:
a) the values of MIN.PERIOD, MAX.PERIOD, secondary system MASS and secondary system DAMPING RATIO from BDF file;
b) the seismogram / accelerogram of FLOOR# (defined in BDF) from corresponding FDO file. If this FDO file does not exist, you will receive the message "CAN'T FIND FLOOR RECORD-CHECK BUILDING DATA FILE". In this case open BDF file thru FLIST or FSEARCH commands to check whether the secondary system MASS was set to nonzero value, or whether the FLOOR# didn't exceed the highest floor number in the superstructure.

3.2 SECONDARY SYSTEM OUTPUT

SEC. SYSTEM DATA FOLDER file (SSDF) is just an extension of BDF file. To engage data processing for BDF record, select SEC. SYSTEM DATA OUTPUT (SSDO) by using FLIST or FSEARCH FNA commands. You will be prompted to select one of the SSDF records from the screen. Record selection will open new or existing SSDO file represented by this record. If this record was never selected before, calculations and output in SSDO file will start automatically; if the output already exists, you will be prompted to regenerate the output. Press <Y> to regenerate and any other button to skip the regeneration. For instance, changing any numerical data in the SSDF file should change the output and regeneration will be necessary. The output will be the spectra for period ranging from zero to the area of MAX.PERIOD value. Values for the current period (peaks of absolute and relative displacement, absolute acceleration and corresponding moments of time) are calculated for all types of superstructure seismic isolators: for the Fixed System, AF&MS System, AF&MS/CD System, Sliding System, Shear-viscous System and Shear-hysteretic System (see section 2.1). It is assumed, that secondary system does not have any seismic isolator. Listed below is one of 35 SSDO records:

```
        SEC. SYS. DATA    Experiment # 2
        record # 6  of  35
PERIOD-T          -  .53 S
U-FIXED           -  104.7974 CM
U-AF&MS           -  7.307262 CM
U-AF&MS/CD        -  7.579798 CM
U-SLIDING         -  41.70878 CM
U-SHEAR/V.        -  75.04686 CM
U-SHEAR/H.        -  82.52672 CM
TU-FIXED          -  4.620577 S
TU-AF&MS          -  13.38161 S
TU-AF&MS/CD       -  13.38161 S
TU-SLIDING        -  14.22171 S
TU-SHEAR/V.       -  13.2316 S
TU-SHEAR/H.       -  13.95168 S
PERIOD-T          -  .53 S
V-FIXED           -  106.9756 CM
V-AF&MS           -  4.08675 CM
V-AF&MS/CD        -  4.171002 CM
V-SLIDING         -  9.267304 CM
V-SHEAR/V.        -  32.18107 CM
V-SHEAR/H.        -  42.45757 CM
TV-FIXED          -  4.620577 S
TV-AF&MS          -  4.56057 S
TV-AF&MS/CD       -  4.56057 S
TV-SLIDING        -  13.32161 S
TV-SHEAR/V.       -  13.20159 S
TV-SHEAR/H.       -  14.76178 S
PERIOD-T          -  .53 S
U''FIXED          -  16878.35 CM/S^2
U''AF&MS          -  613.369 CM/S^2
U''AF&MS/CD       -  624.5047 CM/S^2
U''SLIDING        -  1201.662 CM/S^2
U''SHEAR/V.       -  4036.434 CM/S^2
U''SHEAR/H.       -  5543.274 CM/S^2
TU''FIXED         -  4.620577 S
TU''AF&MS         -  4.860605 S
TU''AF&MS/CD      -  4.860605 S
TU''SLIDING       -  4.290538 S
TU''SHEAR/V.      -  13.20159 S
TU''SHEAR/H.      -  14.76178 S
```

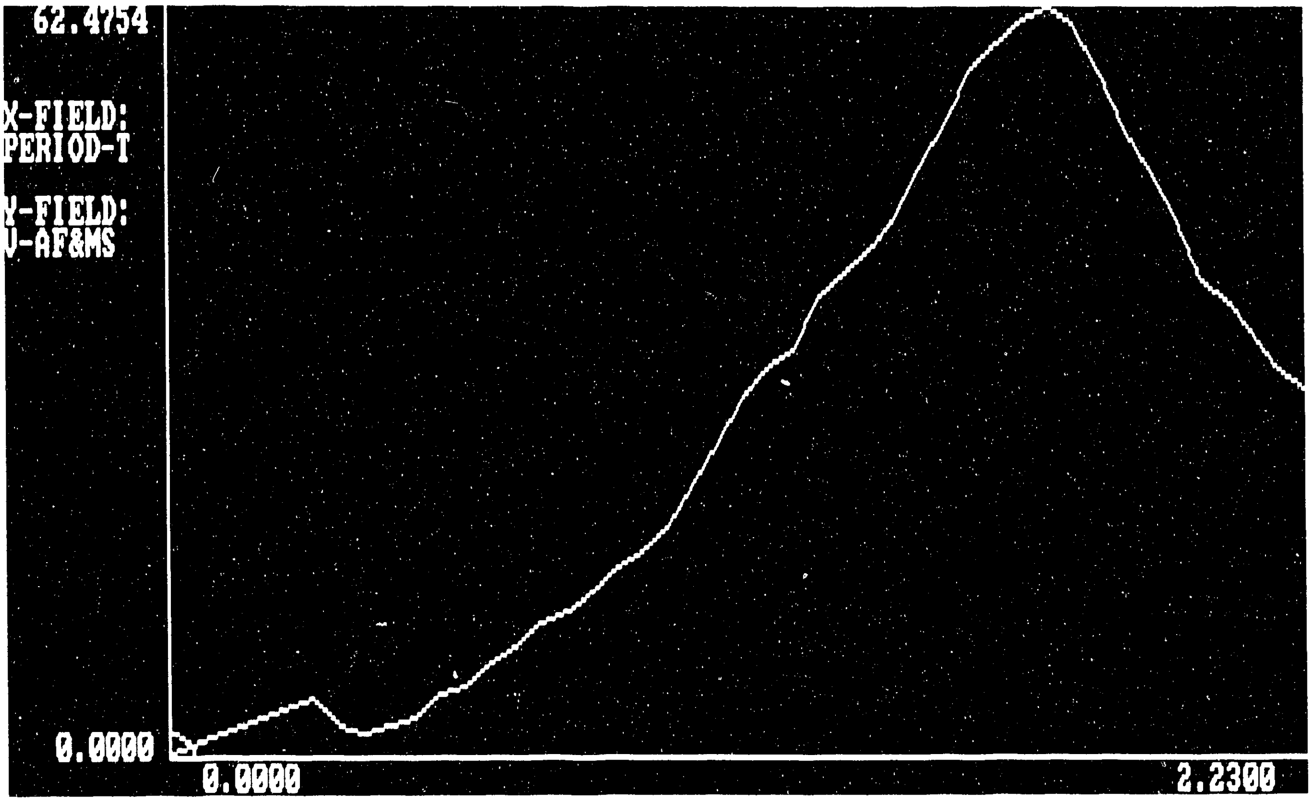
This is the second screen display: a snapshot for the record listed above, made from within RLIST command. All data in the table (relative displacement / time and absolute acceleration / time) are for the same current period (T=0.53 sec) and are presented for comparison between different isolation systems.



SNAPSHOT FOR PERIOD = .53sec
MAX. REL. DISP. FOR ISOLATION TYPE V-FIXED = 106.9756 cm

isolation type	rel.displ. cm	time sec	abs.accel. cm/sec^2	time sec
V-FIXED	106.98	4.6206	16878.35	4.6206
V-AF&MS	4.09	4.5606	613.37	4.8606
V-AF&MS/CD	4.17	4.5606	624.50	4.8606
V-SLIDING	9.27	13.3216	1201.66	4.2905
V-SHEAR/V.	32.18	13.2016	4036.43	13.2016
V-SHEAR/H.	42.46	14.7618	5543.27	14.7618

Shown below is a spectrum for relative displacements (AF&MS System), produced by GRAPHICS FNA command.



3.3 SECONDARY SYSTEM DATA PROCESSING

There are three programs stored to [illegible] input data, [illegible].BAS processes data and ZIB.BAS prepares an output display. Data processing is the same as for the fixed System (see section 2.3), but current rigidity and damping coefficients for the secondary system depend on the current value of the period:

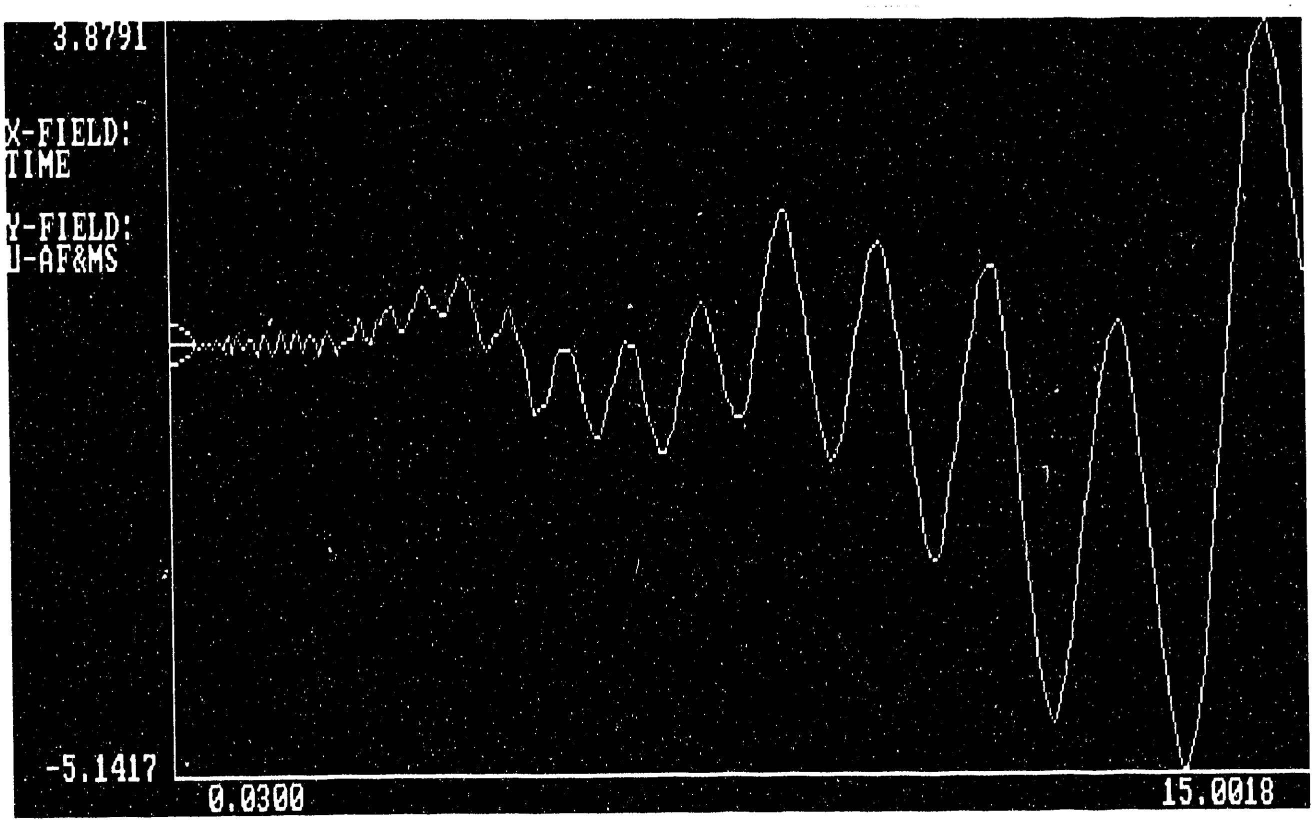
SFA=39.478*SM4/T^2
SBT=2*SDAM4*SQR(SFA*SM4)
Where:
SFA - current rigidity, [kg/sec^2]
SBT - current damping, [kg/sec]
SDAM4 - damping ratio,
SM4 - secondary system mass, [kg]
T - current period, [sec]

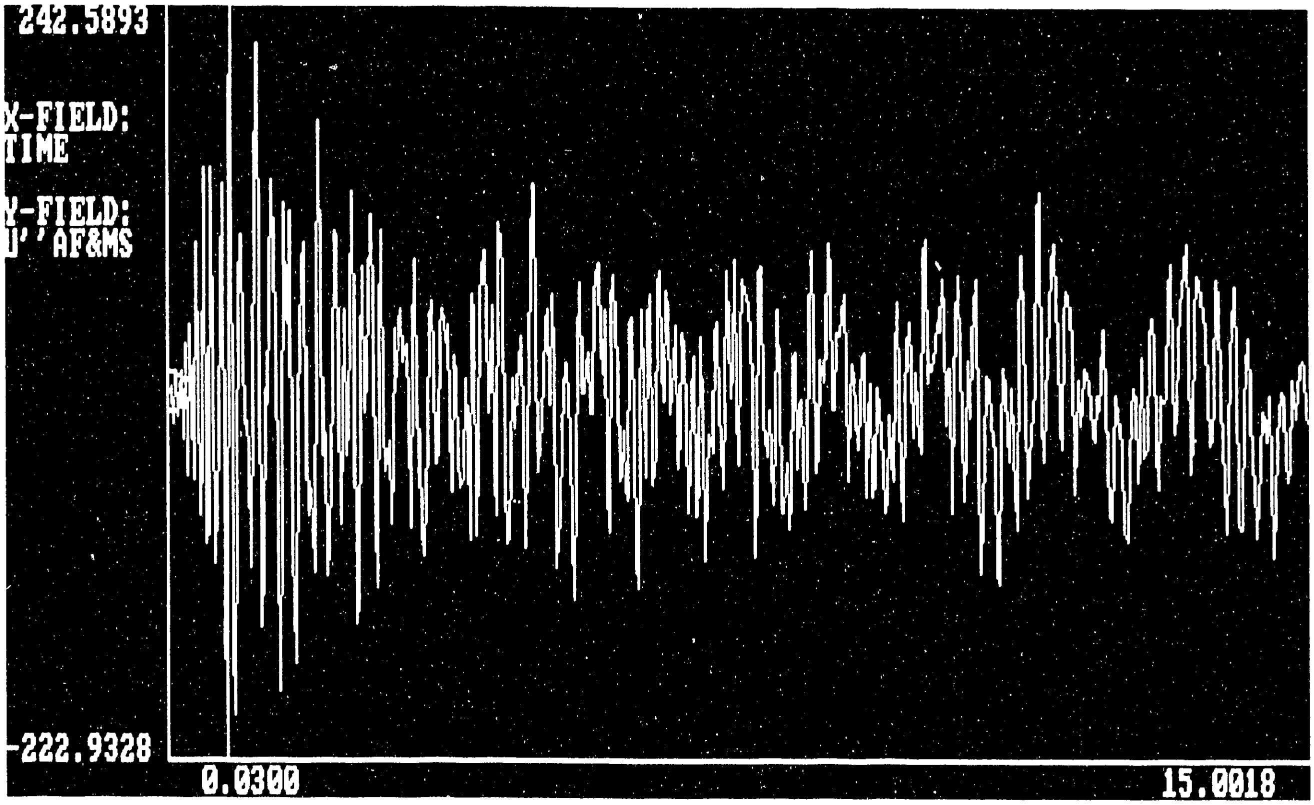
4. FLOOR DATA OUTPUT

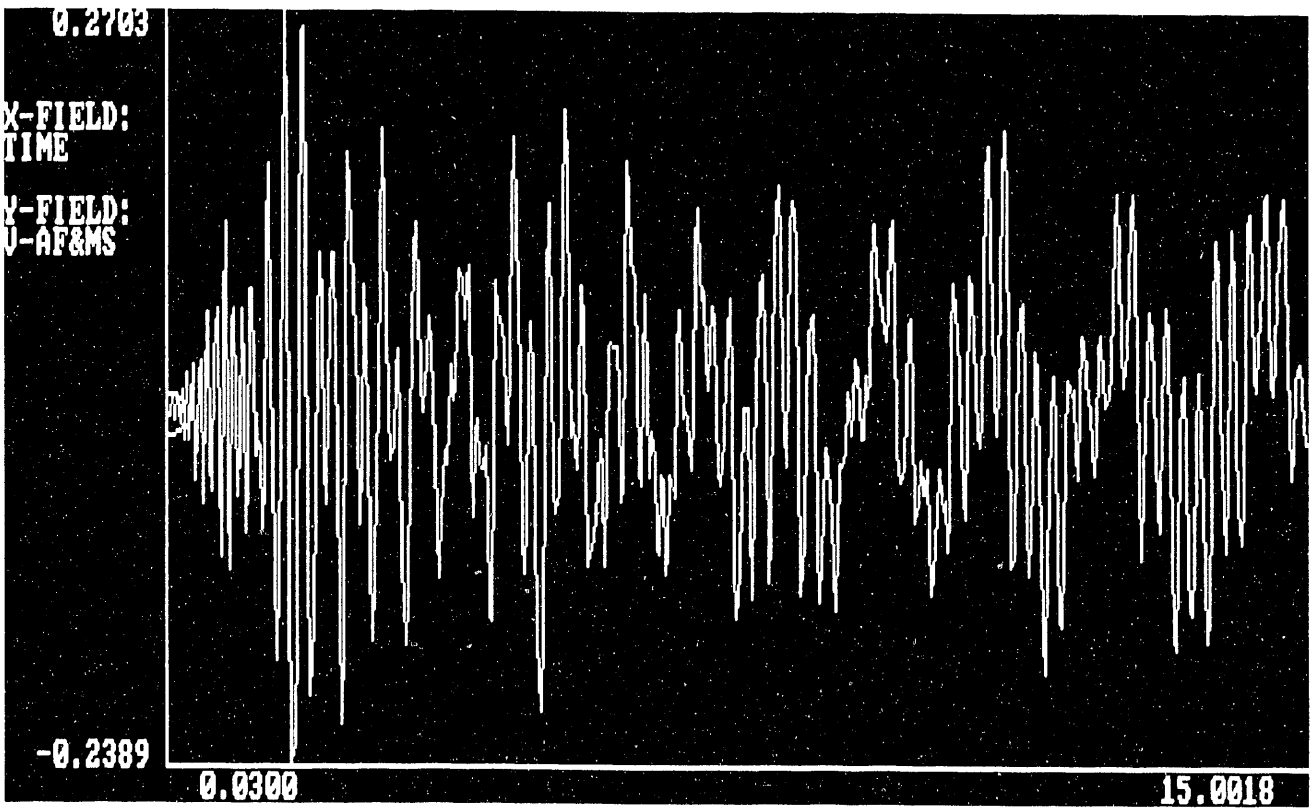
FLOOR DATA FOLDER file (FDF), like SSDF file, is just an extension of BDF file. Select FLOOR DATA OUTPUT (FDO) by using FLIST or FSEARCH FNA commands. You will be prompted to select one of the FDF records from the screen. Record selection will open FDO file represented by this record. This file is a collection of current data for the time ranging from a zero to the TOTAL TIME value. Values for current time (absolute and relative displacement, absolute acceleration and corresponding moments of time) are recorded for all types of seismic isolators: for the Fixed System, AF&MS System, AF&MS/CD System, Sliding System, Shear-viscous System and Shear-hysteretic System (see section 2.1), but only for single superstructure FLOOR#.

```
        FLOOR DATA        EXP.#          :  2
        record # 13  of  500
TIME            -  .3900488 S
U-FIXED         -  3.263757E-02 CM
U-AF&MS         - -1.352838E-02 CM
U-AF&MS/CD      - -2.944569E-02 CM
U-SLIDING       - -2.930853E-02 CM
U-SHEAR/V.      - -7.774285E-02 CM
U-SHEAR/H.      - -9.98325E-03 CM
TIME            -  .3900488 S
U''FIXED        -  197.9608 CM/S^2
U''AF&MS        -  97.87247 CM/S^2
U''AF&MS/CD     -  130.2982 CM/S^2
U''SLIDING      -  224.2798 CM/S^2
U''SHEAR/V.     -  544.3343 CM/S^2
U''SHEAR/H.     -  29.43377 CM/S^2
TIME            -  .3900488 S
V-FIXED         - -.2037138 CM
V-AF&MS         - -4.705461E-02 CM
V-AF&MS/CD      - -5.637089E-02 CM
V-SLIDING       - -.1089212 CM
V-SHEAR/V.      - -.2740149 CM
V-SHEAR/H.      - -6.881578E-03 CM
```

Shown below are three graphs: absolute displacement U-AF&MS, absolute acceleration U''AF&MS and relative displacement V-AF&MS as a function of time (use GRAPHICS command).




242.5893
X-FIELD:
TIME
Y-FIELD:
U''AF&MS
-222.9328
0.0300
15.0018


0.2703
X-FIELD:
TIME
Y-FIELD:
U-AF&MS
-0.2389
0.0300
15.0018

[illegible] - FLOOR DATA [illegible]

5. EARTHQUAKE DATA I/O

5.1 DATA AQUISITION

Earthquake records data contained in FNA files EARTHQUAKE DATA FOLDER (EDF) and EARTHQUAKE DATA OUTPUT (EDO) were acquired from Volume Two records of California Strong Motion Instrumentation Program Report OSMS 85-03. Original files are named as STATION.V2, where STATION is the station name, and V2 (stands for Volume Two) is the file name extension.

EDF file contains information extracted from the first 25 lines of Volume Two Text Header (see p.10 of Report OSMS 85-03). This information loaded automatically each time you select EDO file and input data from STATION.V2 file. All you have to do is to input STATION.V2 path name for the field FILE NAME of EDF file. EDO file contains point-to-point data for time, abs. displacement and abs. acceleration, imported from STATION.V2 file (see p.17 of Report OSMS 85-03).

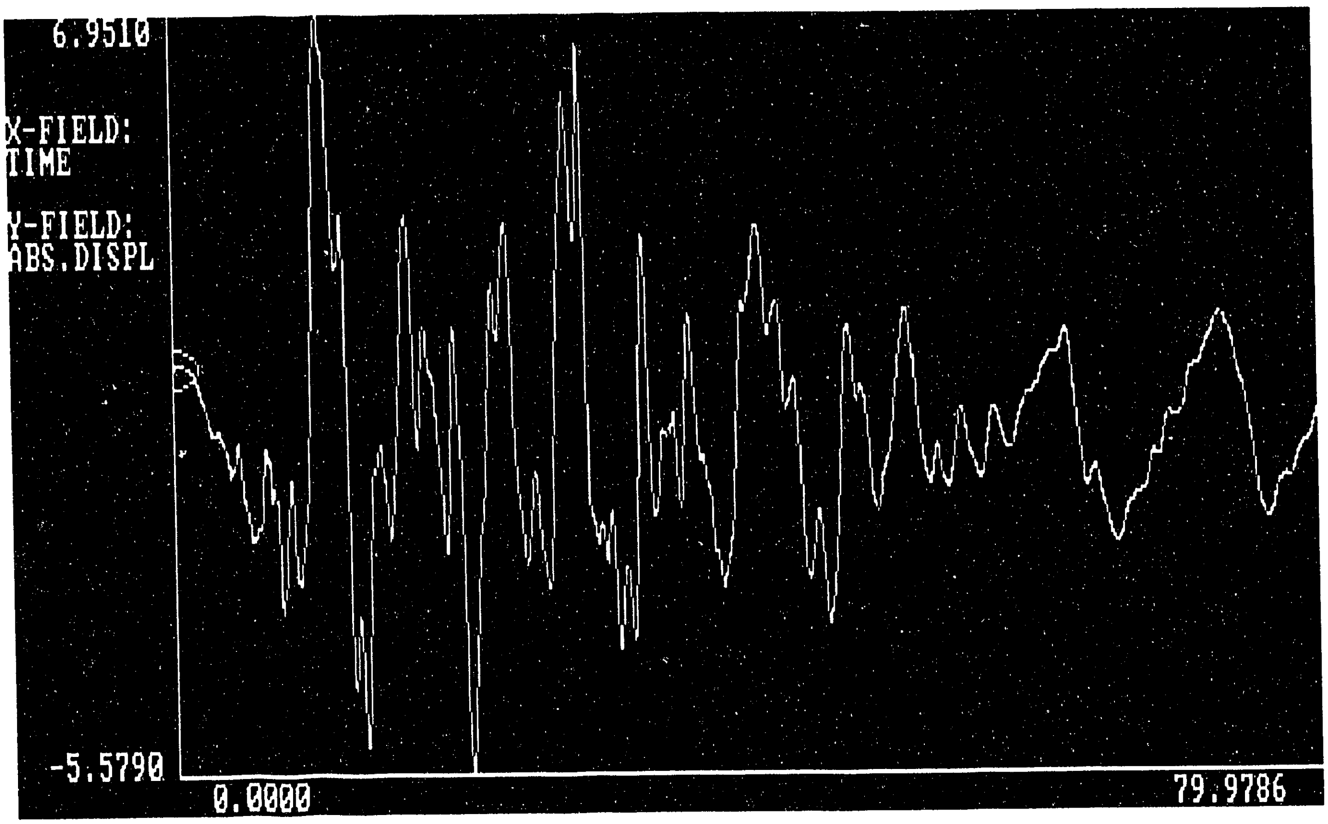
Note: in order to use EDO data for BDO calculations, the ratio between time iteration step and minimum period is not to exceed 0.1. For example, if step TDEL=0.02s and lower roll-off terminaton period T0=0.04s, then EDO data has to be filtered from 0.04s to TDEL * 10=0.2s data bandwidth.

EXAMPLE:

Run FNA.BAT file or choose FNA icon if you are using Windows.
Press <2> to check if you currently in the right directory. If not, input directory name.
Press <1> to run FNA.
Using <UP> and <DOWN> cursors, select EDF file (highlight file name and press <ENTER>).
Press <F2> and select RCHANGE or RADD command (to change existing record or add new record), or type proper command on the Command Input Level (bottom of the screen). Current record number appears on the lower left corner of the screen. To change record, press <BAR> and select [NEXT], [PREVIOUS], etc. from the menu at the screen bottom, or use RLIST command.
Using <UP> and <DOWN> cursors, select FILE NAME and input file path from the keyboard.
Press <BAR> and [SAVE] record, then [EXIT] to the Command Input Level.
Press <F1> and select FLIST or FSEARCH command, or just type it. Select EDO file from the file list. EDF file will be listed on the screen. Select EDF record to open proper EDO file (since each EDF record represents it's own EDO file).
If FILE NAME is entered correctly and EDO file is empty, data will be inputed for both EDF and EDO files. If EDO file already contains data of any kind, you will be prompted to reqenerate data input. To regenerate, press <Y>, otherwise you will skip input. If FILE NAME does not exists or its name wasn't entered, CURRUPT FILE DATABASE message will apphear. Then, if you want to input data (time, abs. displacement and acceleration) manually, use RADD or EXTINP commands.
To exit, press <F1> and select FMENU, or type it.
To exit from FNA, press <4>.

EARTHQUAKE DATA FOLDER
record # 2 of 6

EQ.NAME	- LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME	- JUNE 28, 1992 04:58 PDT PDT
STATION NAME	- DESERT HOT SPRINGS
FILE NAME	- c:\dos\eqdata\hotspr.v2
ACCEL. ID	- 12149-S1832-92180.02 #
STATION	- 12149 #
EQ.HYPOCENTER	- (USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE	- MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD	- .038 S
DAMPING	- .56 FRACT.OF CRITIC.
SENSITIVITY	- 1.82 CM/G
LENGTH	- 79.98001 S
U-MAX	- 6.951 CM
TU-MAX	- 10.2 S
U'-MAX	- -20.802 CM/S
TU'-MAX	- 28.9 S
U''-MAX	- -151.028 CM/S^2
TU''-MAX	- 28.52 S

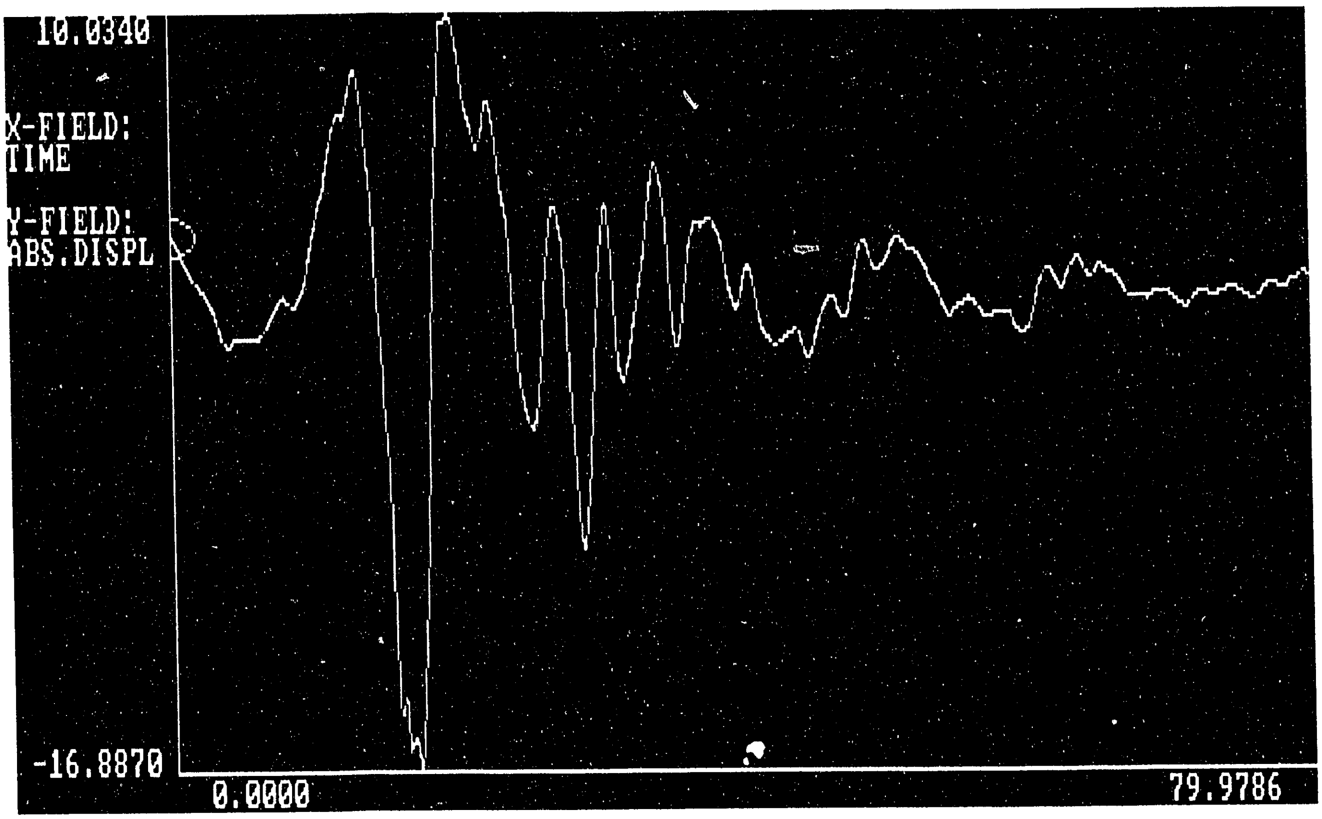


5.2 OSMS 85-03 DATA FILES IMPORTED IN FNA DATABASE

EARTHQUAKE DATA FOLDER
record # 1 of 6

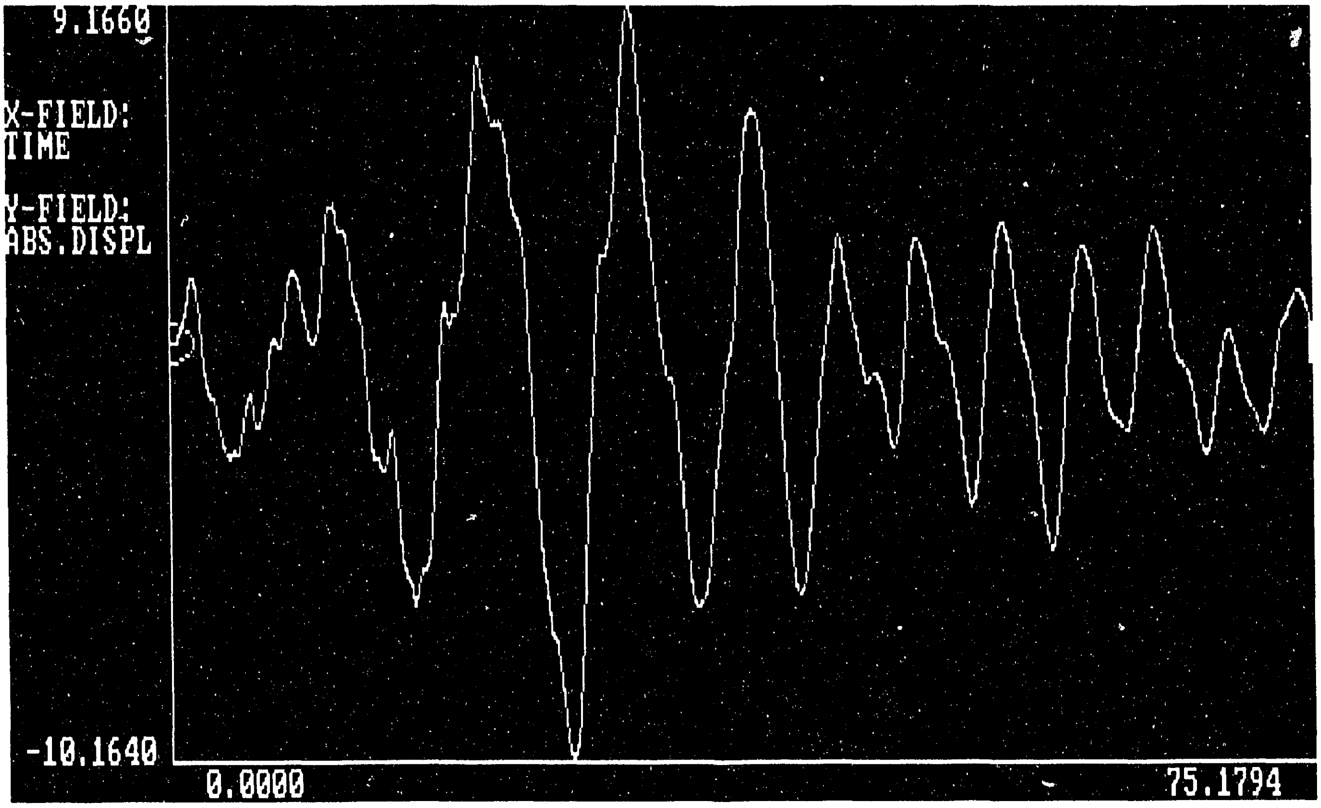
EQ.NAME - LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME - JUNE 28, 1992 04:58 PDT PDT
STATION NAME - BARSTOW - VINEYARD & H ST.
FILE NAME - c:\dos\eqdata\barstow.v2
ACCEL. ID - 23559-S0756-92189.02 #
STATION - 23559 #
EQ.HYPOCENTER - (USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE - MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD- .0395 S
DAMPING - .56 FRACT.OF CRITIC.
SENSITIVITY - 1.92 CM/G
LENGTH - 79.98001 S
U-MAX - -16.887 CM
TU-MAX - 17.1 S
U'-MAX - 25.12 CM/S
TU'-MAX - 18.02 S
U''-MAX - -132.626 CM/S^2
TU''-MAX - 16.08 S

EARTHQUAKE DATA OUTPUT u=f (t)
for record #1



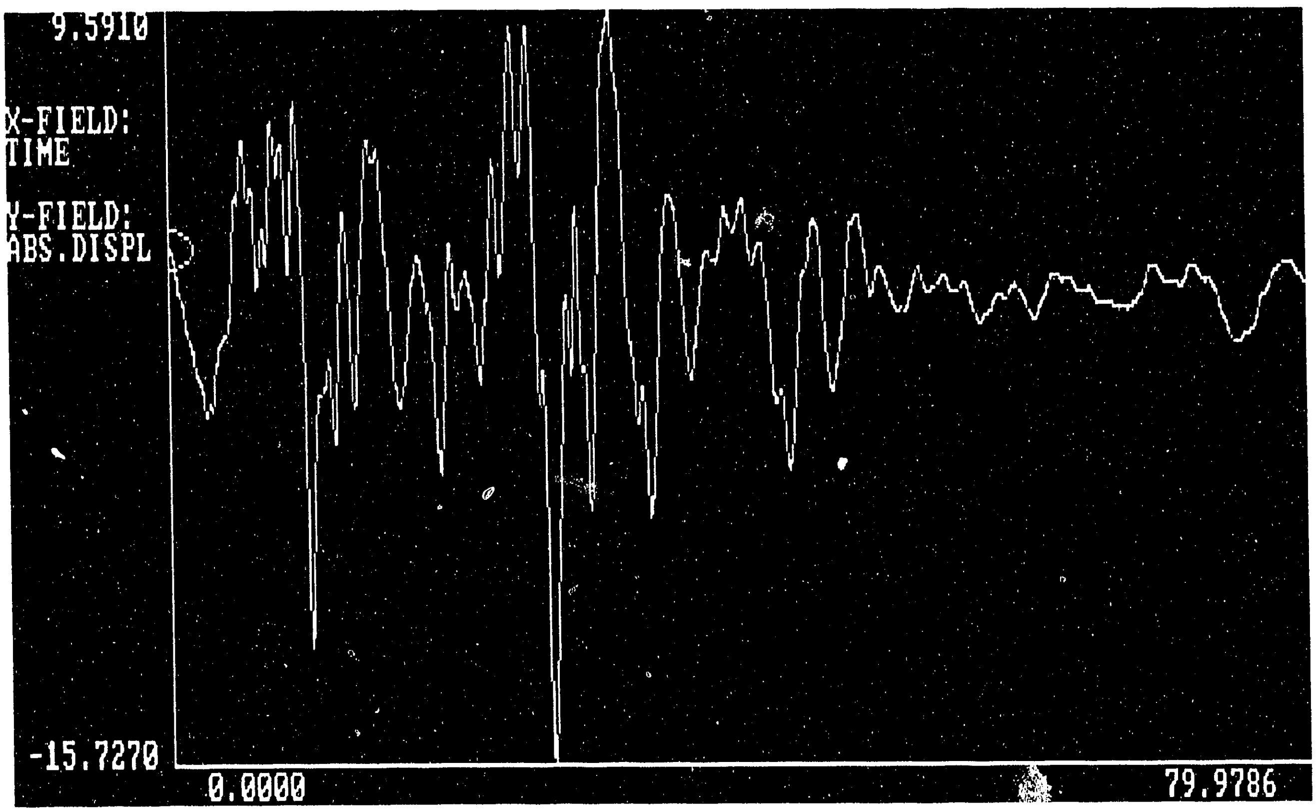
EARTHQUAKE DATA FOLDER
record # 3 of 6

```
EQ.NAME           - LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME     - JUNE 28, 1992 04:58 PDT                PDT
STATION NAME      - INGLEWOOD - UNION OIL YARD
FILE NAME         - c:\dos\eqdata\inglwood.v2
ACCEL. ID         - 14196-S1874-92191.02     #
STATION           -  14196 #
EQ.HYPOCENTER     - (USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE         -        MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD-  .0373 S
DAMPING           -  .63 FRACT.OF CRITIC.
SENSITIVITY       -  1.73 CM/G
LENGTH            -  74.98001 S
U-MAX             - -10.164 CM
TU-MAX            -  26.42 S
U'-MAX            -  10.516 CM/S
TU'-MAX           -  27.34 S
U''-MAX           - -34.275 CM/S^2
TU''-MAX          -  14.46 S
```



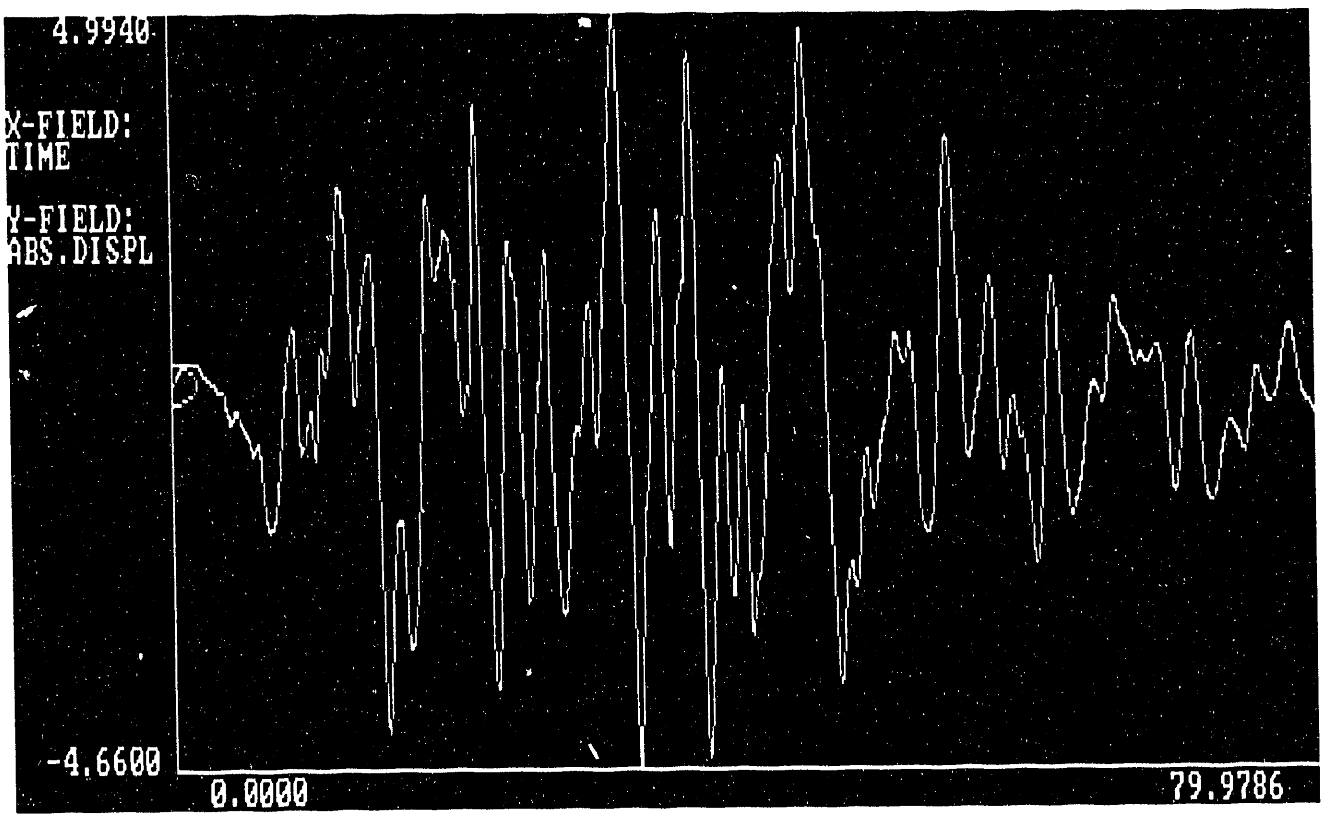
EARTHQUAKE DATA FOLDER
record # 4 of 6

```
EQ.NAME            - LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME      - JUNE 28, 1992 04:58 PDT                PDT
STATION NAME       - JOSHUA TREE - FIRE STATION
FILE NAME          - c:\dos\eqdata\joshua.v2
ACCEL. ID          - 22170-S1612-92180.04      #
STATION            -  22170 #
EQ.HYPOCENTER      - (USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE          -         MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD-   .0382 S
DAMPING            -  .59 FRACT.OF CRITIC.
SENSITIVITY        -  1.74 CM/G
LENGTH             -  79.98001 S
U-MAX              - -15.727 CM
TU-MAX             -  26.86 S
U'-MAX             - -42.71 CM/S
TU'-MAX            -  26.56 S
U''-MAX            -  278.377 CM/S^2
TU''-MAX           -  9.78 S
```



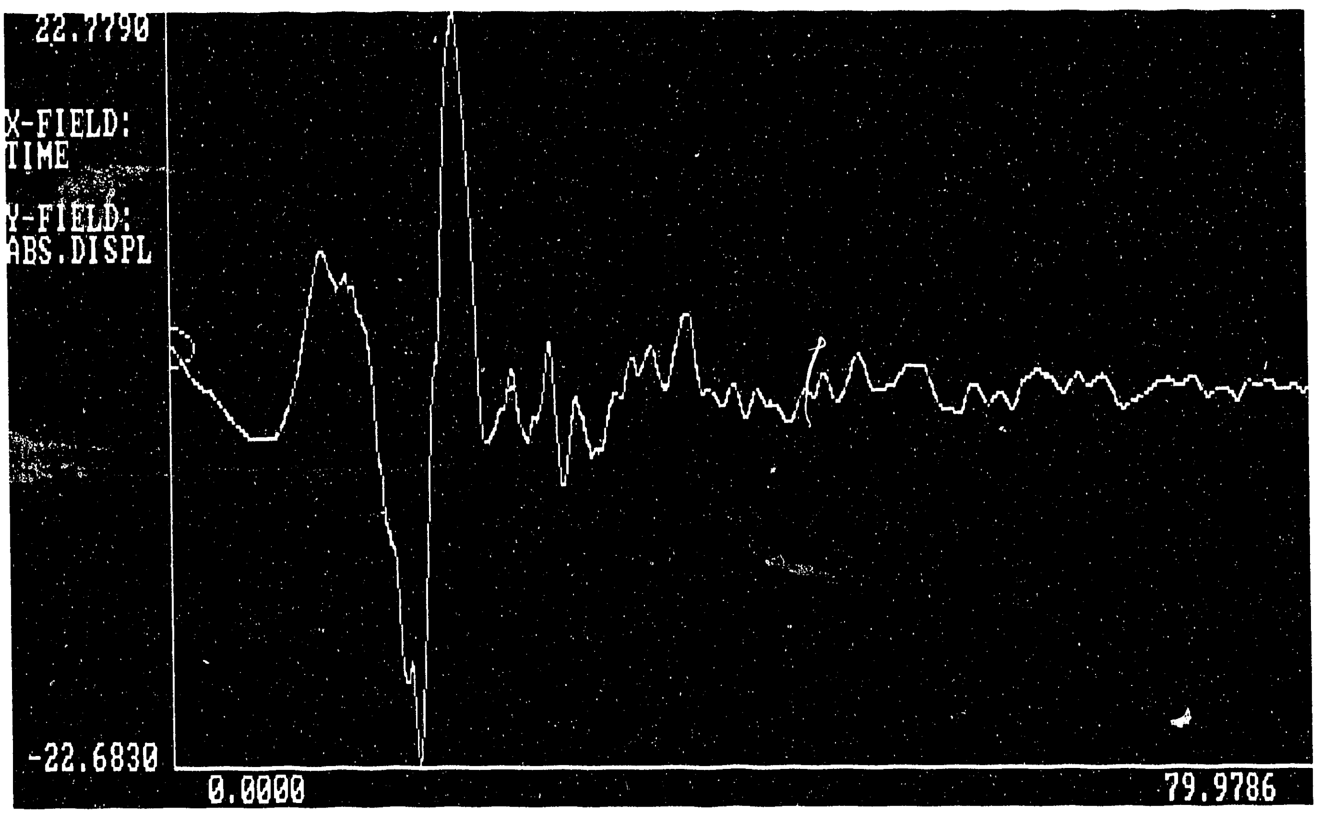
EARTHQUAKE DATA FOLDER
record # 5 of 6

EQ.NAME	- LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME	- JUNE 28, 1992 04:58 PDT PDT
STATION NAME	- PALM SPRINGS - AIRPORT
FILE NAME	- c:\dos\eqdata\plmsprng.v2
ACCEL. ID	- 12025-S1833-92180.04 #
STATION	- 12025 #
EQ.HYPOCENTER	- (USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE	- MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD	- .038 S
DAMPING	- .54 FRACT.OF CRITIC.
SENSITIVITY	- 1.82 CM/G
LENGTH	- 79.98001 S
U-MAX	- 4.994 CM
TU-MAX	- 31.16 S
U'-MAX	- 13.892 CM/S
TU'-MAX	- 21.04 S
U''-MAX	- -87.213 CM/S^2
TU''-MAX	- 21.34 S



EARTHQUAKE DATA FOLDER
record # 6 of 6

EQ.NAME	-	LANDERS EARTHQUAKE (PRELIM. PROCESSING)
EQ.LOCAL TIME	-	JUNE 28, 1992 04:58 PDT PDT
STATION NAME	-	YERMO - FIRE STATION
FILE NAME	-	c:\dos\eqdata\yermo.v2
ACCEL. ID	-	22074-S1695-92189.02 #
STATION	-	22074 #
EQ.HYPOCENTER	-	(USGS): 34.217N,116.433W, H=9KM.
MAGNITUDE	-	MS=7.5(NEIC), MW=7.4(CIT)
TRANS.NAT.PERIOD	-	.0395 S
DAMPING	-	.55 FRACT.OF CRITIC.
SENSITIVITY	-	1.95 CM/G
LENGTH	-	79.98001 S
U-MAX	-	22.779 CM
TU-MAX	-	20.08 S
U'-MAX	-	29.032 CM/S
TU'-MAX	-	19.2 S
U''-MAX	-	-148.574 CM/S^2
TU''-MAX	-	14.82 S



APPENDIX A

SIPP SOFTWARE INSTALLATION

SIPP software package consists of two 3.5" diskettes. Disk #1 is File Network Assistant and Disk #2 is SIPP database. It is assumed, that you have a hard drive with 2M of free space, C:\DOS directory and BASIC.EXE file written on it (for minimum requirements, see section 1.1 of Appendix-B). To install the package, follow these steps:

Put Disk #1 in your 3.5" drive A (or drive B)
Exit to DOS prompt
Create new directory by typing at DOS prompt: MD C:\DOS\SEISMIC
Type CD A:\ (or CD B:\) and press [ENTER], you'll see A:> (or B:>) on your screen
Type FNAINS-A (or FNAINS-B) and press [ENTER]
Type CD C:\DOS and press [ENTER]
Type FNA and press [ENTER]
Put Disk #2 in your 3.5" drive
Press <3> for SIPP database backup
Type A:\ (or B:\) and press [ENTER]
Type C:\DOS\SEISMIC and press [ENTER]

Now you are ready to use FNA and SIPP database (see prior instructions).

APPENDIX B

FILE NETWORK ASSISTANT (FNA)

1. INTRODUCTION

1.1 GETTING STARTED

To run a File Network Assistant, your software has to meet the minimum requirements:

A. Minimum 256K of RAM.
B. MS-DOS or PC DOS version 3.2 or higher.
C. BASIC interpreter version 3.0 or higher.
D. Color display.

There are two support files to start FNA: FNA.BAT batch file and FNA.BAS basic file. All FNA files are put in the FNA directory, except the setup files. If COMMAND.COM, BASIC.EXE, FNA.BAT and FNA.BAS files are in the same root directory, and all FNA files from the FNA directory are written in the FNA directory, you are able to start FNA by entering FNA.BAT file at the DOS prompt. If COMMAND.COM and BASIC.EXE files are in different directories, and/or FNA files are placed in other directory, or mentioned above file names are different, you have to change contents of the FNA.BAT and/or FNA.BAS file(s).

Contents of the FNA directory:

A. PROGMATE.BAS is the main FNA file, responsible for an execution of FNA commands. It contains all FNA subroutines, part of which is described in PEDIT section of the manual.

B. MENU.BAS runs as a menu for FNA (see FMENU section).

C. ????????.BAS or ????????.0xy (where xy is an integer) files are FNA subroutines chained to the PROGMATE.BAS at a time of command execution.

D. Files with HLP extension are written for FNA internal use.

E. FNA database files, which belong to the Working Path, could be of the three categories:
- MASTER.ARR is a file, that contains an information about all FNA database files of this Working Path (File Label, record length, etc.);
- files with the names composed from integers and ARR extensions are regular FNA database files;
- files with BAS extension are FNA programs.

1.2 HOW FNA WORKS

Purpose of a FNA is processing and sharing / redirecting data between FNA and/or DXF format files.

FNA differs database files according to the style, type and their place within the Main File; last quality depends on the current Main File opened.

File styles (see FCOPY and RLIST):

A. Text Style
B. Block Style
C. 2D Style
D. 3D Style

File types (see LADD):

A. Normal Type
B. Folder Type
C. Fake Type

File types as a function within the Main File (see LADD):

A. Main File
B. Extension File

C. File-in-Field File
D. Parent File
E. Child File
F. Program File

Files are listed in special FNA order (see FLIST) to reveal for the user all basic information about subordination and data flux between FNA files. These features are set up thru **LADD** command, responsible for creating file layout.

File might be presented as a spreadsheet in a Text Mode and as a graphics in Graphics Mode. Record can be listed in both vertical and horizontal layouts (see RLIST).

Data can be transfered to (from) DXF format file from (to) FNA file (see **FCOPY**) and to ASCII text file from FNA file (see **FPRINT** and **RPRINT**).

Symbols used in the manual:

[button name] - Screen button to press.
<button name> - Keyboard button to press.
/input/ - Input from the keyboard.
* - Optional parameter.
BOLD TEXT - FNA command.

2. LIST OF COMMANDS

2.1 FILE RELATED COMMANDS

2.1.1 FMENU

<1> <2> <3> <4> <5>

<1> Run File Network Assistant. If MASTER.ARR file doesn't exist or the file is empty, FNA will run in **LADD** mode. Otherwise, FNA will **FLIST** file layouts.

<2> Change current working path. Default: previous path.
/Input working path name/ - if entered name is invalid, the working path will remain the same by default.

<3> Backup entire working path.
/Input source path name/ - invalid input will cancel an execution.
/Input destination path name/ - invalid input will cancel an execution.

<4> Exit to DOS & return to the path designated in FNA.BAT file (parent to FNA directory).

2.1.2 FLIST

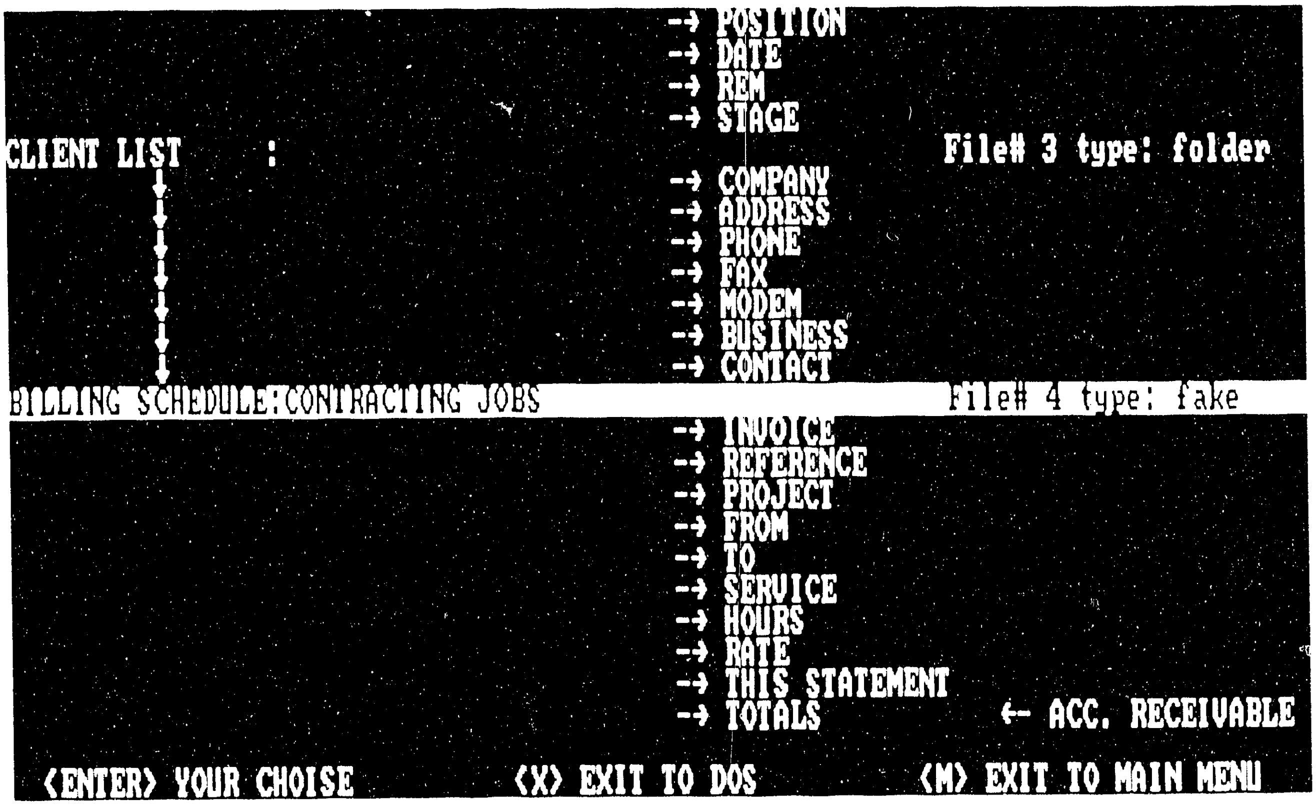
If one or more files are listed in MASTER.ARR file, the file layout list will be presented in hierarchical order: <<<Normal or Folder Files with File-in-Field Files <<Extention Files with File-in-Field Files < Child Files or Fake Files with File-in-Field Files>>>>>>. Information about the file (most left column): File Label, File Description, number of the file, file type.

<ENTER> <X> <M>

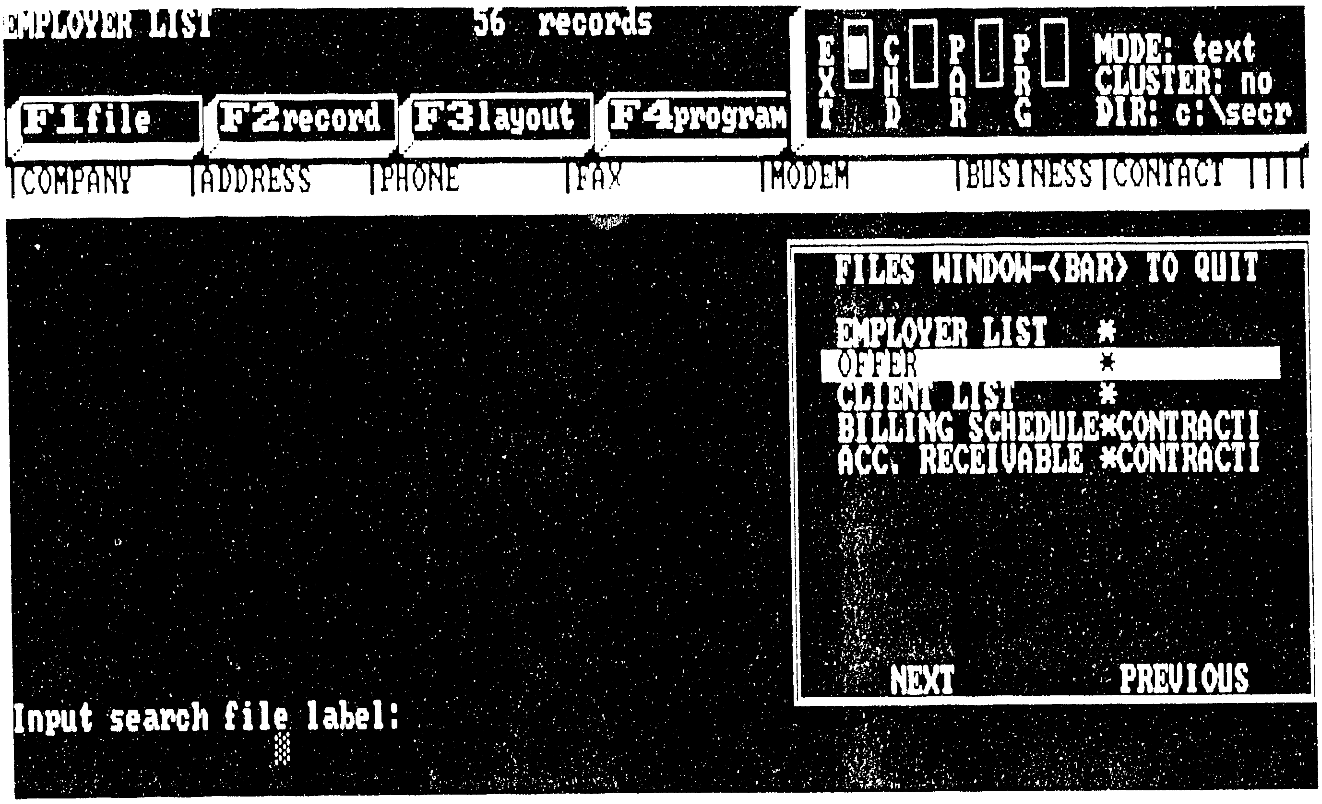
<ENTER> Will open highlighted file as a Main File. If File Label ="SPARE LAYOUT", then FNA will run in **LADD** mode for this file number.

<X> Exit to DOS.

<M> Exit to the Main Menu (see 2.1.1).


-→ POSITION
-→ DATE
-→ REM
-→ STAGE
CLIENT LIST :
File# 3 type: folder
-→ COMPANY
-→ ADDRESS
-→ PHONE
-→ FAX
-→ MODEM
-→ BUSINESS
-→ CONTACT
BILLING SCHEDULE:CONTRACTING JOBS
File# 4 type: fake
-→ INVOICE
-→ REFERENCE
-→ PROJECT
-→ FROM
-→ TO
-→ SERVICE
-→ HOURS
-→ RATE
-→ THIS STATEMENT
-→ TOTALS
←- ACC. RECEIVABLE
<ENTER> YOUR CHOISE
<X> EXIT TO DOS
<M> EXIT TO MAIN MENU

2.1.3 FSEARCH



2.1.4 FDELETE

2.1.5 FCOPY

[TOTALS] Count totals of "ON" fields under condition, that Referenced Fields of input & output files are identical.

<ENTER> <BAR>

<ENTER> Select fields to activato (desactivate).

[ON] Activate selected field.

[OFF] Desactivate selected field.

<BAR>

[SELECT] [COPY] [CANCEL] <BAR>

[SELECT] Select field's value and condition for output file records selection.

/Input field's value for record selection/

[RESET] [=] [<>] [<] [<=] [>] [>=] <BAR>

[RESET] all referenced values & conditions.

[=] Referenced value and field's value of this record has to be equal.

[<>] - has to be unequal.

[<] Referenced value has to be less than field's value.

[<=] - has to be less or equal.

[>] - has to be higher.

[>=] - has to be more or equal.

<BAR> Return to the selection.

[COPY] Copy files without selecting conditions.

[CANCEL] Cancel FCOPY & go to the command input level.

<BAR> = [SELECT]

[FROM MAIN F.] Copies from the Main File to other FNA file (see [TO MAIN FILE]).

[.DXF FORMAT] Copy to (from) Main File from (to) DXF format file. If you are using AutoCAD: to input DXF file in CAD drawing, use DXFIN command. To create DXF file from CAD drawing, use DXFOUT command.

/Input file name/ File could be located in any valid path (default: current working path).

[TO DXF] [FROM DXF] [CANEL] You will be asked to /Input layer name/; entities related to other than specified layer will be ignored. If file is of a Block Type, then /Input scale factor/ for attribute text scaling.

[TO DXF] If file is of a Block Type, select attributes through Fields Window. <BAR> <BAR> to finish selection.

[FROM DXF] If file is of a Block Type, then attributes of valid blocks will reside in fields with Field Labels = Attribute Tag.

[CANCEL] Restart FCOPY

*[TEXT FILE] [GRAPHICS FILE] [CANCEL] <BAR> - optional for Generic Type Files.

[TEXT FILE] Write records as a text in DXF file, using MONOTXT text style, 0.125 text hight and 0.25 space between text lines. Text will be written on standard 11H x 8.5W size, starting from top left sheet corner. If big enough, text will be written beyound sheet limits.

[GRAPHICS FILE] Write records as line entities in DXF file. You will be asked to define [X-FIELD], [Y-FIELD] and *[Z-FIELD]. Lines will belong to defined layer and have BYLAYER color.

[CANCEL] Restart FCOPY.

<BAR> = [TEXT FILE].

[CANCEL] Return to the command input level.

<BAR> = [TO MAIN FILE]

2.1.6 FPRINT

If Main File is empty, you will get "FILE IS EMPTY!" message. Press any button to return to the command input level. If FNA has current GRAPHICS mode and screen does not require regeneration, FNA will print existing graphic screen. If printer is off, then FPRINT will return to the command input level.

[PRINT ALL] [CANCEL] *[CLUSTER] <BAR> Valid for a Text Mode or Graphics mode, if a regeneration is required.

[PRINT ALL] Print file header and all records.

[NORMAL] [UNDERLINED] "Underlined" option put continuous line between each row in a table.

[PRINTER] [FILE]

[PRINTER] Copy file on LPT1 (printer).

[FILE] Copy (append) FNA file on ASCII text file for wordprocessing purposes.

/Input file name: / Filename is set to "C:\TEMP.TXT" by default.

[CANCEL] return to the command input level.

*[CLUSTER] Valid only if Cluster exists. Print selected records.

<BAR> = [PRINT ALL]

2.1.7 FEXIT

[EXIT] [ENVIRONMENT] [CANCEL] <BAR>

[EXIT] If a Child File exists, FNA will open it. Otherwise, you will be returned to FLIST level.

[ENVIRONMENT] If more than one of the listed below file types exist, you will be asked, which one to open. If only one exists, FNA will open it as a default. If there are no Environment Files, you will receive a message "NO FILE ENVIRONMENT!".

*[CHILD] Open Child File as a Main File.

*[PARENT] Open Parent File as a Main File.

*[PREVIOUS] Return to the previously opened file.

*[IN-FIELD] Open one of the File-in-Field File as a Main File.

[CANCEL] return to the command input level.

<BAR> = [EXIT]

2.2 RECORD RELATED COMMANDS

2.2.1 RLIST

Text Mode

If Main File is empty, then "FILE IS EMPTY!" message will appear. If Main File has at least one record, screen will show list of records in a horizontal layout, one line per one record, with file header on top of the screen. If Main File has Extention Files, use left and right cursors to see Extention File records. Use up and down cursors to highlight current (Main) record and <ENTER> it to get vertical layout of the Main Record. Vertical layout will give you FNA header on top of the screen, file header, horizontal layout of Main Record, list of Field Labels and related field values in vertical order, the Main Record number and total number of records. Press any button to return to RLIST level. <ENTER> to return to the command input level.

Pic. 2.3. Rlist Text Mode (Horizontal Layout)

ROOM	TASK/ACTIVITY	AREA	PERIMETE	HEIGHT	CAVITY
1	public area	2669	227	6.5	1.38207
2	office	86	38	6.5	7.18023
3	janitorial spac	34	24	6.5	11.4705
4	utility room	31	22	6.5	11.5322
5	accounting	1420	241	6.5	2.75792
6	reception area	425	104	6.5	3.97647
8	conference room	264	67	6.5	4.12405
9	office	197	56	6.5	4.61928
10	lobby	71	39	6.5	8.92605
11	office	172	53	6.5	5.00726
12	office	203	63	6.5	5.04310
13	office	371	109	6.5	4.77425
14	lobby	42	27	8	12.8571
15	women's restroo	97	45	8	9.27835
16	lobby	36	25	8	13.8888
17	men's restroom	155	55	8	7.09677
18	storage	25	20	8	16
19	electrical room	222	62	8	5.58558

Graphics Mode

*[X-FIELD] [Y-FIELD] *[Z-FIELD] Valid only for Generic Type files. For other types, FNA will skip this input. Once defined, this coordinate setting remains the same, until another FNA file will be opened as a Main, or mode will be changed.

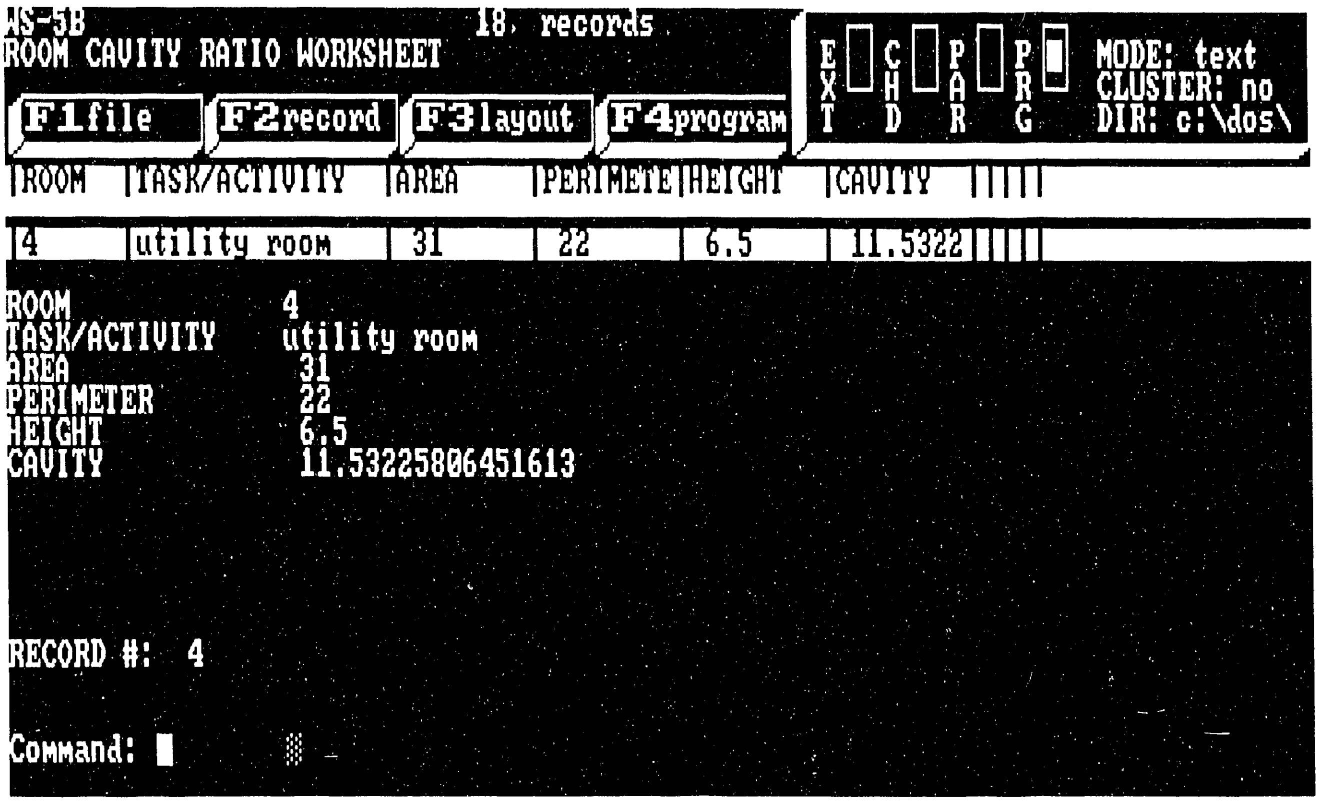
[X-FIELD] Set this field as a horizontal screen coordinate.

[Y-FIELD] Set this field as a vertical screen coordinate.

*[Z-FIELD] Set this field as a third dimention coordinate. Significant only for FCOPY [.DXF FORMAT] [GRAPHICS FILE]; If Z-FIELD is not defined, all entities lay in (Z=0) plane.

For 2D and 3D Type files, each record represents a line. For Block Type files, each record represents a block. Since FNA does not have an information about each particular block, blocks will be substituted by small circles. Circle center coordinates correspond to the block insertion point. For Generic Type files, each record stands for the point, and all points are connected by the lines in the record numbers sequence. For all file types, the target is a circle, placed on the middle of current entity. Use up and down cursors to highlight needed entity. <ENTER> to get vertical layout of current (Main) record (see Text Mode).

Pic. 2.4. Vertical Layout of highlighted record shown above



Pic. 2.5. 2D Type, Graphics Mode. Building floor plan

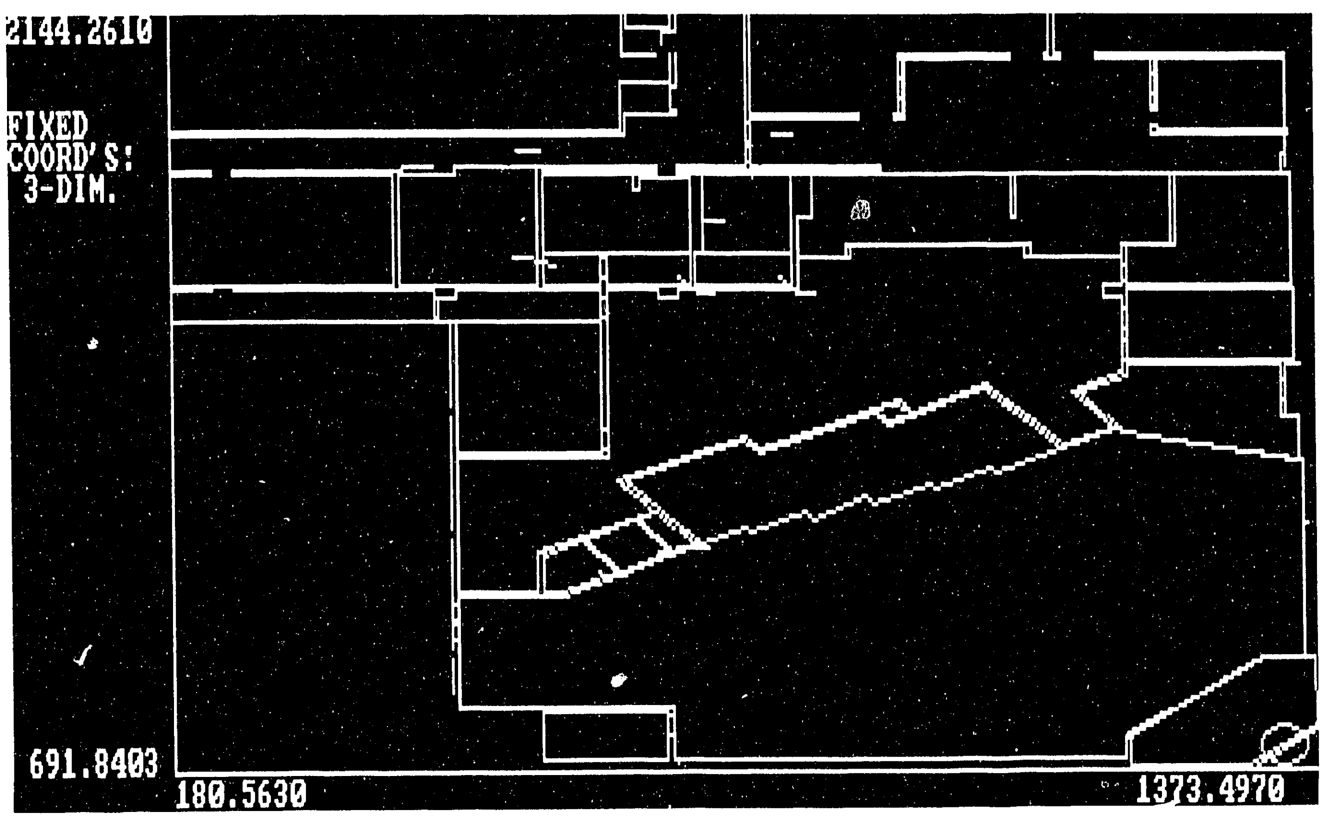
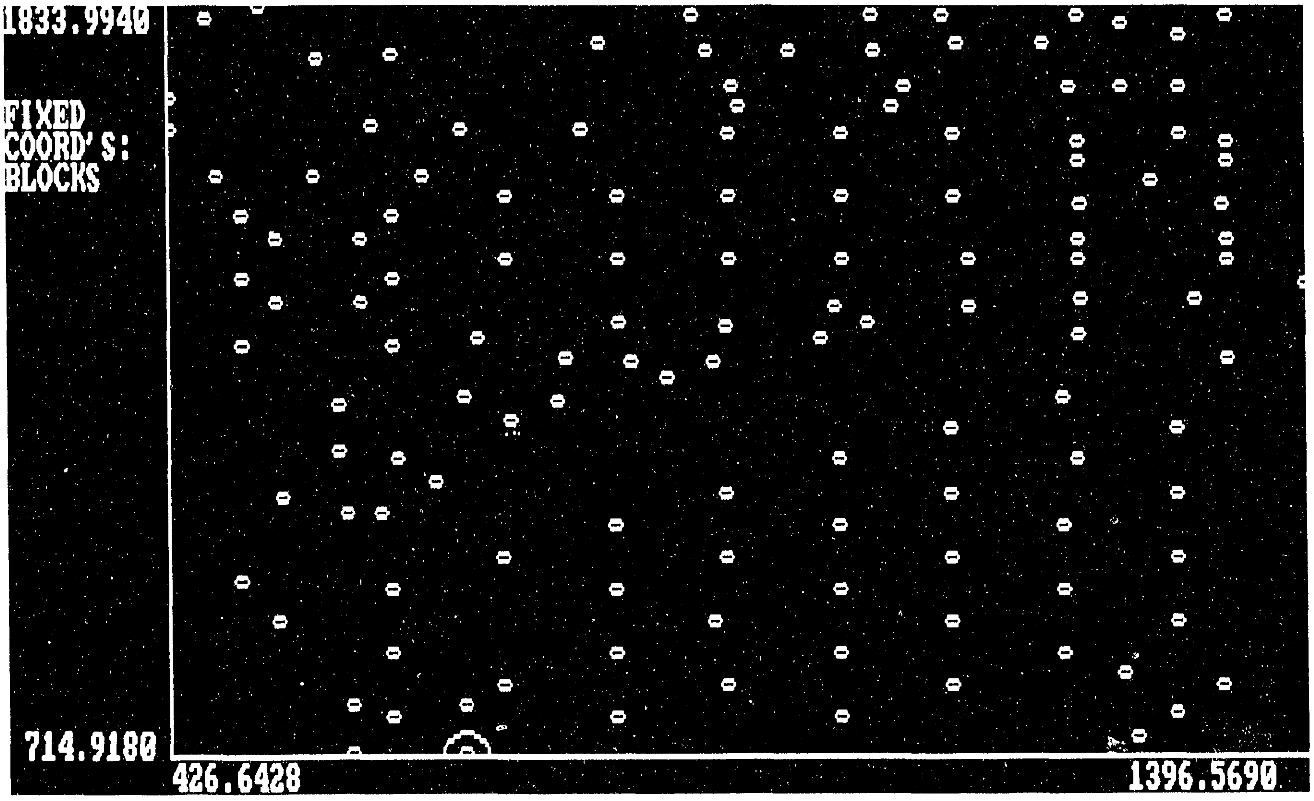


Fig. 2.6. Block Type, Graphics Mode. Features for the same building plan. Pointer (bigger circle) centered around the first record



2.2.2 RSEARCH

[PICK RECORD] [FROM...TO] [SELECT] [CANCEL] •[XFER TO FILE]

[PICK RECORD] Pick records to form a Cluster.

[NEXT] Pick the next record.

[CANCEL] Return to the RSEARCH level.

[EXIT] Return to the [illegible] level.

<BAR> = [NEXT]

[FROM...TO] Select records for Cluster between two record numbers.

Input first record #: Valid if exists.

Input last record #: Valid if bigger than first record number and less or equal than last file record number.

[SELECT] Set fields values and conditions for the records selection.

<ENTER> <BAR>

<ENTER> Get field for setting value and conditions for records [illegible] selection.

[RESET], [illegible] <BAR> (see FCOPY [SELECT]).

<BAR>

[EXIT], [CANCEL], <BAR>

[EXIT] Make Cluster and return to the command input level with Cluster "YES".

[CANCEL] Restart RSEARCH.

<BAR> Restart [SELECT].

[CANCEL] Return to the command input level.

*[XFER TO FILE] Valid only if the Cluster exists. Convert selected records into the Main File.

2.2.3 RADD

Add record to Main File.

<ENTER> <BAR>

<ENTER> Choose the field to add (change).

[KEYBOARD] [FILE] <BAR>

[KEYBOARD] Enter field's value from the keyboard.

[FILE] Enter field's value from other FNA file. Choose file for data export from Files Window. List of records will appear at the left screen corner. To transfer data to the current (Main) record, highlight record in Record Window and <ENTER> <ENTER> it.

<ENTER> <CURSOR UP> <CURSOR DOWN>

<ENTER> To choose the output record in the Records Window.

<ENTER> Transfer data (highlighted left field in the window) to the current field of the current record of Main File.

<BAR>

[LEFT] [RIGHT] <BAR>

[LEFT] Move current field of export file to the left.

[RIGHT] Move current field of export file to the right.

<BAR> Cancel [FILE] and return to RADD level.

<CURSOR UP> List of the records to scroll up.

<CURSOR DOWN> List of the records to scroll down.

<BAR> = [KEYBOARD]

<BAR>

[SAVE] [CANCEL] [EXIT] *[FIRST] *[LAST] *[PREVIOUS] *[NEXT] *[ADD] *[EXTENSION] <BAR>

[SAVE] Save current record as listed.

[CANCEL] Cancel changes for the current (Main) record.

[EXIT] Return to the command input level.

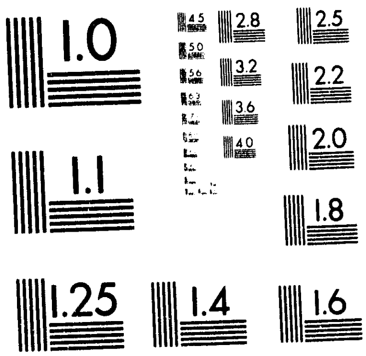
*[FIRST] Set the first record as a current (Main) record.

*[LAST] Set the last record as a current (Main) record.

*[PREVIOUS] Set the previous record as a current (Main) record.

*[NEXT] Set the next record as a current (Main) record.

*[ADD] Add a new record to the Main File.


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

2 of 2

*[EXTENSION] Valid if at least one Extension File exists. Set next Extension File as a current file to list.

<BAR> = first button.

2.2.4 RCHANGE

Change current (Main) record. See RADD.

2.2.5 RDELETE

If Main File is empty, then "FILE IS EMPTY!" message will appear.

[PICK RECORD] [EXIT] *[CLUSTER] <BAR>

[PICK RECORD] Pick record to delete from the screen. If Main File is Folder Type, file represented by this record will be also deleted.

[EXIT] Return to the command input level.

*[CLUSTER] Valid if Cluster exists.

<BAR> = [PICK RECORD]

2.2.6 RCOPY

Copy one record on another record. Invalid, when "NUMBER OF RECORDS LESS THAN 2".

[PICK RECORD] [EXIT] *[CLUSTER] <BAR>

[PICK RECORD] Pick record to copy from and record to copy on. [EXIT] to exit from RCOPY.

[EXIT] Return to the command input level.

*[CLUSTER] Valid if the Cluster exists. Copy entire Cluster.

/Input shift -(up) +(dn) from first record/ If s ift = 0 then FNA will return RCOPY level.

<BAR> = [PICK RECORD]

2.2.7 RREPLACE

Swap records position within the Main File. Invalid, when "NUMBER OF RECORDS LESS THAN 2".

[PICK RECORD] [EXIT] *[CLUSTER] <BAR>

[PICK RECORD] Pick records to swap from the screen. [EXIT] to exit from RREPLACE.

[EXIT] Return to the command input level.

*[CLUSTER] Valid if the Cluster exists. Records will be replaced, one by one, by the records with (current record # + shift) record number.

/Input shift -(up) +(dn) from first record/

<BAR> = [PICK RECORD]

2.2.8 RPRINT

Print current (record in vertical layout - Field Labels on the left, field values on in the middle and Field Attributes on the right.

[PRINTER] [FILE] [CANCEL] <BAR>

[PRINTER] Copy record on LPT1 (printer).

[FILE] Copy (append) record on ASCII text file.

/Input file name: / Filename is set to "C:\TEMP.TXT" by default.

[CANCEL] Return to the command input level.

<BAR> = [PRINTER]

2.3 LAYOUT RELATED COMMANDS

2.3.1 LADD

Add file layout to current Master File (MASTER.ARR).

First level - input file parameters.

[FILE LABEL] [FILE DESCRIPTION] [PROGRAM FILE] [CHILD FILE] [PARENT FILE] [EXTENSION FILE] [FILE TYPE] <BAR>

[FILE LABEL] Max. length is 16 characters. Value is significant for file search and selection.

/Input file label/

[FILE DESCRIPTION] Max. length is 40 characters. Carries complimentary information about the file.

/Input file description/

[PROGRAM FILE] Input program number to be permanently connected to the FNA file. Eligible program name is <program #>.BAS, where <program #> is any integer. Program has to exist in the Working Path and to comply with FNA requirements (see PEDIT).

/Input program number/

[CHILD FILE] Input Child File (Fake File for Folder File and any type file for Normal Type) as a child process. Use Files Window.

[PARENT FILE] Input Parent File (Folder File for Fake File and any type file for Normal Type) as a parent process. Use Files Window.

[EXTENSION FILE] Input Extension File as a parallel extension of the current file. You could chain up to 10 files (10 X 10 = 100 fields) in one chain maximum, rest of the chain will be ignored. Each file - extension has to carry name of the next file-extension. In some cases (uncompatible file types) extension will be canceled. Use Files Window.

[FILE TYPE]

[NORMAL] [FOLDER] [FAKE]

[NORMAL] Any file, which is not a Folder and not a Fake Type.

[FOLDER] Is a file, where each record represents and opens another file (Fake Type and Child File for Folder File).

[FAKE] This layout is shared by a family of files, phisically written into same directory (directory name is this file number, shown in FLIST). Every file from this directory is represented by the record of the Folder File (and Parent File for this Fake File). All file management will be done thru the FNA automatically.

<BAR>

[SAVE] [NEXT] [CANCEL] <BAR>

[SAVE] Go to the second LADD level.

[NEXT] Return to the first LADD level.

[CANCEL] Return to the command input level. All changes to reset.

<BAR> = [SAVE]

Second level - input fields parameters.

[FIELD LABEL] [FIELD DESCRIPTION] [DATA EXPORT] [FIELD TYPE] [FIELD LENGTH] [PRINT LENGTH] [COLUMN (data export)] [STYLE (data export)] <BAR>

[FIELD LABEL] Max. length is 16 characters. Value is significant for field search and selection.

/Input field label/

[FIELD DESCRIPTION] Max. length is 16 characters. Carries complimentary information (units, dollar sign, etc.).

/Input field description/

[DATA EXPORT] Select the file as a File-in-Field File to export its data to the current field. Use Files Window.

[FIELD TYPE]

[STRING] [INTEGER] [SINGLE PREC.] [DOUBLE PREC.] [=RECORD #] <BAR>

[STRING] Field's data to be saved as a string type. Field Length varies.

[INTEGER] Field's data to be saved as an integer (whole number). Field Length is 2 bytes.

[SINGLE PREC.] Field's data to be saved with single precision. Field Length is 4 bytes.

[DOUBLE PREC.] Field's data to be saved with double precision. Field Length is 8 bytes.

[=RECORD #] Field's value is equal to record number of the record. Field's Length is 2 bytes.

<BAR> = [STRING]

[FIELD LENGTH] Set automatically, if Field Type is other than a String.

/Input field length, bytes: / Min. number is a zero (it makes a sense if current field contains File-in-Field File (data export), and all field's data is read from this file). Max. number of bytes is 62.

[PRINT LENGTH] Is a length (number of characters), in which current field will be embedded for listing in a horizontal layout. Sum of all Print Lengths not to exceed 69 characters. Current Print Length available for an input is shown in the right corner of the screen.

[COLUMN (data export)] Choose a field (column) of the File-in-Field File, from which a data has to be exported.

[STYLE (data export)] FNA treats first field of the current file as the first Referenced Field. That is why FNA ignores any data export in the first field of the Main File (exept for the [OVERLAY] and [APPENDIX]). If current file is opened as a Main File and data export defined, FNA will try to match between the first Field Label of the Main File and any of the Field Labels of the File-in-Field File as the second Referenced Field. Failer to match will terminate data export for current field.

[OVERLAY] [APPENDIX] [COMPARE] [COUNTER] [TOTALS] <BAR>

[OVERLAY] Copy data from File-in-Field File (from [COLUMN] field) to the Main File (current field), record number remains the same.

[APPENDIX] Same as [OVERLAY], but appends data to the Main File.

[COMPARE] Compare Referenced Fields data of FIF and Main files and copies data from [COLUMN] field to the current field if a match is found.

[COUNTER] Compare Referenced Fields data of FIF and Main files and count total number of FIF records, matched with Main File record. Save result in the current field.

[TOTALS] Compare Referenced Fields data of FIF and Main files and sum the data from [COLUMN] field if a match is found. Save result in the current field.

<BAR> = [OVERLAY]

[NEXT FIELD] [SAVE RESULT] [STEP BACK] <BAR>

[NEXT FIELD] Next field to input.

[SAVE RESULT] Save input in the Master File and launch current file as a Main. If sum of the Field Lengths is equal to zero, "ERROR: FILE LENGTH EQUALS ZERO!" message will appear. <ENTER> to return to the second LADD level.

[STEP BACK] Previous field to input.

<BAR> = [NEXT FIELD]

2.3.2 LCHANGE

Change Main File layout. If file is not empty, you can't change Field Type or Field Length. See LADD.

2.3.3 LDELETE

Delete file layout. After deletion, File Label will be "SPARE LAYOUT"; the attempt to open this file shall return you to the LCHANGE level. Invalid if file(s) related to this layout is not deleted.

[MAIN FILE] [SEARCH] [CANCEL]

[MAIN FILE] Main File layout to delete.

[SEARCH] Search file layout to delete thru the Files Window.

[CANCEL] Return to the command input level.

2.3.4 LCOPY

Copy file layout to the end of a Master File. Existing file(s) attached to this layout will not be copied.

[MAIN FILE] [SEARCH] [CANCEL]

[MAIN FILE] Main File layout to copy.

[SEARCH] Search file layout to copy thru the Files Window.

[CANCEL] Return to the command input level.

2.3.5 LPRINT

Print entire Main File and Extension Files (if any) layout(s) as it was entered thru LADD/LCHANGE command (see LADD).

2.3.6 LPRALL

Print all file layouts from Master File in the same sequence as they appear in FLIST command (see FLIST).

2.4 PROGRAM RELATED COMMANDS

2.4.1 EXTINP

Quick input thru a horizontal layout (print line and <ENTER>). Pick file from the Files Window; File Label with File Description and Field's Labels with Field's Separators will appear at the bottom of the screen. Print field's data in proper spaces; <ENTER> to add new record at the end of the file. Invalid if the file is SPARE LAYOUT or if the file is a Fake Type and the Parent (Folder) File is empty.

/INPUT NEXT? <Y>/

<N> Return to the command input level.

<Any other button> Input next record.

2.4.2 SORT

Sort Main File for the chosen field of any type. Choose the field from the Fields Window. Truncates record from the Main File if chosen field of the record is empty. Invalid if "NUMBER OF RECORDS IS LESS THAN 2".

2.4.3 TEXT

Set FNA mode as a Text Mode. This is a FNA mode by default. Main File records are listed as the textual data in both vertical and horizontal layouts.

2.4.4 GRAPHICS

Set FNA mode as a Graphics Mode. Main File records are listed as the textual data in vertical layout and as a graph in horizontal layout. Graph differs for different file styles:

A. Text Style: requires input of X-field and Y-field. Each record represents a point which is connected with the lines to the next and previous record(s) (point(s)).

B. Block Style: these files must have the "BLOCK" field, X-field and Y-field. FNA will recognize the Block Style if the file has the "BLOCK", "X1" & "Y1" Field's Labels; "ANGLE" and "Z1" Field's Labels are optional. Each record stands for a block. Records will be shown as the circles since all blocks definitions are contained in AutoCAD file(s).

C. 2D Style: These files must have the X-field and Y-field. FNA will recognize 2D Style if the file has the "X1", "Y1", "X2" & "Y2" Field's Labels. Each record stands for and will be presented as a line.

D. 3D Style: same as 2D, plus Z-field is defined. ("Z1" and "Z2" Field's Labels).

Graphics Mode is invalid if all X-fields or/and Y-fields of the current file are the same (2D area is regressed to the line). All Extension Type (other than Main) files are Text Style files. See RLIST.

2.4.5 PSEARCH

Search the file with a program attached, using Files Window. <ENTER> chosen file to attach its program to the Main File. If Main File already has a program, it will be replaced by the new one. Valid only for the current session. If you want to connect chosen program to the Main File permanently, use **LCHANGE** command. Invalid if chosen file does not have a program attached.

2.4.6 PADD

Add a program to the Main File (valid only for the current session). All files from the Working Path with .BAS extension will be listed on the screen. To attach, highlight file name and <ENTER>. Be sure, that the highlighted file complies with FNA requirements.

2.4.7 PEDIT

Return to the Basic Editor and edit existing or create new program for the Main File. After editing, save file in ASCII format in the Working Path. Be sure that length of your file, amount of reserved memory for the variables and number of nested loops fit in the BASIC memory limits. To return to a FNA, RUN "MENU.BAS". To attach new program to the Main File, use **LCHANGE** command.

To make sure that you are not using variables defined by FNA, try variables with C,D,E,G,H,I,J,K,L,M and N starting characters. The list of FNA variables that can be defined in #4000-4099 program lines:

SWP10=1 if initial calculations and/or input is required. SWP10=0 to cancel/skip.

SWP11=1 if fields calculations and/or input is required in the event of the editing the Main File records. SWP11=0 to cancel/skip.

SWP12=1 if fields calculations and/or input are required at a time of exiting from the Main File. SWP12=0 to cancel/skip.

SWP14=1 if you want to squeeze customized display between horizontal layout in Text Mode and vertical layout. SWP14=0 to cancel/skip.

SWP$ (19) First string array to hold the names of program variables.

SWP1$ (19) Second string array to hold the values and names of program variables.

To finish this part of the program (it is typical for all program segments), use RETURN statement. Listed below are the main program segment lines:

1380 Line for field data processing (for ex., line 1380 R$ (0,1)=STR$ (VAL (R$ (0,2))*MASS) set the first field variable (R$ (0,1)) equal to the second field variable times SMASS value).
4000-4099 Initialization.
4100-4199 Processing SWP10=1 request.
4200-4299 Processing SWP11=1 request.
4300-4399 Processing SWP12=1 request.
4400-4899 Processing SWP14=1 request.
4900 line must to exist for CHAINing purposes.

Example:

Request for initial calculations is placed in line# 4000 (SWP10=1); calculation process by itself described in lines# 4100-4130; stub line#4900 is present. Note, that all others SWPxx are set to zero.

```
1380 R$ (0,5)=STR$ (VAL (R$ (0,3))*VAL (R$ (0,4))):IF VAL (R$ (0,5))>VAL (R$ (0,6)) THEN R$ (0,7)=R$ (0,6) ELSE
R$ (0,7)=R$ (0,5)
4000 SWP10=1:SWP11=0:SWP12=0:SWP14=0:RETURN
4100 DATA f,5,6,10.1,g,26,13,0,h,63,33,0,i,130,65,0
4101 ON ERROR GOTO 4130
4102 FB=9:FF=40:GOSUB 1190:FB=10:FF=39:GOSUB 1190:FOR P10=1 TO LOF (2)/FNFLEN  (0):FB=0:R=P10:GOSUB
1370:X2$=LEFT$ (R$ (0,1),INSTR (R$ (0,1)+" "," ")-1):IF X2$= "" THEN X2$=" "
4105 FB=10:FOR R=1 TO LOF (12)/FNFLEN (10):GOSUB 1370:IF LEFT$ (R$ (10,0),LEN (X2$))=LEFT$ (X2$,LEN (R$ (10,0)))
THEN R$ (0,2)=LEFT$ (R$ (10,1),3):GOTO 4115
4110 NEXT R
4112 FB=9:FOR R=1 TO LOF (11)/FNFLEN (9):GOSUB 1370:IF LEFT$ (R$ (9,0),LEN (X2$))=LEFT$ (X2$,LEN (R$ (9,0)))
THEN R$ (0,2)=LEFT$ (R$ (9,1),3):GOTO 4115
4113 NEXT R
4115 X=VAL (R$ (0,8)):IF X<=3.5 THEN X=0 ELSE IF X<7.1 THEN X=1 ELSE X=2
4120 RESTORE 4100:X$="":WHILE LEFT$ (R$ (0,2),3)<>LEFT$ (X$+"  ",3):READ X$,S (0),S (1),S (2):WEND:R$ (0,4)=STR$
(S (X))
4122 FB=0:R=P10:GOSUB 1720
4125 NEXT P10:RETURN
4130 IF ERR=4 THEN R$ (0,4)="":RESUME 4122 ELSE RESUME NEXT
4900 'stub
```

List of variables most frequently used in FNA programs:

SP2$ Current Working Path name;
SWPAR2 =1, if Cluster exists, =0, if not;
SWPAR3 =0, if screen regeneration is required; =1, if not;
SWPAR4 =0, if Main File is of a Text Style with defined coordinates; =1, if coordinates are not defined, =1.5, if Main File is of a Block Style, =2, if -2D Style, =3, if -3D Style;
SWPAR5 is a total number of files opened with the Main File (=1, if Main File does not have an extension);
SWPAR6 =0, if the Text Mode is current, =1, if the Graphics Mode is current;
FFMAIN is a record number of Main File within a Master File;
FB is a file number (=0 for the Main File and 1<=FB<=9 for the Extension Files);
R is a record number within the Main File. 1<=R<=LOF (2)\FNFLEN (0), where LOF (2)\FNFLEN (0) is a total number of records.
R$ (FB,X) is a field's values. FB is a file number, X is a field's number.

List of subroutines that can be used from the program:

GOSUB 750 Row pointer.
Input: P1-left margin; P2-right margin; P3-current row number; P6-top margin; P7-bottom margin.
Output: P-row number (varies from 1 to 24, if <ENTER> and equal zero, if <BAR>).
GOSUB 800 Button pointer.
Input: SW1-number of the buttons.
Output: P-button number (varies from 1 to SW1, if <ENTER> and equal zero, if <BAR>).

GOSUB 920 Input analyzer.
Input: X$-default input value; X1$-comment; SW1-input style (=1, if output is in uppercase letters, =2, if output is in lowercase letters, =3, if output is a numerical value); P3=24; P4-left margin; P5-right margin.
Output: X$-output value.
GOSUB 1190 Main File Launcher.
Input: FF-Master File record number.
Output: FF file to open as a Main File.
GOSUB 1370 Get record.
Input: FB-file number; R-record number.
Output: R$ (FB,X)-field's values from FB file. R$ is an array for X from 0 to 9.
GOSUB 1510 Record - horizontal layout.
Input: FB-file number. Records are listed in a horizontal layout.
Output: R-record number.
GOSUB 1660 Record - vertical layout.
Input: FB-file number; R-record number. Record is listed in a vertical layout.
Output: screen.
GOSUB 1720 Put record.
Input: FB-file number; R-record number; R$ (FB,X)-field's values.
Output: put record in FB file.
GOSUB 1770 Message.
Input: X$-message text.
Output: <ENTER> to continue.
GOSUB 1820 Draw buttons.
Input: SW1-buttons number (2<=SW1<=5); X$-buttons text (centered for each button).
Output: screen.
GOSUB 2300 Files & Fields Window.
Input: SW1=1 for the Files Window; X2$-value to select (X2$="" to list all files). SW1=2 for the Fields Window; FF-Master File record number.
Output:
For Files Window: FF-Master File record number & FF field values for FB=10 file number. SW1=0, if <BAR>.
For Fields Window: FD-field number. SW1=0, if <BAR>.

2.4.8 POFF

Switch the attached program "off".

2.4.9 PPRINT

Print the attached program. If the program is not exists, "4000 'stub" and "4900 'stub" will be listed.

DATE FILMED

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END